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ENERGY EFFICIENCY MODEL FOR CLOUD DATACENTERS

[1]Harpreet Kaur ,[2]Dr Sudesh Kumar ,[3]Harminder Singh
[1,3]SGHS Khalsa College , Panjokhra Sahib Ambala
[2]BRCMCET, Behal , Bhiwani
[1]harpreetsial@gmail.com ,[2]sudeshjakhar@gmail.com ,[3]harminder.singh2125@gmail.com

Abstract:**Cloud computing is an evolving paradigm that has redefined the way information technology based services can be offered. It is a computing model which is developed based on other computing model like distributed computing, parallel computing, cluster computing, grid computing, cloud computing is a modern technology which contain a network of system that form a cloud. Energy conservation is one of the major concern in cloud computing. Large amount of energy is wasted by the computers in cloud computing and the carbon dioxide gas is released into the atmosphere polluting the earth environment over the decades, power consumption has become an important cost factor for computing resources.**

Green computing is an emerging technology which focuses on preserving the environment by reducing various kinds of pollutions like CO_2 emissions, energy losses in computing. Efficient cloud computing for achieving Green Cloud Environments is only possible by reducing wasteful in different infrastructure required for the data centers in Cloud computing. In this paper we will have tried to explain various metrics used to measure energy consumption for various infrastructure in data centers and address the methods to reduce power requirement for cloud infrastructure with respect to QoS (Quality of Service) specified by users in SLAs(Service Level Agreements).

Index Terms— **Cloud computing, energy efficiency, green computing, energy consumption, energy saving.**

I.INTRODUCTION

Cloud computing has emerged as a new consumption and virtualization model for the high cost computing infrastructures and web based IT solutions. The main goal of cloud computing is to use the resources in an efficient way and also to gain large profit energy consumption is the key concern in content distribution system and most distributed system .These demands an accumulation of networked computing resources one or multiple providers on data centers extending over the world. This consumption is censorious design parameter in modern data center and cloud computing systems. The power and energy consumed by the computer equipment and the connected cooling system is a major constituent of these energy, cost and high carbon emission. The energy consumption of data centers worldwide is estimated at 26 Giga Watt which corresponds to about 1.4% of worldwide electrical energy consumption and with annual growth rate of 12% [1]. For instance, in 2010, Google ran about 900,000 servers that consumed 1.9 billion kWh [2]. It becomes urgent to improve the energy efficiency of such infrastructures. This work will aim at designing energy-efficient resource allocation for Cloud infrastructures. Yet, energy is not the only criteria to take into account at risk of losing users. A multi-criteria approach is required in this context to satisfy both users and Cloud providers.

However, minimizing this energy consumption can result to conceal cost reduction in cloud computing. Moreover apart the enormous energy cost, heat released increases with higher power consumption increases the probability of hardware system failures. Minimizing this energy consumption does not only reduce the huge cost and improves system reliability, but also helps in protecting our natural environment and leads to green computing. Thus reducing the energy consumption of cloud computing system and data center is a challenge because data and computing application are growing in a rapid state that increasingly disks and larger servers are required to process the fast within the required period of time. Cloud applications are deployed in remote data centers where high capacity servers and storage system are located. A fast growth of demand for cloud based services results into establishment of enormous data centers consuming high amount of electrical power. In this paper, we show that by applying energy optimization policies through energy consumption models. It is possible to save huge amount of energy in cloud environments and data centers.

II.ENERGY CONSUMPTION IN CLOUD DATA CENTERS

Data centers are the backbone of the modern economy -- from the server rooms that power small- to medium-sized organizations to the enterprise data centers that support American corporations and the server farms that run cloud computing services hosted by Amazon, Facebook, Google, and others. However, the explosion of digital content, big data, e-commerce, and Internet traffic is also making data centers one of the fastest-growing consumers of electricity in developed countries, and one of the key drivers in the construction of new power plants.

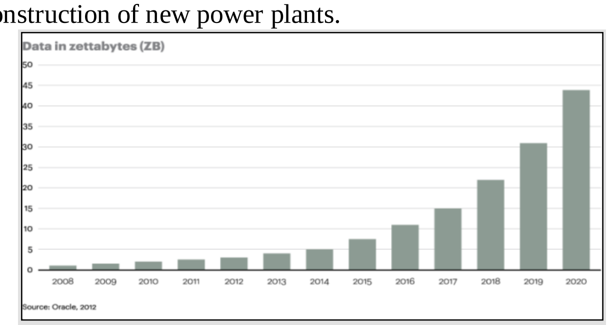

Fig. 1. Year wise growth rate of data. *(Source Oracle 2012)*

The amount of data kept in digital format is expected to rise and the amount of energy required to keep this data is large and rising. An estimated 2.5 ZB (1 Zettabytes = 10^{21} bytes) of data were generated in 2012 alone, and trends indicate that the volume of business data will grow significantly every. Data is growing at a 40 percent compounded annual

rate, The rate of increased storage of data and the associated energy and carbon dioxide emissions from this are very significant. Furthermore, data centers are expected to contribute hugely to electricity consumption and the global emissions from data centers are already comparable to carbon dioxide emissions from small countries. reaching nearly 45ZB by 2020[3].

The graph in figure 1 depicts the derived electricity consumption in data centers worldwide in 2007, and gives forecast figures for electricity consumption in 2020. In 2007, derived electricity consumption in data centers came to 330 billion kilowatt hours. And at 12% growth rate the electricity consumption in data centers will become approx 1012 billion kilowatt hours by the year 2020[4].

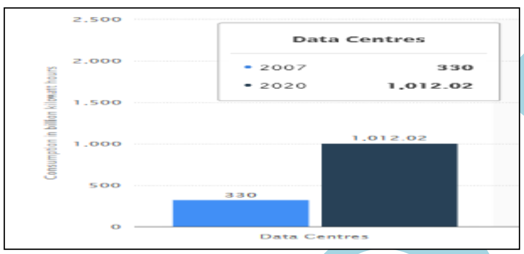

Fig. 2. Electricity consumption comparison by data Centers worldwide. *(Source satista.com)*

This creates a major challenge for all of us, especially the data center operators and companies that use them. Energy now represents around two thirds of the total data center cost; greater than the total hardware costs [5]. This energy is mainly consumed in the ancillary systems such as cooling and Uninterrupted Power Supplies. At the regulatory level, this massive growth in energy use and carbon dioxide emissions associated with running data centers is likely to draw scrutiny by regulators looking for ways to reduce carbon dioxide emissions. Companies that is able to produce products or services that result in significant energy and carbon dioxide savings in the operation of data centers will potentially gain a competitive advantage and benefit from a sustained increase in demand for their products.

A data center size may vary like occupying one room of a building, one or more floors or an entire building [6]. In order to maintain the energy efficiency in data centers, various factors are needed to have considered. If there are any servers that are not in use then they can be turned off. Some servers are underutilized and they run at a maximum if 15 percent. Hence tasks in such servers can be given to other high efficient servers which are having less space and so the former servers can also have turned off [7]. In efficient power supplies can also result in wasting half of the power before it goes to the server. The tasks given to the servers should be scheduled within the particular processing time.

III.ENERGY CONSUMPTION ANALYSIS IN DATA CENTER

Data centers, the large facilities that house computer servers and other systems, can consume 100 to 200 times more electricity than standard office spaces depending upon size of data center. Less than half the power used by a typical data center powers its IT equipment, according to the US Department of Energy 30 percent of the total energy consumed in IT equipment and about 42 percent of energy is consumed in cooling solutions provided in Data center [8]. The figure 3 shows approximate distribution of energy in data center.

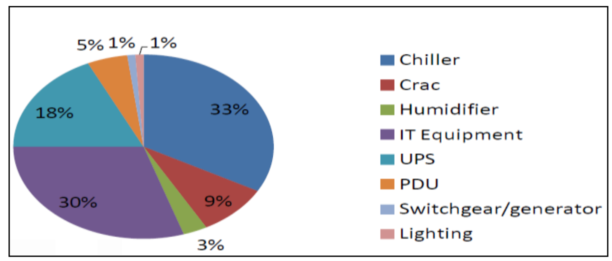

Fig. 3. Energy consumption distribution in data Centers *(Source US Department of energy)*

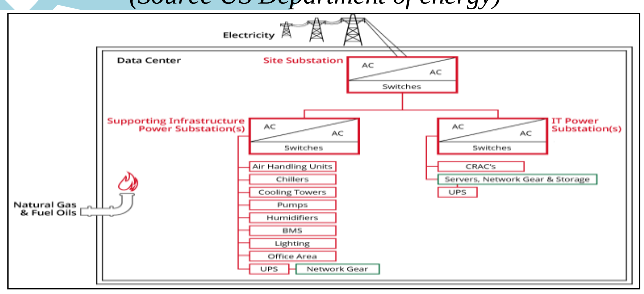

Fig. 4. Energy distribution in Google Data Center *(Source Google)*

The remaining energy is used to support infrastructure including cooling systems, UPS inefficiencies, power distribution losses and lighting. By 2012, the power costs for data center equipment over its useful life are expected to exceed the cost of the original capital investment. Companies with large data centers operations, such as Apple, Google, HP, and eBay, have taken a variety of measures to reduce energy, improve efficiency and shrink their carbon footprint.

IV.ENERGY EEFFICIENCY METRICS OF DATA CENTER

To calculate the amount of energy consumed by data centers two metrics were established by Green grid, an international consortium [9]. Consumption of energy in a cloud environment having n number of node and m number of switching elements can be expressed as:

ECloud = n (ECPU + EMemory + EDisk + EMainboard + ENIC) + m(EChassis + ELinecards + EPorts) + (ENASServer + EStorageController + EDiskArray) + EOthers

The metrics are power usage effectiveness (PUE) and data center infrastructure efficiency (DCIE) are defined [10]

PUE = Total facility power/ IT equipment power

DCIE = 1/PUE = (IT Equipment power/ Total facility) *100%

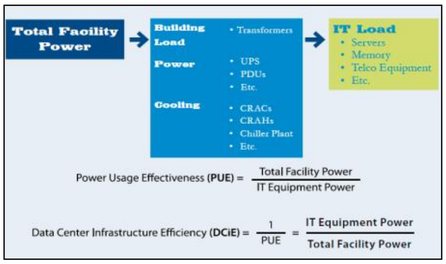

Fig. 5. PUE and DCiE

The IT equipment power is the load delivered to all computing hardware resources, while the total facility power include other energy facilities, specifically, the energy consumed by everything that supports IT equipment load [11]. In cloud infrastructure, a node refers to general multicore server along with its parallel processing units, network topology, power supply capacity.

Fig. 6.

V.CLASSIFICATION OF ENERGY IN CLOUD INFRASTRUCTURE

The energy in cloud computing infrastructure is classified into two broad categories:-

1) Fixed energy consumption (energy consumed during server idle state)
2) Dynamic energy consumption (energy consumed by Cloud tasks and cooling system)

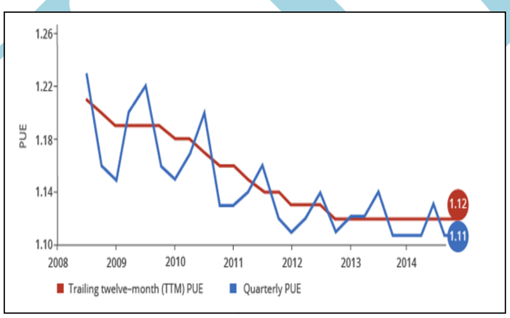

Fig. 7. Continuous PUE improvement for Google Datacenters in US.

The Total energy consumption of an active server for a given time frame is the sum of energy consumed when the system is fixed and dynamic defined as □
ETotal is formulated as follows:

□□□□□□□ E_{Total} E_{Fix} □ E_{Dyn}

There is additional energy is generated by scheduling overhead, denoted by E_{Sched}. This makes the energy consumption of two tasks, not equivalent to the sum of individual consumed energy. In this paper, we focus on the energy consumed by, server idle state, cooling systems, computation, storage and communication resource utilizations.

These are defined as follows:

1. Energy consumption of server idle mode is denoted by E_{Idle}
2. Energy consumption of cooling system is denoted by E_{Cool}
3. Energy consumption of computation resources is denoted by E_{Compu}
4. Energy consumption of storage resources is denoted by E_{Store}
5. Energy consumption of communication resources is denoted by E_{Commu}

Therefore, the above formula can be transformed into:

E_{Total} □(E_{Idle} □□E_{Cool} □□E_{Commu}□E_{Store} □□E_{Compu})□□E_{Sched}

VI.ENERGY EFFICIENCY IN CLOUD INFRASTRUCTURE

Building an energy efficient cloud model does not indicate only energy efficient host machines. Other existing components of a complete cloud infrastructure should also be considered for energy aware applications. Several research works have been carried out to build energy efficient cloud components individually. In this section we will investigate the areas of a typical cloud setup that are responsible for considerable amount of power dissipation and we will consolidate the possible approaches to fix the issues considering energy consumption as a part of the cost functions to be applied[13].

- Energy efficient hardware.
- Energy efficient cooling system
- Energy efficient cluster of servers
- Energy efficient resource scheduling.

a) Energy Efficient Hardware- The energy-efficient hardware is fostered with replacing hard disc drives with solid disc drives which consume less energy. The Cool n Quiet, PowerNow technologies provided by AMD'S [14] reduces noise and heat. The different redundant hardware can be also hibernated in order to have energy efficiency. Power management techniques are available which are characterized as static power management and dynamic power management. The static power management deals with CPU level and register level energy efficiency. The dynamic voltage scaling when combined with portioned sharing scheduling algorithms reduces the energy efficiency. The energy consumption of adaptive dynamic voltage scaling is less than static power management.

b) Energy Efficient Cooling system- The CRAH unit energy consumption dominates the total cooling system energy consumption a transfer heat server hot exhaust to chilled water cooling loop while supplying cool air all over the facility. The efficiency of cooling processor varies on the speed of the air existing the CRAH unit, the substance used in the chiller etc.

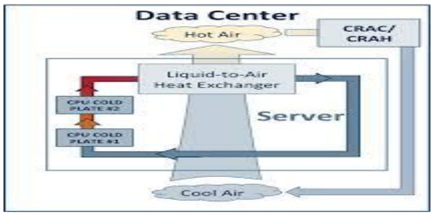

Fig. 8. Cooling block diagram in Data Center.

The efficiency of a CRAH unit is measured using the Coefficient of Performance (COP), which is defined as the ratio of the amount of heat that is removed by the CRAH unit (*Q*) to the total amount of energy that is consumed in the CRAH unit to chill the air (*E*) [15].

$$COP = Q / E$$

The COP of a CRAH unit varies by the temperature (*TS*) of the cold air that it supplies to the cloud facility. The summation of energy consumed by the CRAH (*CRAH E*) and IT (*IT E*) equipments in cloud environment equal the total power dissipation [16]. The energy consumed by the CRAH unit may be specified as:

$$E_{CRAH} = \frac{E_{IT}}{COP(T_S)}$$

Energy consumed by the CRAH unit is dominated by fan power, which increases dynamically with the cube of mass flow rate (*f*) to some maximum amount. Additionally, some fixed energy is consumed by sensors and control system. Thus, the energy consumed by the CRAH unit totals it's fixed and dynamic activity:

$$E_{Cool} = E_{CRAH_{Idle}} + E_{CRAH_{Dyn}} f^3$$

The efficient of heat exchange and the mass available to transfer heat increases as the volume flow rate through the CRAH increases.

c) Energy Efficient Clusters of servers- Power dissipation is primarily reduced by optimal CPU utilization and tasks scheduling. However other cluster components such as memory, storage discs, network peripherals etc. also consume power and hence a VM having idle CPU may still use considerable amount of energy. Figure 8 shows a typical cloud cluster structure. New approaches aim to reduce the energy consumption as a whole at clusters of servers while considering system's latency and throughput

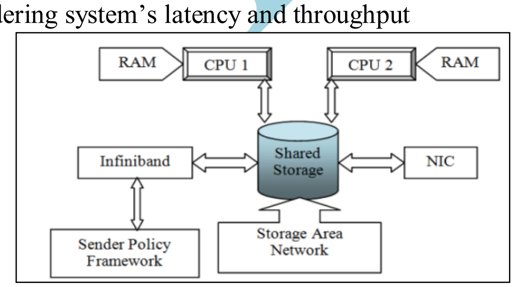

Fig. 9. Typical Cloud Cluster Structure

i) Resource management architecture: At server side, the operating system of the machine hosts several separate instances of virtual machines. Optimal resource management architecture should be built based upon the energy estimation in different nodes of a server cluster. Depending upon external situation and workload, the cluster can be easily affected by overloading and overheating despite sufficient cooling system. While a complete shutdown of cluster causes unwanted business downtime, it is the operating system that should take care of auto-scaling of power demand from different cluster components. Dynamic Thermal Management [17] is a technique that controls power dissipation in high performance, server processing unit and provides low "worst case power consumption" with no or little impact on

performance. Cluster's network infrastructure is a major area of power dissipation that holds a substantial share of operating cost. Balancing of QoS and resource utilization during outage can also be a descent way of energy management in clusters. Policies are developed for resource management in economic way [18] where cluster always checks for system's work load and allocates resources by calculating their effects on system's overall performance. A greedy allotment method can be used to estimate supply – demand tradeoffs for an efficient allocation of resources.

ii) Dynamic Server Provisioning and load dispatching: In order to save energy, Dynamic Server Provisioning method is useful in switching off unnecessary and idle hosts in a cluster [19]. As the number of internet services is increasing rapidly, the servers are also increasing in number to host those services, resulting huge amount of power dissipation in form of heat. Dynamic Server Provisioning algorithms [20] are designed to turn off extra servers and to allow the cluster to run on minimal number of host machines to satisfy the service load. Thereafter, load dispatching technique effectively distributes the current load among available servers. These techniques can be implemented in servers operating request-response services (example: web services) as well as host machines connected to huge number of long lived TCP connections.

For multi-tier internet services, queuing method can be implemented in dynamic provisioning technique that can be defined as a proactive and reactive approach to estimate short-term and long-term workload fluctuations in cluster. It can predict minimum capacity required for maintaining the required QoS and can also balance sudden surges in server load.

d) Energy Efficient Resource Scheduling- Several research works have been carried out on energy efficient resource scheduling in virtual machines and grid systems.

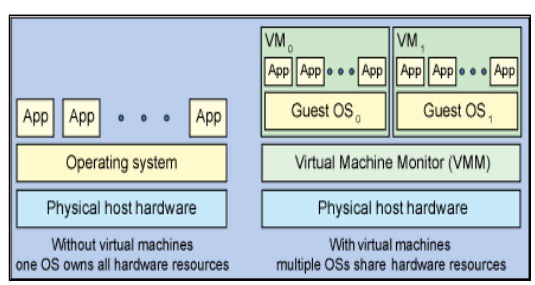

Fig. 10. Virtual Machine concept
Fig. 11.

The important technology for energy-efficient framework for data centers is virtualization. Virtualization eases the software customization, patching and the portability. Virtual machines(VM) or hyper visors can even shift the data from one cloud to the other through the Open Virtualization Format in case any compatibility issue arises. This technology provide a way to manage resources efficiently due to easy in mapping between virtual resources and physical resources as shown in figure 9. The reduction the redundancy helps to gain energy-efficiency.

VII.EESS FOR CLOUD COMPUTING

EESS (Energy Efficient Scheduling Schemes) is design on the base of above characteristics for save energy number of virtual machines, total time, full workload utilization on less number virtual machines; these are important metrics of our scenario. And by using Virtual machine is running in different modes, we say state of virtual machine categories in different states in EESS like running ,active, pause, resume ,power on & off for achieving energy efficiency. EESS is for virtual machines in private cloud environments. Energy saving paradigm is complex than other paradigm, as practical implementation of that methods difficult, various tools required, again that tool have capability support virtualization, para-virtualization for maximum workload balancing on virtual machines provides to consumer.

Cloud computing approaches are exploring the beneficial of virtualization technology to maximize the use of physical resources. The huge scope is possible to do work in the better lease scheduling in the Clouds.

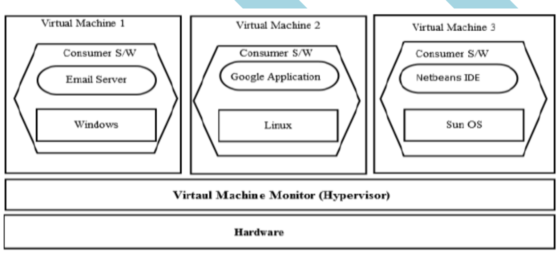

Fig 11. Basic Cloud Architecture

The commercial industry is widely spreading the Clouds such as Amazon, VMWare, UnivaUD, Eucalyptus and RightScale etc. need such algorithms which will improve the efficiency of storage and computational units.

This research work has been background of interacting with Nimbus Science Cloud. This work can be performed with the help of laboratory set up. The better results can be checked by working with some High Performance computing units such as scalar and vectors. The results for research work can be well-formed into the API library.

Afterwards, through knowledge transfer process it can be converted into industry useful product.

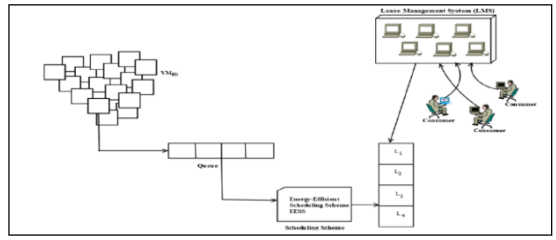

Fig. 12. Working process of EESS

The schemes designed in Design and Optimization of Scheduling Scheme in Cloud Computing (DOSSCC) useful for energy efficiency, and would be useful for the finding out the solutions to the challenging scientific applications. The DOSSCC schemes will be designed such that power saving directly prepositional to time of given jobs, number of virtual and physical resources. In Virtual box mentioned basic architecture of cloud computing, hardware virtualization allows running multiple operating systems and software stack on a single physical platform as depicted in figure 10 below:

The EESS concept can be used to schedule number of requests from clients connected to cloud simultaneously from the figure 11 below:-

VIII. PSEUDO CODE OF EESS

Steps of Algorithm

// Set default values of U, H, VM_{Hi}, i, j, J, L, VM_S, VM_T, VM.

1. Start
2 .If (j <= 0) //VM request equals to zero or less than zero
3. Exit();
4.end if .
5. If (j < J) // VM request is less that Total number of VM request i.e. // least load first
6. PowerONVM (j, H, VM_{Hi}); // power on Virtual machines
7 if (VM_{Hi} = = Pause) then Resume(VM_{Hi});
8. if (L= =P) then Clone(VM);
9. end if.
10. $VM_{Hi} \leftarrow$ j // Assign the number of jobs to Virtual machines by using //First Come First Serve
11. else
12. if (j=>J) // VM request is greater than or equals to total number of VM
// request, maximum load schedule using migration
13. Find(VM_S , VM_T); // required Migration so find source & Target //Virtual machine
14. $VM_T \leftarrow$ PowerOFF VM_{Hi} state and on its Teleport-In
if (VM_T= = Running) then Pause(VM_T);
15. $VM_T \leftarrow$ Teleport-In(VM_T) //Teleport-In state in Target virtual machine
16. $VM_S \leftarrow$ Active VM_{Hi} state as a source
17. Migration (VM_S, VM_T);
18.end if
19. end if
20. Update (VM_{Hi} , j, J, L);

21. end of EESS.

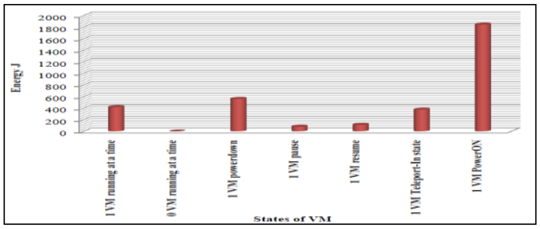

Fig. 13. Energy Consumption of VM in different States

TABLE I

Methods \ Energy (E) in Joule	Conserved Energy (J) per minute	Conserved Energy (J) per Total time
EESS	2064	226345.2
Bully Approach	102	62318.4
Round-robin	0	0
Hybrid energy-efficient scheduling algorithm	1698	196999.2

Table 1 Energy conservation comparison of different Scheduling schemes

IX.CONCLUSION

The overall energy efficient of cloud infrastructure depends upon many parameters as discussed in this paper. Cooling solutions should efficient as most of the energy consumption of Data Center in cooling but energy consumption can also be decreased by implementation of energy efficient scheduling. Cloud computing is a new computing paradigm that offers a large quantity of compute and storage resources to the masses. Scientist and startup companies can have access to these possessions by paying a minute amount of money just for what is really wanted. In their various contour and flavors, cloud aim at offering compute, storage network, software, it is combination "as a service". IaaS, PaaS, SaaS are three most common nomenclatures for level of generalization of cloud services, ranging from "raw" virtual servers to sophisticated hosted applications. Virtualization enables high, reliable, and agile deployment mechanisms and management of services, providing on demand cloning, live migration services which improve reliability. A great popularity and apparent success have been seen in this area. How to provide an energy-efficient scheduling method for the cloud platform has become a challenging problem. Thus Energy-efficient scheduling scheme call EESS is always beneficial for power generation plant and their survive problems that needs today, and we move towards Green Computing which really needs for us.

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