Energy Efficient Resource Provisioning through Energy and SLA Aware(ESA) Algorithm in Cloud Computing

A Thesis

submitted in partial fulfillment of the requirements for the award of the degree of

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in

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by

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Certificate

I hereby certify that the work which is being presented in the thesis entitled," ***Energy Efficient Resource Provisioning through Energy and SLA Aware(ESA) Algorithm in Cloud Computing***", in partial fulfillment of the requirements for the award of degree of **Master of Engineering** and submitted in Computer Science and Engineering Department of Thapar Institute of Engineering and Technology, Patiala, is an authentic record of my own work carried out during the period under the supervision of **Associate Prof. Neeraj Kumar** and refers other researcher's work which are duly listed in the reference section.

The matter presented in this thesis has not been submitted elsewhere for the award of any other degree or diploma from any institution.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Acknowlegement

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Abstract

Cloud Computing is an Internet-based computing in which services provided by the Cloud Service Providers (CSPs) are in the same way as utilities i.e, pay-per-use model. It enables the clients and endeavors to store and process their information in a cloud infrastructure to give them a chance to concentrate better on their business needs. With the rapid increase in popularity of Cloud Computing growth of data centers also increases to accomplish the routine services. As a result, a great amount of energy is consumed by data centers even when they remain underutilized. Proper management of this energy consumption becomes a key issue.

Virtualization plays a vital role in reducing energy consumption. The process of migration of Virtual Machine (VM) from one server to another is known as Virtual Machine Migration (VMM). Fault tolerance, load balancing, improved performance, and energy management are some benefits of VMM. But it leads to degradation of performance and SLA violations that cannot be ignored.

In our work, we propose an algorithm namely Energy and SLA Aware (ESA) VM placement algorithm that reduces the overall energy consumption based on 1) After allocation, host utilization 2) VM creation history and 3) the difference between power consumption, SLA violation by the host before and after allocation. It also considers energy efficiency which is a function of power and SLA. The implementation of the proposed algorithm is done in CloudSim. The results show that our method provides a considerable amount of reduction in energy consumption and average SLA violations.

Keywords: Cloud Computing, Energy Efficiency, SLA violations, ESA algorithm.

Table of Contents

List of Figures

List of Tables

Table No. **Title** **Page No.**

List of Notations

i,k,c	Number of DCs, servers, cloudlets
P_i	Power consumption by i^{th} DC
P_i^k	Power consumption by server of i^{th} DC
P_{static}	Fixed power consumption by the k^{th} server
P_{max}	Maximum power that k^{th} server can consume
U_k^i	Utilization level of k^{th} server of i^{th} DC
$(R_k(t))$	Resources consumed at time t by k^{th} server
$(R_{max}k)$	Maximum capacity of k^{th} processor
i^{th} DC	Energy Consumption of i^{th} DC
E_k	Energy consumption by k^{th} server
E_{idle}	Idle energy consume by the k^{th} server
E_{max}	Maximum energy that k^{th} server can consume
SLA_k	SLA violations of k^{th} server
(t_k^{th})	Time for which threshold utilization level is experienced
t_k^{ac}	Total time during server is active
D_k^{mig}	Performance degradation due to migration
φ_c^{dg}	Estimate of performance degradation due to migration
φ_c^{cp}	Resources requested for migration
EE	Energy Efficiency

List of Abbreviations

ARPA	Advanced Research Projects Agency
AWS	Amazon Web Services
CSP	Cloud Service Provider
CC	Cloud Computing
CDC	Cloud Data Center
DC	Data Center
DVFS	Dynamic Voltage Frequency Scaling
ESA	Energy and SLA Aware
IaaS	Infrastructure as a Service
MBFD	Modified Best Fit Decreasing
NIST	National Institute of Standards and Technology
PC	Personal Computer
PaaS	Platform as a Service
SaaS	Software as a Service
SLA	Service Level Agreement
QoS	Quality of Service
DC	Data Center
VM	Virtual Machine
VMM	Virtual Machine Migration

Chapter 1

Introduction

1.1 Cloud Computing Evolution

Evolution of Cloud Computing unknowingly began almost 50 years ago. John McCarthy, a professor at MIT(Massachusetts Institute of Technology) University in the US, a computer scientist, in 1961 expresses the idea of sharing computer technology as the same logic used for sharing electricity. He stated that computation can be delivered as a public utility [1]. For example, a power plant is considered as a service provider which provide services, distribution network as internet and households or firms as customers [2].

J.C.R Licklider developed a network in 1969 called ARPA to connect everybody on the earth and recovering projects and information at any site, from anywhere. Initially, it was used for military and scientific purposes but later in 1988, it became popular for its commercial use in services like email and telnet. That is why the internet is foundation of all the facilities provided by CSP.

Cloud computing risen through different stages which include grid computing, autonomic and utility computing and SaaS. One small success was achieved with the advent of Salesforce.com in 1999, which began the idea of conveying business applications via a website. Then in 2002, Amazon created AWS, providing a package of cloud services involves the capacity to the calculation. Next big milestone achieved in 2009 as Google along with other service providers started offering enterprise applications, namely Google Apps and Windows Azure by Microsoft. Fig 1.1 shows the evolution of cloud computing.

1.2 Cloud Computing

Cloud computing is one of the popular Internet-based technology, in which services, resources provided to PCs and other gadgets are on request just as a public utility. So the term 'CLOUD' can be explained as Common Location Independent Online Utility On Demand. In other words, CC is using the internet to access someone elses software running on someone elses hardware in someone else data center. There are various defi-

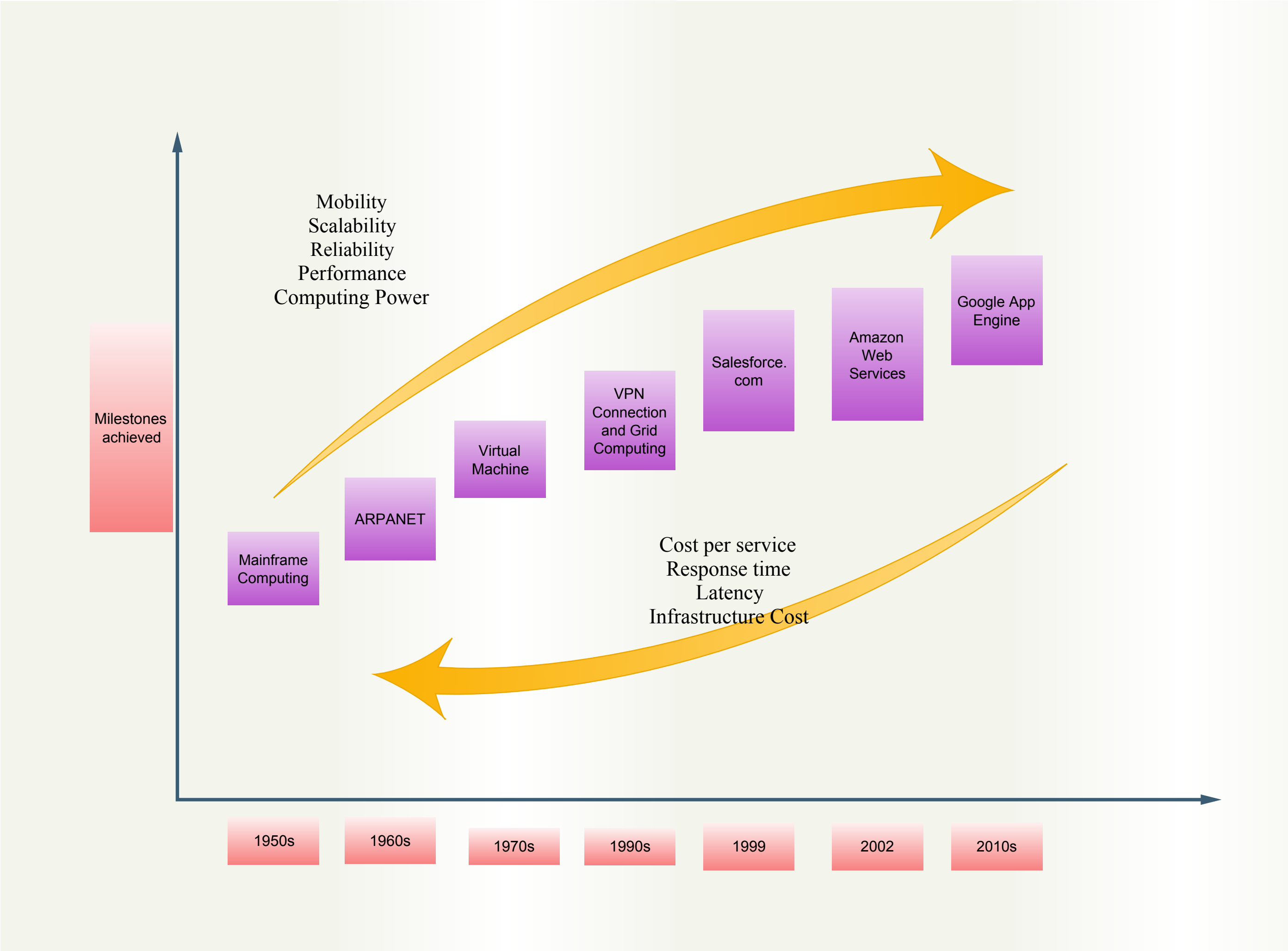

Figure 1.1: Evolution of cloud Computing.

nitions of CC defined by various researchers and scientists, e.g. Michael Brown, Gartner, Rajkumar Buyya. But in 2011 NIST defined a standard definition of CC which defines the essential features, deployment models and service models.

According to NIST ”CC is a representative for empowering pervasive, easy, on request network access to a regular pool of configurable processing assests (e.g., systems, storage, and services) which can be immediately provisioned and discharged with insignificant effort or collaboration with CSP.” [3].

1.2.1 Characteristics of Cloud Computing

Cloud Computing has interesting essential characteristics that are beneficial to both CSPs and CSCs.The following table 1.1 describes the essential characteristics [3].

Table 1.1: Description of the Characteristics.

Characteristics	**Description**	Applications
On-demand self-service	Cloud users can accessed the services automatically through a self service web interface without any human communication with CSP.	Server time, network and storage
Broad Network Access	Cloud services are broadly available over internet means these can be accessed from any where at any time using various range of platforms, protocols, devices and technologies.	Mobile phones, notebooks and workstations .
Resource pooling and Multitenancy	Several users draw resources from regular pool through multitenant model.	Physical and Virtual resources include capacity, memory, processing and bandwidth are dynamically assigned according to user demand.
Elasticity	Elasticity of a cloud is the ability to transparently scale IT resources automatically, as required in runtime conditions by the cloud user.	Adding and releasing servers,resources etc.
Measured Services	In measured Services, cloud users are charged only for the services(resources)they actually used and for the time duration they access those granted resources.	Resource usage can be monitored, controlled, and reported

1.2.2 Cloud Computing Service Models

CSPs grant services to users in the form pre-defined set of services (IT resources)known as cloud service models.There are three cloud services models as in fig.1.3 shown below.

- **Infrastructure as a Service(IaaS):** This is a self service model for accessing, monitoring, and managing remote datacenter infrastructures, such as compute (virtualized or bare metal), storage, networking, and networking services (e.g. firewalls). The cloud customer can deploy and run arbitrary software, such operating systems and applications.For example:Google Compute Engine in which user can develop his own programs to be run on high performing google's computing infrastructure. Some IaaS Service Providers are:AWS,Google Compute Engine,Windows Azure,Rackspace Open Cloud,IBM SmartCloud Enterprise etc.

Figure 1.2: Characteristics of Cloud Computing.

- **Platform as a Service(PaaS):** The PaaS layer is on the top of IaaS.This service model allows cloud users to deploy applications created using libraries ,tools ,services provided by CSP. User need not to manage or control Cloud Infrastructure But has controlled over the deployed applications. For example:Google App Engine in which user can develop applications and run on the platform (as system software and hardware) provided by CSP which take care of the execution. Some PaaS Service Providers are:Engine Yard, Google App Engine, AppFog, Heroku ,Windows Azure Cloud Services etc.

- **Software as a Service(SaaS):** The SaaS layer is on the top of PaaS.In this service model ,CSP allows cloud users to run applications on a Cloud Infrastructure provided by CSP. For example: Gmail, Google+ etc. Some SaaS Service Providers are:Zoho, Help Desk Providers, Customer Service Providers, Office Suit Providers.

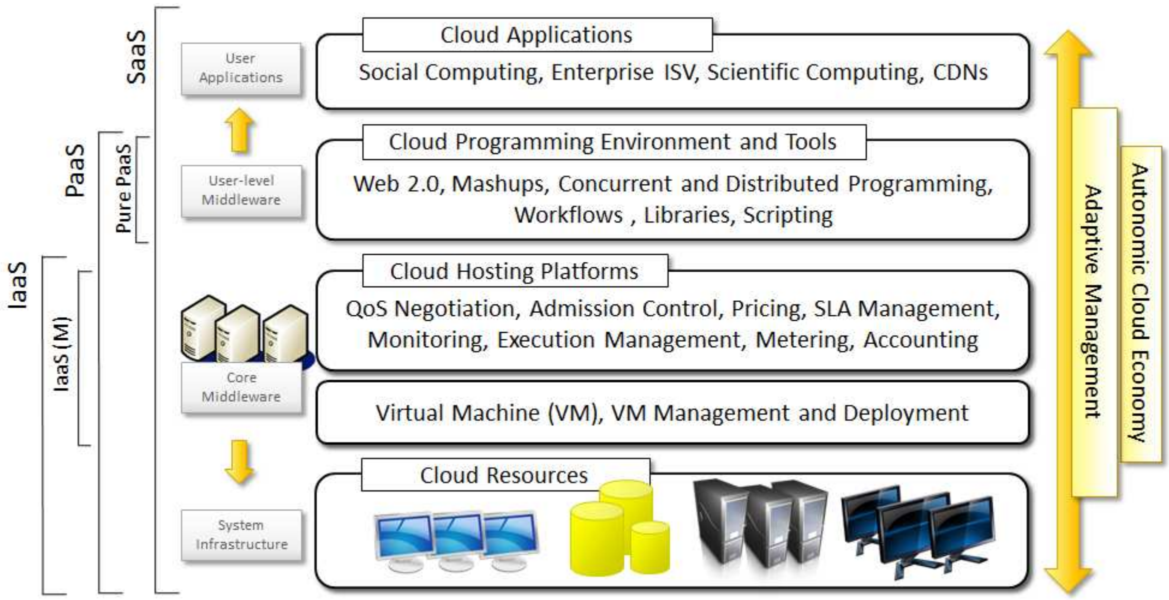

Figure 1.3: Cloud Service Model Architecture.

[4]

1.2.3 Cloud Computing Deployment Models

The hosting environments that are differentiated on the basis of size, access and ownership is known as Deployment Model.There are basically four types of deployment models.

- **Public Cloud:** A public cloud is a cloud environment,in which services provided by CSP for open use by the general public.It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.
- **Private Cloud:** A private cloud is a cloud environment provided CSP for exclusive use by single organisation consists of multiple users. It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.
- **Community Cloud:** A community cloud is a cloud environment shared by different cloud organisations, users having same interests and concerns(e.g., privacy, security requirements, mission etc). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.
- **Hybrid Cloud:** The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities,

but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

1.3 Traditional data center vs Cloud data center

With the quick development in the data flow, data storage is one of the biggest concern. Along with storage, cost and scale are other key variables as huge amount of data and information is transmitted worldwide. So the question emerges on how to store and retrieve information efficiently. In traditional data centers, every application requires its own infrastructure so, in the event that it runs a thousand applications, it would require a thousand servers. While in Cloud data center every one of the applications is facilitated in one basic distributed storage which decreases the cost when contrasted with Traditional information centers.

1.3.1 Traditional data centers

The fig1.4 shows the traditional data center workflow. It involves n number of applications hosted in a network with each its own storage with an increase in applications, increase in storage also increases.

1.3.2 Traditional data center Features

- Data stores within the local network of an organization
- Special knowledge and equipment requires
- Hardware with the heterogeneous environment and complex workloads
- Different management tools and software architectures
- Cost is more and more secured
- Owners has to keep up entire control over equipment and programming
- Leasing depends on physical machines
- Requests semi-computerized repair if there should be an occurrence of a failure

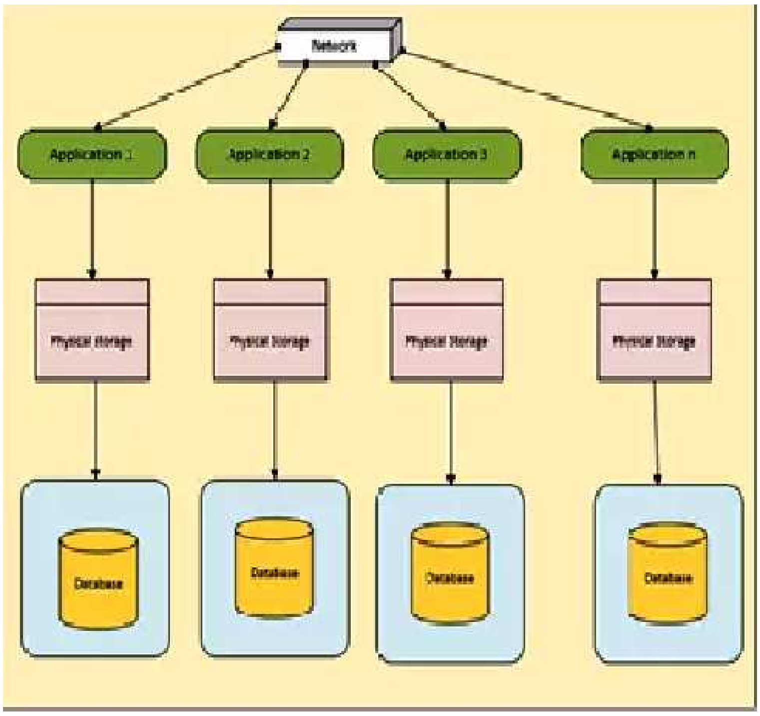

Figure 1.4: Traditional Data Center workflow.

1.3.3 Cloud data centers

Fig1.5 shows the basic workflow of Cloud Datacenter. Applications located in different locations are hosted on the same cloud. New applications can be added to the cloud anytime as it is effectively adaptable. Both essential and optional databases are on a similar cloud, so regardless of whether essential database bombs, there will be no loss of information. Applications facilitated on the cloud are utilized by clients worldwide through the Internet. Stores data on the Internet.

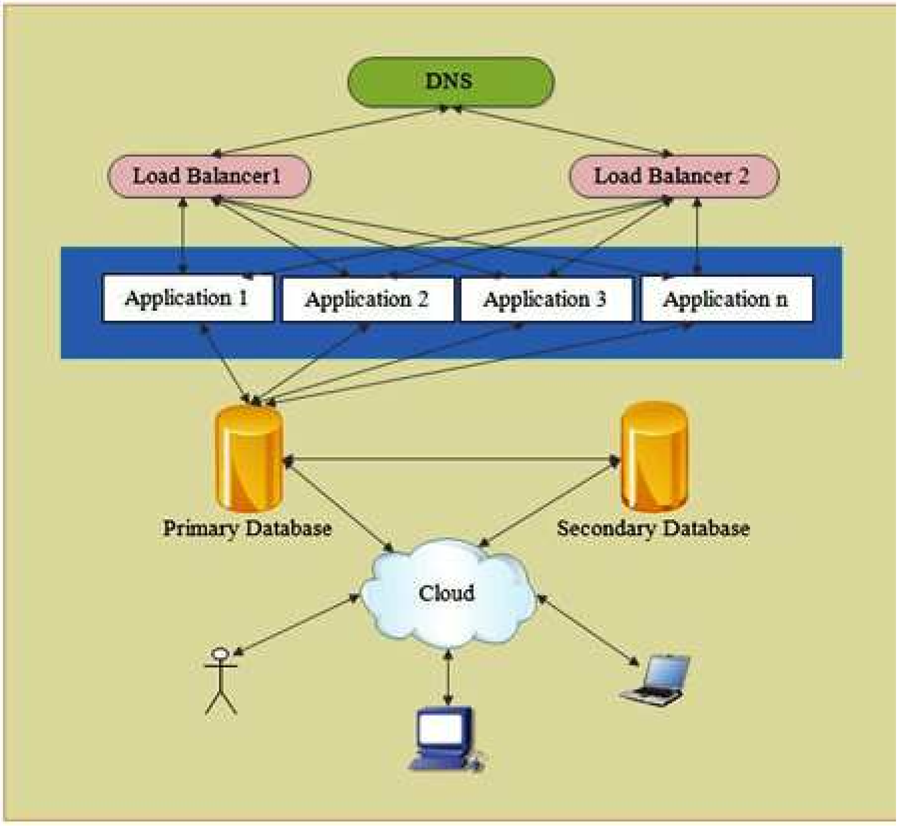

Figure 1.5: Cloud Data Center workflow.

1.3.4 Cloud data center features

- No special knowledge and equipment requires
- Hardware with the homogeneous environment and simple workloads
- Standardized management tools and single software architecture
- Cost is less as compared to traditional data centers
- Self-service, pay per use and easily scalable on demand
- In the event of failure automated recovery

1.4 Thesis Organisation

The thesis is organized into following chapters:

Chapter 1: This chapter describes the evolution of Cloud computing, its definition, service models, deployment models and comparison of traditional and cloud data centers.

Chapter 2: This chapter provides a review of the state of the art in the related area.

Chapter 3: In this section, problem formulation along with research objectives are provided.

Chapter 4: This chapter gives details about the proposed method along with pseudocode and flowchart. It also contains various equations that are used in the algorithm.

Chapter 5: Results obtained from proposed method are provided in this section. This chapter evaluates the performance of the proposed method and compares its result on various parameters with existing algorithm i.e, MBFD.

Chapter 6: Finally, conclusion and future scope of the proposed method are provided in this chapter.

Chapter 2

Literature Review

2.1 Literature Review

Many studies have focused on Energy management of DCs in terms of energy consumption minimization, SLA violations minimization, and energy efficiency. Energy efficiency in CC is considered as major research challenge during resource management[5]. To handle this challenge many solutions have been proposed by the researchers which are either based on DVFS or workload consolidation techniques.

Wu et al. in [6] proposed a DVFS based scheduling algorithm that effectively improves resource utilization by reducing the energy consumption of servers in CDCs.

Alnowiser et al. [7] use improved weighted round-robin algorithm based on DVFS for monitoring, consolidation and migrating hosted VMs to reduce energy consumption.

A lot of research work has been done on the energy-aware resources allocation, i.e., VMs placement and migration in the DCs. Beloglazov et al. [8] proposed Best Fit Decreasing (BFD) heuristic for optimal and efficient resource utilization;they also proposed heuristics for VM migration in order to to decrease SLA violations and power consumption.

Beloglazov et al. [9] proposed a basic algorithm which include VM allocation and VM placement such that it searches for overloaded and underload hosts from host list.After finding the host next it searches for new place for host migration. This algorithm is not suitable for complex workload type.

Bobroff et al. [10] proposed VM provisioning technique for reducing hosts power consumption and SLA violations. This technique uses resource usage history and time series analysis for predicting future demand in order to reduce the number of hosts used.It uses First Fit Bin heuristics for reducing the number of hosts used with increase in number of VM migrations. The similarity between both algorithms i.e. their and ours is that both attempts to reduce energy consumption, and SLA violations but we also reduces the number of migrations and hence increases energy efficiency.

In [11], the issue of energy consumption in network architectures and DC is explored by the authors.They apply network optimization only at DC design level but not apply dynamically.

Kusic et al. [12] proposed a technique ,named Limited Look ahead Control (LLC) in order to address the problem of power management in heterogeneous visualized environment. The main purpose was to decrease power consumption, increase the profit of an CSP, and also decreases SLA violations.

In [13] the authors proposed Energy Aware Best Fit Decreasing (EABFD) algorithm to decrease Energy consumption and the number of VM migrations.

Xiao et al. in [14] presented the idea of "skewness" measurement of unevenness in the use over different resources of a server. They introduce a computerized framework to accomplish the objective of dynamic resource management with avoidance of overload and support green computing. A Fast and Slow down (FUSD) approach is utilized to assess the future asset utilization of resource without looking inside a VM and using prediction based method exponentially weighted moving average (EWMA) in a TCP-like scheme.

Dabbagh et al. [15], proposed energy-efficient, resource allocation framework for over-committed clouds. This framework mainly focuses on reducing overload PMs via proper VM resource usage monitoring and prediction. Additionally, it focuses on reducing the number of active VMs in order to reduce the number of unpredicted overloads, increase resource utilization, minimize migration overhead, and reducing cloud energy consumption.

Many researchers also focused on resource allocation policies in order to tackle energy efficient resource management problem in CDC. Resource allocation can be done based on various parameters shown in fig 2.1.

Resource allocation adaption policy defines the degree to which allocation allocator able to respond to dynamic and uncertain conditions [16]. The objective function is the mathematical function, expression or metric that needs optimization along with system constraints. Allocation methods define how to allocate resources, VMs taking care of power or thermal-aware minimization.

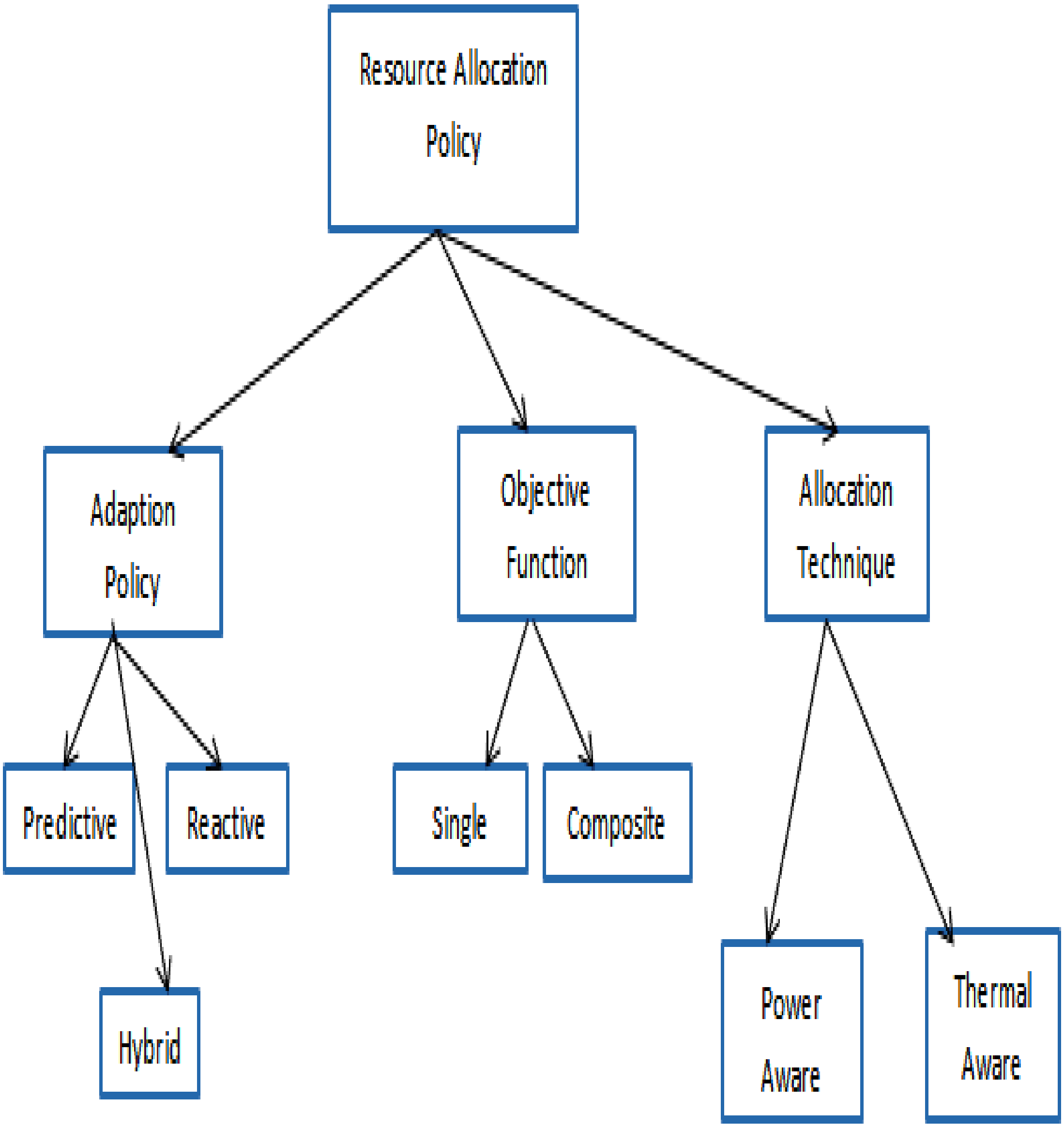

Figure 2.1: Resource Allocation Policy.

Chapter 3

Problem Statement

3.1 Research Motivation

In Cloud Computing, DCs consume a great amount of energy to carry out their daily activities (computation, online data analytics, data storage etc.). Many of the servers in these DCs run continuously for servicing cloud users requests. VMs are hosted on these servers to fulfill the request. These VMs are provisioned and released dynamically according to the requirement. As a result, servers consume 70% of the resources in their idle state.[17] Along with servers, cooling system also consumes an extra power consumption of .3 to .8 W on consuming 1W power by computing resource. CSPs are supporting various energy efficient approaches (such as VM consolidation, migration, workload prediction etc.) to handle daily activities of DCs. These approaches mainly focus on minimization of energy consumption by not considering SLA violation.[18] Also, it is necessary to provide QoS parameters like response time, bandwidth throughput etc. to cloud users up to negotiated performance levels. So, there is a need for approaches that can effectively minimize energy consumption in CDCs while maintaining low SLA violation.

3.2 Problem Statement

In CC, the greater part of the DCs are servers which are running persistently, devouring maximum energy in sitting still state.Along these lines, it is exceptionally hard to measure with precision the threshold values as the entire usage history of the host must be figured. In the event that a host has been under utilized for a noteworthy measure of time then it is smarter to shut it down in order to save energy.Be that as it may shutting down a host isn't as simple as simply turning a switch on or off. It can prompt SLA violations and degrade the performance.So VM allocation ways to deal with Host must need improvement to reduce energy consumption, SLA violation and hence maximize Energy Efficiency.

The problem of Energy minimization can be mathematically defined as:

minimize :

$$\sum_{1}^{m}(E_{dc}) \tag{3.1}$$

and

$$\sum(SLAVs) \tag{3.2}$$

subject to following constraints

$$0 < \sum_{tasks}(U_j) <= S_i \tag{3.3}$$

where (E_dc)is the energy consumption and (SLA Vs) are the service level agreement violations by CDC. The objective is to minimize them in order increase energy efficiency. Constraint 3.3 ensures that for each task the resource demands of each VM hosted on server does not exceeds the total capacity of that server.

3.3 Objectives

Following are the goals that this thesis work accomplishes

- Minimize the overall energy consumption of data center.
- Minimize SLA violations.
- Minimize number of VM migrations.
- Maximize overall Energy Efficiency of data center.

Chapter 4

Proposed Scheme

This chapter explained the proposed scheme i.e a new VM placement policy that considers both minimal increments in energy consumption and SLA violation. We called this policy as Energy and SLA aware VM placement (ESA).

4.1 Energy and SLA aware VM placement algorithm

Scheduling and placement of VM are studied according to resource scheduling and VM migration. In CC, VM allocation must be done such that the stability of target host is expanded, i.e, it should not be included for a longer period of time in any migrations. To accomplish this, we have proposed an algorithm called ESA. It is based on an MBFD algorithm with linear in complexity. The ESA algorithm considers various factors that have not been considered in MBFD algorithm for choosing a best appropriate host for a specific VM from the hosts whose list is available. The additional factors are:

- After allocation, maximum host utilization.
- VM history creation.
- After allocation, host power

In general, VM migration process consists of four steps i.e, when to migrate a VM, which VM is suitable for migration, deciding target host for migration of selected VM and last which host switched on/off. Selection of target is very crucial. The proposed approach depends on the way that sufficient amount of energy and resources consumes during migration. Besides, a cloud client may witness degradation in execution. Therefore, we have to limit or minimize the number of migrations in order to improve performance and energy efficiency. The working of proposed algorithm 1 is shown as below.

In the algorithm, the "hostList" is the set of all eligible hosts, the "vmList" is the set of VMs in the datacenter and "threshold" is the upper threshold values of the utilization of the resource.[19]These three parameters are taken as input for the algorithm. After execution, the host with less power consumption and maximum energy efficiency is returned as output for allocation of VM.

Algorithm 4.1 Energy and SLA aware VM placement Algorithm

```
Input: hostList,vmList ,threshold
Output: VM allocation to host
PowerVmList.sortByCpuUtilization
for vm:vmList do
  minPower = MAX
  minEEfficiency = MIN
  allocatedHost = null
  for host:hostList do
    if host suitable for Vm then
      Calculate maxUtilization after allocation
      if  vm recently created && maxutilization exceeds threshold then
        calculate power and SLA violation of host using equations 4.2,4.6
        calculate powerDiff and slaDiff after allocation
        calculate energyEfficiency using equation 5.4
        if energyEfficiency > minEEficiency then
          allocate VM to that host
        end if
      end if
    end if
  end for
end for
```

ESA algorithm at first sorts all VMs in decreasing order of their CPU utilization. For each host, check the suitability of that particular VM. After checking, we compute the max utilization of each host for that particular VM. If VM is not recently created and also exceeds the max utilization value then get the power and SLA violation value for that VM. Then compute power difference of power after allocation and current allocation, SLA difference before and after migration. Calculate energy efficiency and at last allocate the VM to that host whose power, SLA is minimum and energy efficiency is maximum.

4.2 Flow Chart of ESA

The Flowchart for proposed approach ESA is shown in fig 4.1.

4.3 Equations used in ESA algorithm

Various formulae and equations are used in ESA algorithm in order to compute power and energy consumed by the host. SLA violations and energy efficiency is also calculated to improve the basic MBFD algorithm.Following are the equation models that are

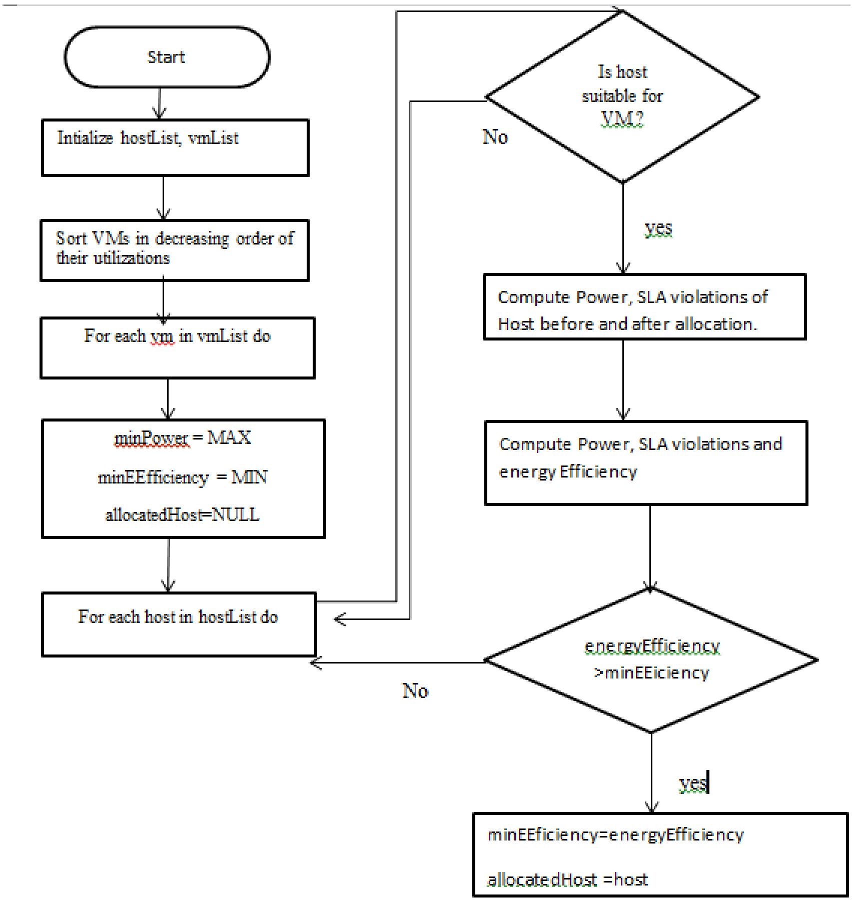

Figure 4.1: Flowchart of the proposed algorithm.

used.

1. Power Model

   Power consumption by processing hosts in DCs is mostly utilised by the CPU, memory, cooling systems and other infrastructure. Major part of power is consumed by hosts(server). Recent studies have demonstrated that there is a linear relationship between the power consumption and CPU utilization[9]. So, power consumption of i^{th} DC is given as below.

$$P_i = \sum P_i^k \tag{4.1}$$

   Now, power consumed by server is given below.

$$P_k = P_{static} + (P_{max} - P_{static}) * (U_k^i) \tag{4.2}$$

   where, P_{static} is the fixed power consume by the k^{th} server, P_{max} is the maximum power that k^{th} server can consume and U_k^i is the utilization level of k^{th} server.

   The level of utilization of k^{th} server of i^{th} DC depend on the amount of resources consumed $(R_k(t))$ at time t and maximum capacity of processor $(R_{max}k)$ and is given as below.

$$U_k^i = ((R_k(t))/R_{max}k)) * 100 \tag{4.3}$$

After computing power, this power can be converted to energy consumption by dividing calculated power through $(3600 * 1000)$ which is energy in KWh.

2. Energy Model

   Energy consumption is one of the important parameter that need to be considered while designing an algorithm. Energy Consumption of i^{th} DC can be defined as a function of energy consume by the servers which is given below.

$$E_i = \sum E_i^k \tag{4.4}$$

   Now, energy consumed by server is given below.

$$E_k = E_{idle} + (E_{max} - E_{idle}) * (U_k^i) \tag{4.5}$$

   where, E_{idle} is the idle energy consume by the k^{th} server, E_{max} is the maximum energy that k^{th} server can consume.

3. SLA Model

   SLA is one of the most vital requirement in CC environment as QoS are enclosed in the form of SLAs. SLA violations occurs, when the resources required to process the task exceeds the available capacity of resources with a DC or host. SLA violations are measured as a function of time during which k_{th} server is experiencing threshold utilization (t_k^{th}), total time during server is active t_k^{ac}, performance degradation due to migration (D_k^{mig}). The SLA violations of pth server of ith DC is given as below.[20]

$$SLA_k = \frac{1}{k} \sum \frac{t_k^{th}}{t_k^{ac}} D_k^{mig} \tag{4.6}$$

   Now, performance degradation due to migration is given below.

$$D_k^{mig} = \frac{1}{C} \sum \frac{\varphi_c^{dg}}{\varphi_c^{cp}} \tag{4.7}$$

   where, φ_c^{dg} and φ_c^{cp} denotes estimate of performance degradation due to migration and resources requested for migration.

4. Energy Efficiency

   Energy efficiency includes two important parameters: energy consumption and SLA violation.The energy efficiency(EE) is given below.

$$EE = \frac{1}{energy(E) * SLA} \tag{4.8}$$

where, energy(E)represents the energy consumption, SLA defines SLA violations.

Chapter 5

Results and Discussion

This chapter is devoted to the performance evaluation of the proposed ESA VM allocation algorithm defined in the previous chapter. First, we present the simulation environment setup. From that point onward, simulation results are presented from various perspectives, including energy consumption, number of VM migrations, SLA violations, and energy efficiency.

5.1 Simulation Setup

For analysis and comparison of the proposed algorithm, we implemented and simulate ESA VM allocation algorithm in Cloudsim simulator.CloudSim is a simulation framework designed by the GRIDS research center of the University of Melbourne which provides consistent modeling, simulation and experimenting with designing Cloud computing infrastructures. It can be utilized to model data centers, service brokers, host, scheduling and allocation policies of a large-scale Cloud infrastructure[21]. The Simulation parameters used for experiment describing characteristics of host and VM are described in Table 5.1 shown below.

Table 5.1: Characteristics of Host and VM.

HOST	
maxPower	250W
staticPowerPercent	0.7 70%
mips	(1000, 2000, 3000)
ram	10000 MB
storage	1000000 MB
bandwidth	1000000Mbps
VM	
mips	(250, 500, 750, 1000)
number of CPU	1
ram	128 MB
bandwidth	2500 Mbps
VM size	2500 MB

For analysis purpose, different input sets in the form of cloudlets(tasks) are given to the system. At runtime, cloudlets are created randomly and then added to central cloudlet list. Additionally, VMs is also arranged at runtime comprising of all the randomly made VMs. Both cloudlet and VM list are given to the data center broker during execution. Datacenters containing hosts are also created. After simulation environment setup, execution starts and results are recorded for comparison using different parameters.

5.2 Comparison of Energy Consumption between ESA and MBFD algorithm

The following fig 5.1 shows the comparison of energy consumption between ESA and MBFD algorithm. MBFD is Modified Best Fit Decreasing algorithm where ESA is Energy and SLA aware VM allocation algorithm, which is an improvement over MBFD. From the following graph, it is clear that the energy consumption of ESA is less than MBD with the increase in the number of Cloudlets.

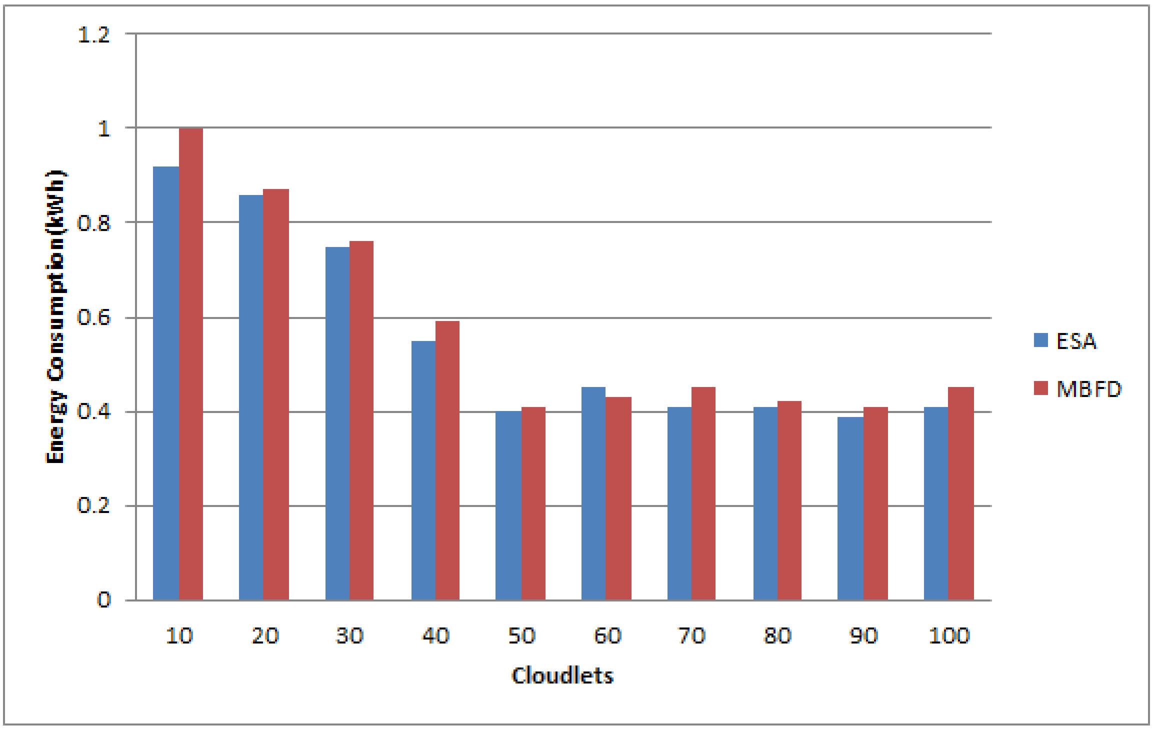

Figure 5.1: Comparison of Energy Consumption between ESA and MBFD algorithm.

5.3 Comparison of Number of VM Migrations between ESA and MBFD algorithm

The following fig 5.3 shows the comparison of Number of VM migrations between ESA and MBFD algorithm. It is clear from the graph below that the VM migrations are increasing in MBFD case as compared to ESA with an increase in the number of cloudlets eg(after 70 cloudlets).

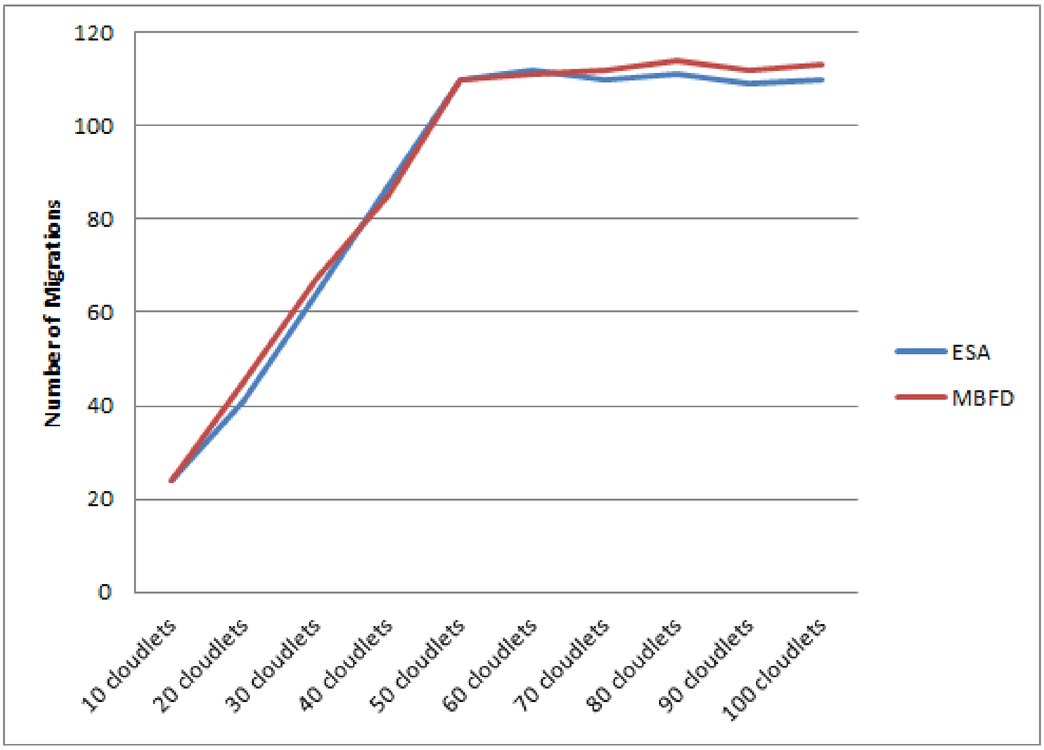

Figure 5.2: Comparison of Number of VM Migrations SLA between ESA and MBFD algorithm.

5.4 Comparison of Average SLA between ESA and MBFD algorithm

The following fig 5.3 shows the comparison of Average SLA between ESA and MBFD algorithm. It is clear from the graph below that the average SLA violations are increasing with increase in the number of cloudlets in case of MBFD but remains less and stable in case of ESA.

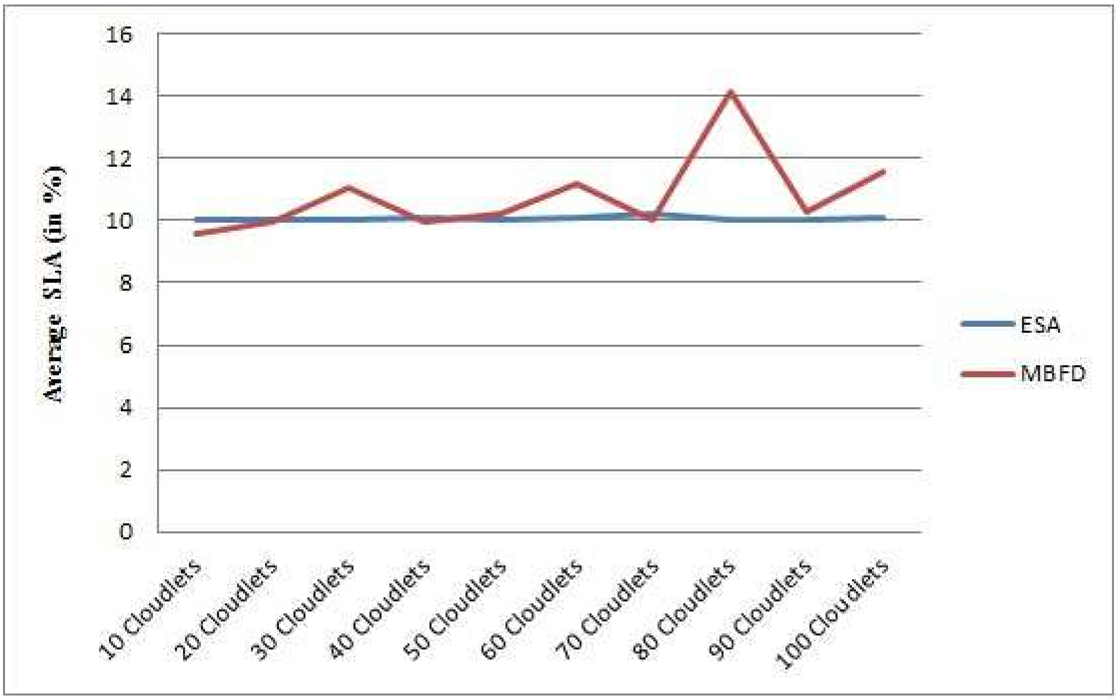

Figure 5.3: Comparison of Average SLA between ESA and MBFD algorithm.

5.5 Comparison of Energy Efficiency between ESA and MBFD algorithm

The following fig 5.4 shows the comparison of Energy Efficiency between ESA and MBFD algorithm. ESA is considered to be good as compared to MBFD if Energy efficiency is increased.

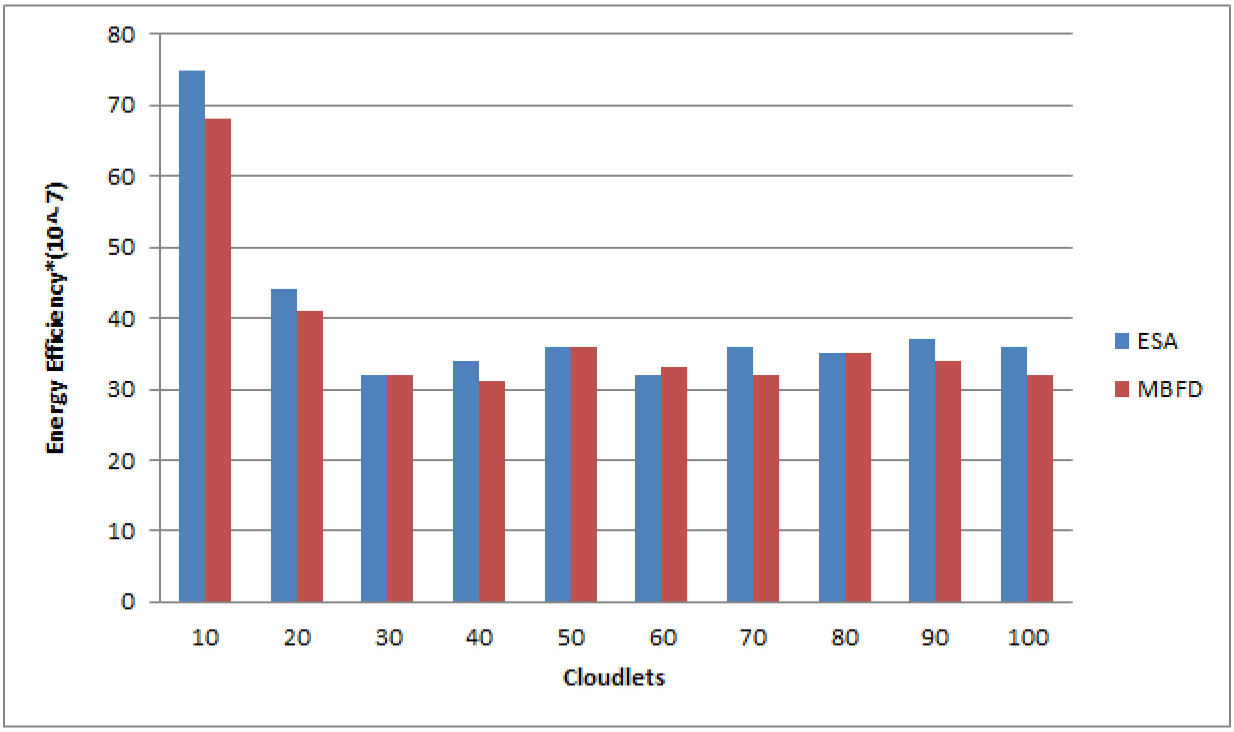

Figure 5.4: Comparison of Energy Efficiency between ESA and MBFD algorithm.

Chapter 6

Conclusion

In this thesis, an energy-aware VM allocation scheme is proposed using ESA algorithm. The objective of this scheme to reduce the energy consumption, SLA violations and number of VM migrations of DCs.The performance of ESA is evaluated in CloudSim 2.0 simulator for validating the effectiveness and accuracy of results. During each simulation, maximum utilization, SLA, and energy efficiency of host is calculated before and after each allocation. After that VM is allocated to suitable host.The results show that our method provides a considerable amount of reduction in energy consumption and average SLA violations.

In future, software-defined networks and network resource virtualization would be explored to utilize DC network infrastructure efficiently .

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