Energy Efficient Technique for Live Virtual Machine Migration

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

Master of Engineering
in
Software Engineering

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "*Energy Efficient Technique for Live Virtual Machine Migration*", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Software Engineering* 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 under the supervision of *Dr. Inderveer Chana* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

(Jasteen Kaur)

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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During the course of thesis, I have been lucky to be blessed by a lot of supportive and kind people. Let me take a moment to thank each one of them.

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ABSTRACT

Cloud is dynamic platform for delivering computing services. The demand of Cloud infrastructure has rapidly expanded with an increasing data rate of 50% every year. The increased volume of data results in more processors, larger storage devices and more administration efforts. It is estimated that in next ten years the data consumed by data-center will be more than 150 Terawatt hours (TWh). The percentage of data consumption and cooling equipment will reach 10% of the total energy consumption in world. Virtualization is the technique widely used in modern data-centers in order to realize energy efficient operations. Live Virtual Machine (VM) migration plays an important role in Cloud and holds various benefits such as energy aware server consolidation, load balancing and resource distribution. It causes transfer of large unnecessary memory pages known as dirty pages and thus leads to increase in downtime and total migration time.

Existing approach of live VM migration suffers from problems like high energy consumption, high response time and more migrations. Proposed approach of optimizing live VM migration by using hybrid BFO (Bacterial Foraging Optimization) algorithm reduces unnecessary migrations and execute all Cloudlets in minimum time and least migrations. BFO algorithm divides workload over VM network based upon the performance of nodes. Then migration is performed on the network with the help of Post-Copy technique. This architecture makes the execution process highly accurate and less time-consuming. VM allocation and load balancing is done in which processing of VM load is checked along with length of each Cloudlet. The optimal host is selected for migration through BFO algorithm and Post-Copy algorithm is applied which migrate the VM and launch migration process without interrupting the execution.

This thesis focuses on providing energy efficient Live VM migration technique so that number of migrations can be reduced and Cloudlets can finish their tasks efficiently in minimum time with less consumption of energy.

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Chapter 1

Introduction

Increase in information across internet along with tremendous cost reduction and improved accessibility lead to usage of Cloud Computing. Cloud means on demand retrieval of resources across the internet from cloud database without direct connection to server. Cloud platform is integrated in everyday life and provides services in medical, education, business sector etc. This chapter describes a brief introduction of Cloud Computing, service and deployment models, characteristics, challenges faced in Cloud Computing, benefits along with multiple application supported by Cloud.

1.1 Cloud Computing

Information technology is progressing at rapid pace since the invention of first digital computer and is continuously shaping up the world [1]. Technology has changed the way business operates and is foremost requirement in our day-to-day life starting from small-scale business to large enterprise. Likewise, initially the computers were very large and operated by professionals then scenario changed and computer usage was based upon demand as per need is the concept of grid computing. The cluster computing involves multiple nodes and presented as single entity. Then, finally the concept Cloud Computing emerged in which storage, services are flexibly accessed without any upfront investment or management of hardware [2]. Cloud Computing provides access to distributed Data Centers (DC) by allowing access to abstract computing resources through virtualization and thus by aggregating resources into a single system view. Cloud Computing cannot offer services without virtualization.

Grid Computing and Cluster Computing are foundations of Cloud Computing and are related to each other. Table 1.1 shows comparison between Grid Computing, Cluster Computing and Cloud Computing.

Table 1.1 Comparison of Cluster, Grid and Cloud Computing [3]

	Cluster	Grid	Cloud
On demand service	×	×	✓
Resource pooling	✓	✓	✓
Broad network access	✓	✓	✓
Measured service	×	✓	✓
Rapid elasticity	×	×	✓

1.2 Characteristics of Cloud Computing

The key characteristics of Cloud Computing are described below [4] [47]

i. **Cost Reduction:** Cloud has neither upfront investment nor maintenance of hardware required by cloud user. Cloud provider does take care of all of this and user just pay for the services he need as a result large number of organizations has moved their business to cloud

ii. **Multitenancy:** Contributes to resource sharing among multiple tenants and thus improvement in utilization is improved along with cost reduction as the resources are shared through a centralized infrastructure.

iii. **Network Access:** Cloud provides broad network access as the services can be accessed anytime, anywhere and on any device like PCs, laptop, tablets, smart phones.

iv. **Service Measuring:** Cloud systems are monitored and controlled by cloud providers to have an account of usability and provides transparency like earlier service agreements were used. This varies according to type of service.

v. **Resource Pooling:** The vendor's resources are shared among multiple tenants through dynamically virtual resources and can be provisioned on demand.

vi. **Quality of Service (QoS):** The cloud service provider is available to customer 24/7 and is not supposed to refuse in emergencies.

vii. **Quick Implementation:** The software an organization needs are available within short span of time without any restriction of memory, installation or license agreements.

1.3 Service Models in Cloud Computing

Cloud services can be accessed from any corner of the world. Subscription based services according to requirement are offered through IaaS, PaaS, SaaS models [36]. These models possess different characteristics along with specific associated service and a user can access them anytime from anywhere through internet. Following are the service models stated in cloud as shown in Figure 1.1:

i. **Software as a Service:** SaaS is multi-tenant platform in which clients or end user can use applications without any need of installation. Common resources and a single instance is used for both object code as well as underlying database. Key providers of SaaS are Microsoft, IBM, and Oracle, etc.

ii. **Platform as a Service:** An environment or platform given to developers to develop their desired software without any installation. For example, Google App Engine, Microsoft Windows Azure, Force.com, etc.

iii. **Infrastructure as a Service:** Virtual infrastructure is provisioned on demand and on which desired number of operations such as store, create, manage can be done. For example, Amazon EC2, Go Grid, Flexi scale [38].

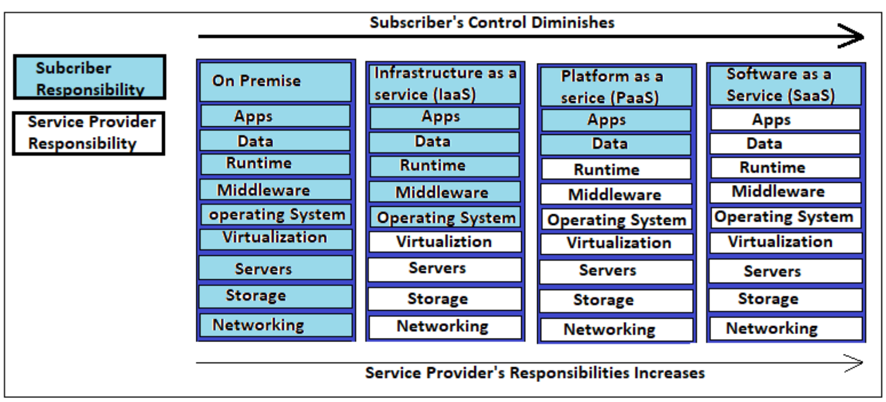

Figure 1.1 Different Service Models in Cloud Computing [36]

1.4 Deployment Models in Cloud Computing

Cloud deployment models fulfill particular and unique needs of a business and are categorized according to area, access and ownership of an organization. Description of these models is illustrated in Figure 1.2. Broadly, there are four models, which are discussed as [37] [5].

i. **Private Clouds:** It is also called Internal Cloud as it is used within an organization without any restriction for its personal use and offers high degree of security and reliability. Organizations that have particular needs and have their own DC along with developed infrastructure prefer privacy.

ii. **Public Cloud:** Cloud providers offer their resources on internet to public. Thus, it has restricted control over data, security and network, which makes it different from private Cloud environment. It is also known as External Cloud. It provides services free of cost. Google is an example of public Cloud where searching and retrieval of data can be used by anyone.

iii. **Hybrid Cloud:** It is an intermediate between External and Internal Cloud and uses services of both of them. The main aim is collaboration of valuable data and services from multiple models to develop an automated, flexible and well-managed environment. Thus, it uses features of both public as well as private Cloud models. Apart from its key advantages, load balancing is the issue faced by hybrid Cloud.

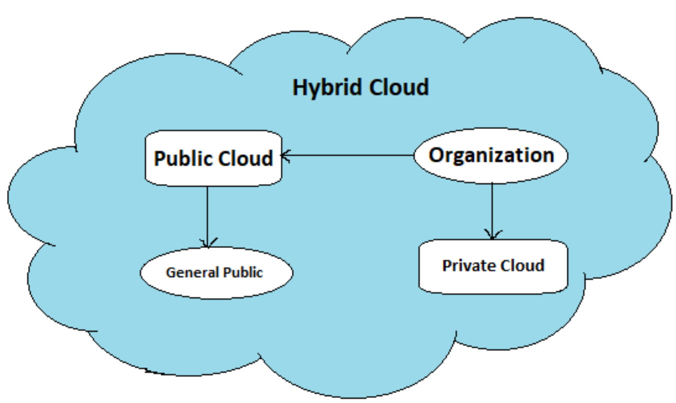

Figure 1.2 Deployment Models in Cloud Computing [5]

1.5 Applications of Cloud Computing

The applications of Cloud Computing are increasing at a rapid pace due to its fundamental features like flexibility, availability and scalability. Cloud adapts effectively with new technologies.

Broadly, Cloud applications are categorized as follows [6] [7]:

i. Mobile applications are merged with Cloud so that these can be accessed seamlessly from remote areas. Business, healthcare, gaming are the applications of mobile Cloud Computing. Data can be efficiently stored and can be accessed with mobile applications.

ii. One of the applications is finding location and direction on web with the help of Yahoo Maps and Google Maps. They are free of cost tools and help public in day-to-day activities.

iii. Cloud Computing is used in pattern analyzing, making predictions and correlations within an organization of large scale. Decision-making and future forecasting of data is performed and relevant tolls are used with performs operations on real time data like Hadoop, HPCC etc.

iv. Communication is one of the key domains performed through Cloud with the help of apps and tools like Gmail, WhatsApp, and Skype etc. The information user access is handled and stored by service provider and user can perform operations on his information without any hurdle.

v. Social networking domain cannot survive independently and thus make use of Cloud Computing for hosting its applications. Facebook, Instagram, Google+ are powerful real time applications to access real-time data with ease anywhere.

1.6 Challenges in Cloud Computing

Amazon, Microsoft, Sales force [8] are top Cloud providers and Cloud applications cover variety of areas like medical, business, science etc. Many benefits are provided by Cloud to its customers and at the backend virtualization technology is used which uses single instance and is used by multiple customers with a feel that everyone is using individual operating system. Along with holding numerous benefits and enhancing business value, Cloud is not free from challenges. It has following issues [9] [10]:

i. **Privacy and Security Concerns:** Organizations find difficult to store and operate their data on systems as the data reside outside company's firewall and hacking and security attacks can occur on data. Cloud service provider can monitor and control the data of an organization, which is uncomfortable for user as lot of confidential data, can be revealed to outsider. Migration of data can cause unnecessary exposure and reduce privacy. To mitigate this, the data handling process should be transparent to the client.

ii. **Portability:** This enables re-usability of data and application components across different applications and Cloud services. There should be standard platform so that if an organization wants to shift its data from one PaaS model to another it can be done without any loss of information. Therefore, service providers or vendors should follow standard interface so that clients can combine their services and can re-use them together.

iii. **Management concern:** The implementation of services in Cloud has brought a major change in the implementation of daily activities of organizations. The management of interface, platform and selection data to be moved is a major concern as organizations are concerned while migrating their data, they will not face any interference. Requirement of auto Scaling is an example, which provides scalability and balancing load on various nodes [11].

iv. **Internet Dependency:** For using Cloud services the foremost requirement is internet, which is required every time in order to do any task in Cloud environment. In case internet goes down, there is no alternative through which work can be performed. Wireless internet can be adopted to continue using services but in case that also fails then there is no alternative left which is a major issue in Cloud.

v. **Energy Management:** The rapid increase in data retrieval, storage and processing consumes high amount of energy in Cloud DC. Thus, Total Cost of Ownership (TCO) is increased which is a serious issue. Proper workload management is the solution to raising energy problem, which ensures maximum utilization of resources.

1.7 Virtualization

The concept of creating virtual (rather than actual) version of a machine is the terminology behind virtualization. The process of creating duplicate version of actual machine, which is not, limited to network, storage and processor devices. It is done with the help of hypervisor. Virtualization addresses multiple logical names to the single physical source. Popek and Goldberg [40] states some conditions that satisfies virtualization. Foremost requirement is that the environment exhibit by virtual machine should be same as that of local system and if it fails to do so, it is unable to perform virtualization. Secondly, it can control resources securely in order to safeguard data from attacks or performance degradation [41]. Virtualization can be categorized into seven types as shown in Figure 1.3:

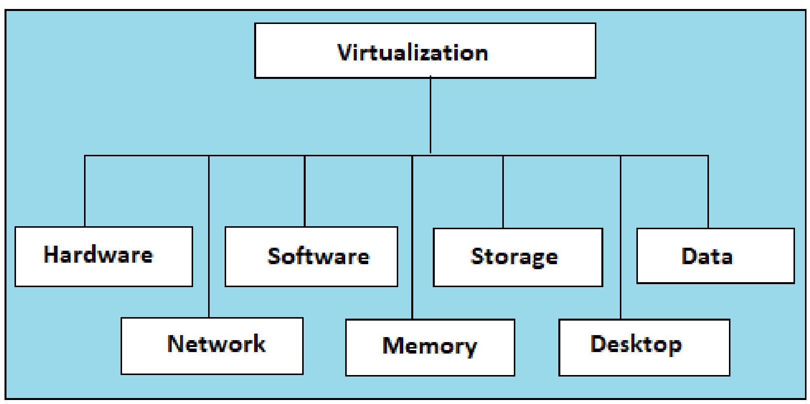

Figure 1.3 Types of Virtualization [40]

1.7.1 Hypervisor

It is the interaction between hardware and virtual machine in order to achieve virtualization through this layer of abstraction (hypervisor) and is called VMM (Virtual Machine Monitor). It handles CPU, interrupts, I/O transfers, memory and instructions. The hypervisor environment is categorized into two types [42]:

i. **Type-I (Bare Metal Hypervisor):** It runs directly on hardware of host machine as shown in Figure 1.4 and handles guest OS. IBM in 1960 developed first hypervisor known as native hypervisor. Examples of this type are Sun Xvm Server, Xen, and VMware etc.

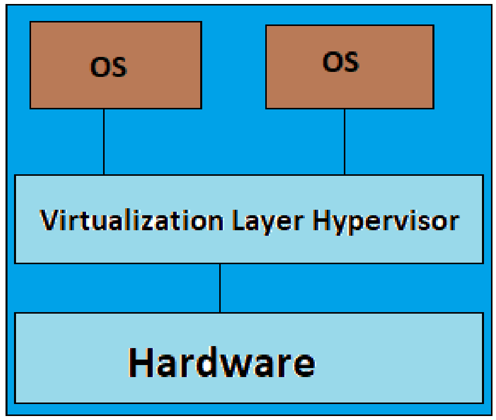

Figure 1.4 Type-I Hypervisor [48]

ii. **Type-2(Hosted Hypervisor):** Hypervisor is placed on the top of OS and above hardware, there is OS. This makes management of virtual machine easy due to support of hardware system along with OS layer as shown in Figure 1.5. VMware workstation, QEMU, Virtual Box come under this.

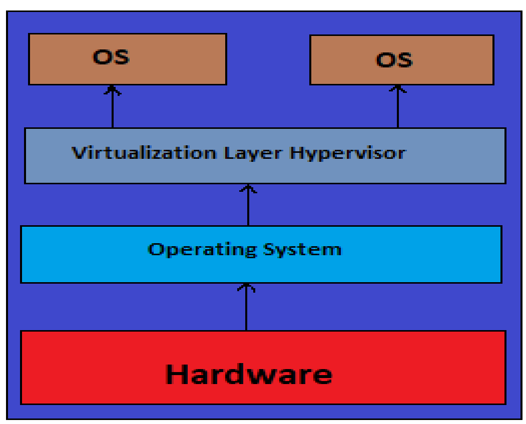

Figure 1.5 Type-II Hypervisor [48]

1.8 Research Motivation

Demand for computing is rapidly increasing and number of organizations are shifting their workload to Cloud. The growing data storage and high computation has tremendously effected the power and energy consumed by Cloud data-centers. Though Cloud provides numerous benefits to users and organizations, it has a major challenge of energy management. Traditionally research focused on energy consumed in data-centers which violate SLA (Service Level Agreement) but now there is a need to manage dynamic energy in VM migration in which data gets migrated from one node to another [12].VM migration facilitates load balancing, server consolidation, fault resilience etc. Migrating a VM can be based on either live or non-live approaches. Live migration transfers the VM from source node to destination node without interfering or suspending the applications and hence results in advantage of reduced downtime. Whereas non-live migration follows traditional, approach of suspending the machine at current host and then migrates the data. As all real time applications need live migration in case of a node failure or load balancing. The need is to devise efficient live VM migration approach that reduces energy consumption also.

1.9 Organization of Thesis

Chapter 2: This includes literature survey in detail to study live VM migration techniques in Cloud Computing.

Chapter 3: This proposes the problem statement, gap analysis, objectives and methodology to implement the proposed technique.

Chapter 4: The chapter proposes solution to problem in detail.

Chapter 5: This chapter discusses the result of performed experiments and comparison of existing technique and proposed technique.

Chapter 6: This chapter gives conclusion and future direction for the proposed technique.

Chapter 2

Literature Survey

The system's ability to migrate data in an optimized manner with minimum number of physical hosts working and switching off idle hosts along with load balancing is defined as efficient management of energy in Cloud. [13] There is ample amount of work done in energy efficiency and this research has been conducted to outline the work that has been conducted in VM Migration. This enhances performance by balancing workloads at run time, efficient resource utilization along with maintaining SLA's and QoS requirements stored etc. Virtualization is the main concept, which is used, in software energy efficient technique [14].

2.1 Energy Efficiency Techniques in Cloud Computing

Energy consumption (e) at Cloud DC can be defined as the total power (p) consumed in a given duration of time (t) while work is being performed.

$$e = p*t$$

The energy management approaches can be categorized into static and dynamic management approaches. Static approach deals with low power hardware components. It fails to work at run-time and is very costly.

The dynamic resource management reconfigures the system based upon current resource requirement. It makes use of hardware components such as processor, network components that are scalable and software techniques such as VM migration, server consolidation etc. and optimize energy consumption. Dynamic resource management techniques are surveyed to achieve energy efficiency in real-time environments [20].

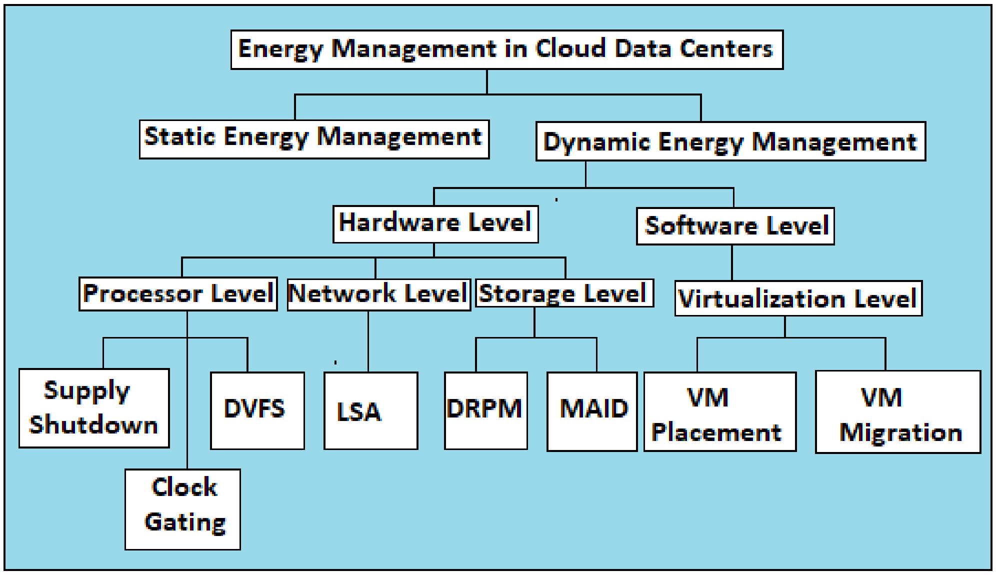

Figure 2.1 Energy Efficient Techniques in Cloud Computing

2.1.1 Types of Dynamic Energy Management Techniques

Dynamic energy management is categorized into two types. Hardware level and software level techniques. These techniques improve energy efficiency in various Cloud layers such as virtualization layer, DC layer, node layer, OS layer, application layer.

I. Hardware Level Techniques

The techniques of energy management are applied on hardware components like processor, storage and networks so that overall hardware level energy can be minimized [15] [16] [17].

i. **Storage Level:** Storage device has considerable role in whole budget of energy consumption. It is categorized into two techniques. Firstly, MAID (Massive Array of Idle Disks) in which copy of files is put or placed on file sub-set known as cache-disks and non-cache disks are spin down thus perform in conserving energy. Second is DPRM (Dynamic Rotations per minute) technique, which control power in spindle motor that drives platters by modifying the speed of disk (RPM) rotation per minute.

ii. **Processor Level:** It is comprised of static power, which is used even when the processor is sitting idle and dynamic power, which depends upon resource usage at server.

$$\text{Dynamic Power} = X * Y * Z * V^2$$

X=Number of active gates, Y= processor's clock frequency, V= supplied voltage and Z=processor's capacitance load.

It is further divided into Supply Shutdown, DVFS (Dynamic Voltage and Frequency Scaling) and Network Level Clock Gating.

iii. **Network Level:** The rapid growth of size of DC effects the network infrastructure as it is important to monitor energy consumed by network devices like routers, switches and NIC cards. Switches play major role in delivering services across the network. The energy of switch depends upon switch type, transmission rate of port, rate of transmission of port.

The hardware techniques do not contribute much in energy conservation as they are applied at individual server level. Reduction of energy can be improved more by using Software Level techniques.

II. Software Level Techniques

The key technology for better utilization of resources along with conservation of energy is software level techniques and is done with the help of virtualization which shields working of applications from the underlying infrastructure. The techniques are comprised of [18] [19]:

i. **VM Consolidation:** The typical server is under-utilized most of the time. VM's running on under-utilized servers consolidate to a single server and thus saves surplus power consumption by switching off underutilized nodes. This maximizes suspended servers by implementing VM migration. The tasks or applications run on minimum number of servers and the power is saved. This also helps in fault tolerance because hardware, which is failure prone, can be transferred to steady machine. An efficient consolidation policy consists of various number of users, availability of resources, workload characteristics and so on.

ii. **VM Scheduling:** The process of utilizing resources efficiently by switching off under-utilized or idle nodes. The tasks are scheduled according to the requirements. It provides load balancing and minimizes task execution time. In DC, the VM requests are schedule to physical machines in accordance to resource requirements. The scheduling algorithm firstly search for particular physical machine for the set of VMs, then scheme for provision is analyzed and then the tasks are scheduled on the Virtual machines. There are static and dynamic scheduling algorithms. First come first serve is an example of static scheduling algorithm whereas genetic algorithm is an example of dynamic scheduling algorithm.

iii. **Task Scheduling:** Task is a small piece of work which has to be completed in a given time period. Task scheduling maps the user tasks to service provider on respective resources. Scheduling effects overall performance of Cloud environment. There are various attributes of tasks based on which decision has to be taken by service provider. A task may have memory requirements, access requirements or network requirements. Each task is handled according to service request and service level agreements. Each task is allotted to server and after executing the task, the response is given back to client.

iv. **Virtual Machine Migration:** Migration is primarily for dynamic resource management. The process of transferring a VM between different physical machines is a concept behind VM Migration. The machine will respond all time from user side in live VM migration and it holds numerous benefits like workload balancing, energy efficiency, online maintenance and prevents unnecessary utilization of certain machines. It holds vital part in consolidation. VM migration is broadly divide into live and non-live VM migration. In live VM migration, a VM is transferred without switching off the machine and in non-live migration, suspend or power off virtual machine is moved to a new host machine. The downtime and total migration time is minimized during live migration process.

2.2 Migration Techniques

The live migration techniques for moving VM's memory state are categorized broadly into pre copy and Post Copy migration [43] [44] [46].

i. **Pre-copy Migration:** Warm-up phase is the initial step in which hypervisor creates duplicate copies of contents of memory to send at destination host.VM is not stopped; it is continuously running in this phase. The page content can be altered while the process is running and is iteratively copied to target host. This follows continue iterative process till the achievement of stable threshold value or the remaining pages reach a small value, whosesoever occurs first.

In stop and copy phase, the source VM is hauled and after that, leftover data, which is known as dirty pages, is shifted to target host. The VM recommences at the target host. This results in decrease downtime but total migration time is increased.

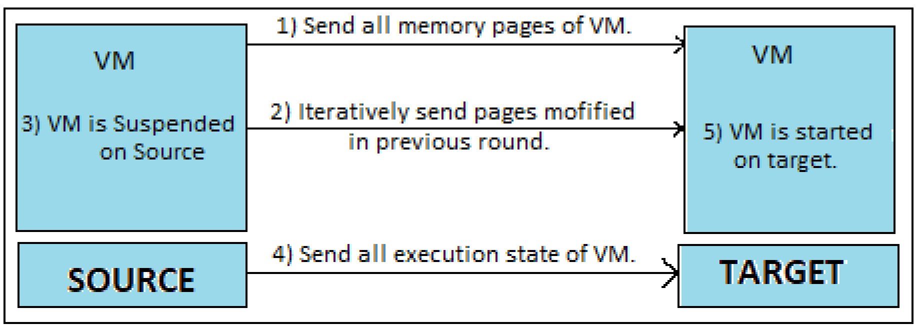

Figure 2.2 Pre-copy based Migration [48]

ii. **Post-copy Migration:** VM suspends on source, process states (CPU, non-page able memory and register) is transferred to target host, and it starts running on destination even though some memory pages still reside at source and not all of the memory pages are transferred to destination. Page faults occur because access to memory contents are yet to migrate. This generates frequent service disruption and degrades performance. The total migration time is considerably reduced as memory contents are copied once but results in more service disruption as result of more memory faults.

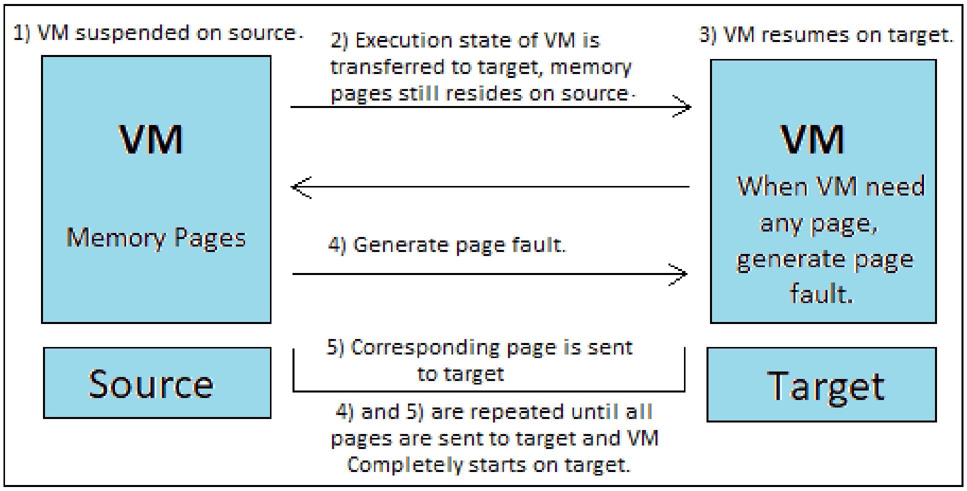

Figure 2.3 Post-copy based Migration [48]

2.3 BFO Algorithm

Kevin Passino gave the idea of Bacterial Foraging Optimization algorithm in the year 2002.There are many algorithms inspired and derived by natural phenomenon observed around in our surroundings. Bacterial Foraging Optimization algorithm is the newest entrant in this category of algorithms. The principal concept of this algorithm is the application of group foraging method of large moving group of Escherichia coli bacteria in multi-optimal operation optimization. Bacteria finds nutriments in such a way to increase the get maximum energy gained per unit time. Bacterium interacts with others by transmitting signals to each other. The Bacterium takes a call on foraging selection method after taking into account previous two aspects. Chemo-taxis is the process in which bacterium movies in small little steps while seeking nutriments. The principal idea of this algorithm is intimating this movement of virtual bacterium in search space problem [50].

D: Dimensions of the search space,

Z: Total count of bacteria in the entire population,

C: The count of chemo-tactic steps taken by bacterium,

S: length of swimming.

Crep: The counts of steps of reproduction

Cedl: The counts of events of elimination-dispersal

Pedl: Probability of elimination-dispersal

T (i): The size of the steps taken in the random direction as specified by the tumble. This foraging theory revolves around one supposition. This supposition is that animal finds nutriments in such a way to increase its energy gained P per unit time S while seeking nutriments. They try to increase a function like P/S or they try to achieve their high long-term average speed of energy intake. Achieving high long-term average speed of energy intake gives sufficient time to origin of nutriments to survive and much more time for miscellaneous activities. These miscellaneous activities include finding shelter, escaping, reproducing etc. Few activating like making shelter and searching for mating partner resembles the process of foraging. Mechanism of foraging varies species to species.

Herbivores usually get food very fast but it should be consumed at high quantity. Carnivores have to toil hard to get nutrients and they manage it by eating less quantity as their food has high energy level. Environment identifies the pattern of nutriments available and it restricts on getting that nutriments. There are some risks involved in the foraging because of predators. The prey might be moving so that it would require following it in order to catch it. The physiological attributes of the forager, hamper the abilities and as a result would affect the solution. The following steps can elucidate the bacterial foraging optimization theory [51]: -

I. Chemotaxing

Chemotaxing models the motion of Escherichia coli cell by tumbling and swimming via flagella. Naturally, Escherichia coli Bacterium can advance in two distinct approaches. Escherichia coli can swim for a duration of time in identical direction or Escherichia coli Bacterium can tumble and alter between the two forms of activity until it dies. Let, β^i (x, y, z) represent x^{th} bacteria at y^{th} chemotactic, z^{th} reproductive and l^{th} elimination-dispersal step. T (i) represents the size of the step moved in the arbitrary direction as specified by the tumble. Then the movement of the bacterium can be denoted as follows:

$$\beta^i(y+1, z, x) = \beta^i(y, z, x) + T(i) + \frac{\partial(i)}{\sqrt{\partial^T(i)\,\partial(i)}}$$

Here, ∂ is a vector in the arbitrary direction and elements lie at [-1, 1].

II. Swarming

An exciting group characteristic was noticed for many mobile species of bacteria. There species are Escherichia coli and Salmonella Typhimurium, whose delicate and firm spatio temporal models are made in semi solid nutriment medium. A cluster of Escherichia coli cells aligns themselves in a moving ring by increasing the nutriment gradient whenever it is kept in the interior of the semi solid matrix with a nutriment chemo effecter. Whenever cells are activated by a high level of succinate, it gives out attractant aspartate. It enables them to make clusters and proceed in a concentrically fashion of swarms. These swarms have high bacterial density.

III. Reproduction

Whenever, each of healthy bacterium, which supplies least value of the objective function, is break into two bacteria by asexual mode of reproduction. This breaking up of healthy bacterium results into death of weak bacterium. The newly two bacteria are kept at the same location. This process allows the size of swarm to be stable throughout.

IV. Elimination and Dispersal

There are various reasons that cause slow or fast changes in the environment where the bacterium population resides. Sometimes, events happen that result in the death of the whole bacterium population or even dispersion of the entire population into a new place of the environment. To illustrate this, we can take an example of a scenario where there is substantial increase in temperature. It will result in killing the entire population of the bacterium that are currently residing in the place with high levels of nutriment gradients. These events keep happening in the environment. These events over the course of time has resulted in to the spreading of various types of bacteria into the new regions of the environment like bacteria from springs to underground water levels. In order to model these events in the BFOA (Bacterium Foraging Optimization Algorithm), some bacteria are liquidated arbitrarily with small probability while the newly replacement bacteria are initialized arbitrarily over the search space.

These occurrences of Elimination and Dispersal events can have consequence of destroying the entire chemotactic process of bacterium of a specified region. They also can result in boosting the chemotaxis as dispersal may put the bacteria into a new place with good sources of food and energy. However, we can say that these events of elimination and dispersal are integral component of population level long distance motile behavior.

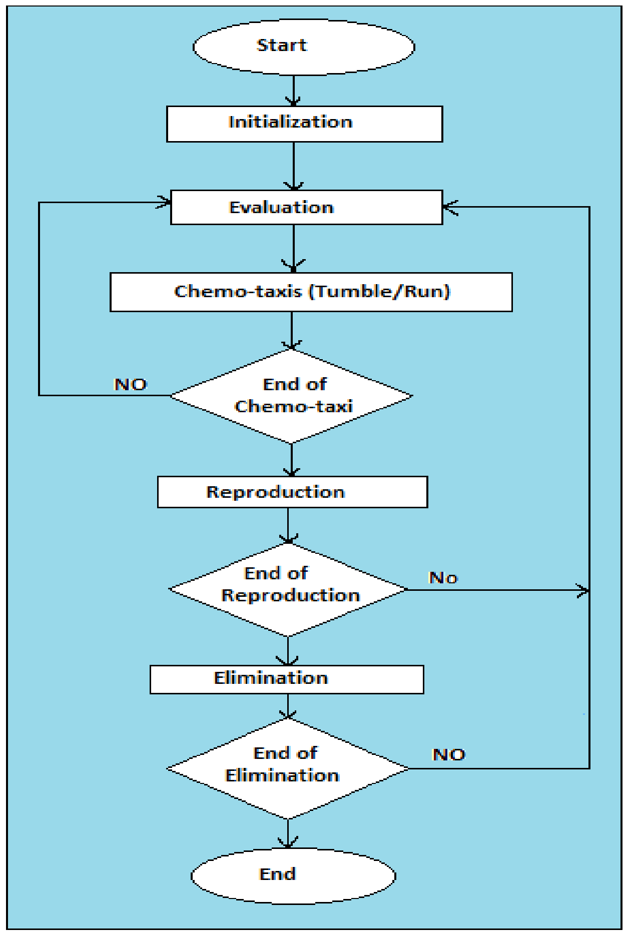

Figure 2.4 Flow Chart of BFO

2.3.1 ALGORITHM: -

The algorithm of BFO described as [52]:

STEP I: Initialization of the values of the parameters B, C, S, Crep, Cedl, Pedl and the T (i), (i =1, 2, Z). Select the first value for the $\beta^{i,}$ (i=1, 2....Z). These initialization of the values of the parameters should be done in the region where there is high probability of optimum value to exist. Reactive power(SVC) and line reactance (TCSC) are the control variables. Control variables are arbitrarily dispensed over the domain of the optimization space. When the calculation of β is finished, then value of P is updated on its own and termination test is started for the maximum number of repetitions.

P - position of each member of the entire bacteria Z population existing in a specific region.

STEP II: Loop of Elimination Dispersal: - z = z + 1

STEP III: Loop of Reproduction: - y = y + 1

STEP IV: Loop of Chemo taxis: - x = x + 1

1. For i= 1, 2, Z select a chemo tactic step for bacteria "i" as below mentioned:

2. Calculate the cost Q (i, x, y, z)

3. Let, Q (i, x, y, z) = Q (i, x, y, z) + Q_{cc} ((β^i (x, y, z)), P (x, y, z))

4. Let, Q_{last} = Q (i, x, y, z) need to store this value as better value is to be calculate via run.

5. Tumble: - It generates a random vector $\Omega(i) \in V^{p,}$ with single element Ω_m (i) 1,2,3, ..., p a random number on [-1,1]. Here, V signifies a real number.

6. Let

$$\beta^i(x+1, y, z) = \beta^i(x, y, z) + T(i) + \frac{\partial(i)}{\sqrt{\partial^T(i)\,\partial(i)}}$$

It leads to a step of size T (i) towards the tumble for the bacterium "i".

7. Calculate Q (i, x+1, y, z). The N-R method is used to carry out the load flow analysis. It is used to determine the value of FLSI/L-index, total cost and total power loss. If the calculate cost is the minimum, then next step is executed else proceed to Step 3.

8. Swim

(i) . Let sl = 0 (counter for swim length)

(ii). While sl < S,

sl = sl + 1

If Q (i, x+1, y, z) < $Q_{last,}$ (If there is improvement)

Q_{last} = Q (i, x+1, y, z)

$$\beta^{i}(x+1, y, z) = \beta^{i}(x, y, z) + T(i) + \frac{\partial(i)}{\sqrt{\partial^{T}(i)\,\partial(i)}}$$

Use the above formula to calculate the new Q (i, x+1, y,z)

Else, let sl = S

End of While

9. If i is not equal to Z, then proceed to next Bacterium i = i +1

STEP V: If x < C, continue with STEP III. Here, Chemotaxis continues as life of bacterium is not over yet.

STEP VI: Reproduction

(i) For the given y and z, and for each i = 1,2,3, ..., Z.Let,

$J^{i}_{health} = \sum_{x=1}^{C+1} Q(i, x, y, z)$ be the health of the Bacterium "i".

Arrange bacteria and the chemo tactic parameter T(i) in ascending order of cost of Q_{health}.

(ii) Z_r Bacterium with the maximum Q_{health} and rest Z_r with the best value split up.

STEP VII: If y < Crep, proceed to STEP II. This means we haven't reached the specified the number of reproduction steps yet.

STEP VIII: Elimination Dispersal

Values of L-index, total cost, real power loss, bus voltages and FVSI are calculated separately. The Parameters of the BFOA are given in Table 1 and Algorithm's flowchart is depicted in Figure 1.

2.4 Existing Techniques of Energy Efficiency in Cloud

I. Xiaodong Wu et al. [45] proposed energy efficient technique for optimization of VM placement by using VM consolidation technique process framework is to first of all find the overloaded machines, select VM which need to be migrate, select the underutilized host on which VM can be migrated and then migrate VM’s to that host. THR_MUG algorithm is used and the idea behind using this technique was to reduce overhead of live VM migration by reducing the number of VM migrations.

II. Soamar Homsi et al. [21] proposed resource utilization technique for consolidating workload with guaranteed QoS by using GWPC (Green Workload Packing and Consolidation algorithm) approach in which different service requests are handled or served on same server. The Green Cloud Computing Prototype is used and it consists of user input module in which users define type of service and different QoS requirements according to request class they have, next is service management module which takes input from previous module and schedules workload through resource allocator and scheduler to resources. Thus by saving power consumption and reducing electricity cost.

III. Tanasak Janpan, Vasaska Visoottiviseth et al. [22] uses technique to consolidate Virtual Machine with the help of live VM migration strategy. In order to achieve load balancing, a web application can consolidate and deconsolidate Virtual Machine. The load of CPU utilization is balanced among physical hosts as in response to active physical hosts.VM consolidation is done with Zabbix system in order to collect data from each host so as to measure the status of devices with threshold value.

IV. Sara Nikzad et al. [23] identified technique of future prediction of CPU utilization so that SLA (Service Level Agreement) and energy consumption can be maintained. An optimal solution for dynamically minimize threshold value is also proposed. DES (Double Exponential Smoothening Algorithm) is used which identifies highly utilized and underutilized machines and then migration takes places accordingly. It uses concept of “troublemaking hosts” in which the decision making and prediction process gets stopped on arrival of such type of hosts. The algorithm does necessary steps to alter them or switch off them.

V. Jyothi Sekhar et al. [24] describes techniques to minimize energy and consolidate server with the use of live VM migration strategy. Virtualization improves power consumption and optimize resource consumption. In this paper a technique is demonstrated through greedy heuristics for allocation of virtual machines. Greedy heuristics sort machines according to their size which means resource utilization and thereby power consumed. The workload is split into multiple VM machines and cost of migration is analyzed in this approach.

VI. Dilshad H. Khan et al. [25] explains various algorithm and techniques of scheduling in Cloud at single or multiple DCs. The load balancing Min-Min algorithm is used which finds minimum execution time of VM and that VM having minimum execution time is scheduled prior to other VM's. The minimum computation time is analyzed and after that resources having high load are assigned again with lightly loaded resources.

VII. Abdul Razaque et al. [26] deals with scheduling of tasks in Cloud Computing model. Traditional task scheduling approaches works on processor storage, time of execution, resources needed in task so on but the paper emphasis on network bandwidth which is not described much earlier by researchers. The model used is non-linear programming model in which tasks in queue checks for ideal VM and then network bandwidth is checked of both VM and required task before execution.

VIII. T. Veni. et al. [27] describes various energy efficient dynamic techniques based on virtualization. This paper gives classification of static and dynamic energy efficient techniques in DCs. Static techniques are not mentioned in detail whereas detail description of dynamic level based upon hardware and software levels are described and why software techniques are better than hardware level techniques are clearly stated in the paper.

IX. Ali Bagherinia et al. [28] describes two-phase strategy for scheduling tasks and is based upon load balancing. First scheduler along with the task of resources creates Virtual Machine task description in network, computing, storage in accordance to resource requests. The next scheduler finds suitable resources in accordance with VM's description of task. Working according to both phases the resources is allocated to appropriate tasks without wasting any resources. Resource demand and reaction time is considered and if all tasks appear simultaneously, they are deal in ascending order in accordance with resource provision by clients.

X. Bhaskar Prasad Rimal et al. [29] discuss the detail fundamentals of Cloud Computing. The architecture Cloud uses along with service layers IaaS, PaaS, SaaS in it. Virtualization technology is discussed, fault tolerance concept is explained and security of Cloud is mentioned in this paper. Issues of balancing load, scalability and interoperability is stated. Cloud Computing infrastructure, PaaS, SaaS providers and open source services are compared in tabular form.

XI. Karan D. Prajapati et al. [30] explored VM scheduling algorithms in Cloud and comparative study is illustrated using time, power, memory bandwidth, cost efficiency, security considerations and round robin, genetic match making, TADCS and memory aware algorithms are applied on each of them by using Open Nubela platform. The most appropriate scheduling algorithm is detected and analyzed for further considerations.

XII. Pradip D. Patel et al. [31] describes a detailed survey on Live VM Migration. Techniques of VM migration such as load balancing, energy management, fault tolerance are discussed. Types of VM migration known as Post Copy and pre copy with its phases and their method of work are discussed. The performance metrics resume time, downtime, total migration time and so on is explained in this paper thereby a clear overview of live migration is explained.

XIII. V.K. Saxena et al. [32] discusses the characteristics of Cloud and services provided by Cloud Computing. This paper discusses about virtual computing laboratory VCL research issues faced comprises of standard level snapshot of images which has complicated mapping and needs extra storage Security is one of the challenge faced by Cloud which is discussed broadly in this paper.

XIV. Mahdi Aiash et al. [33] describes that while moving a VM from one host to another there are numerous security issues which are involved. This paper discuss the various challenges faced by live VM migration. The paper works on X.05 standard for analyzing security attacks which occur during migration of VM. Brief description of X.05 standard is mentioned which consists of end –user plane, control plane and management plane. From the view point of attacker, eight types of security breaches can be possible which are mentioned and solutions for the live VM migration are discussed in the end.

XV. Anusha Bamini [34] explored optimized model for parameters of resource allocation. The analogy of PSO (Particle Swarm Optimization) and BFO (Bacterial Foraging Optimization) on the basis of output parameters cost, execution time span, number of tasks and throughput is considered. CART (Classification Regression Tree) and MBFO (Modified Bacterial Foraging Algorithm) are used and CloudSim toolkit is used.

XVI. Akshat Dhingra et al. [35] discusses energy can be consumed in data-center without effecting performance. The Bacterial Foraging Algorithm is used with minimizes the cost. This algorithm optimizes the resources, which are allocated. The phases in optimization layer are resource utilization, service analyzer, optimizing function, VM manager, off/on button, migration control and so on. The work is done in two phases. In first phase, VM is placed on hosts and then optimization of multiple VMs take place in the second phase.

XVII. Korir Sammy et al. [39] proposes an energy-efficient resource provisioning on virtualized consolidated platform. Dynamic round robin algorithm is useful in reducing power consumption thus achieving energy efficiency. Security is the issue to be maintained during and after migration. Integrity and privacy are the main factors contributing in security. Fuzzy logic based controller which monitors resource utilization prevents from attacks such as replay attacks and (time of check to time of use) TOCTTOU attacks and thus provides security.

Table 2.1 Comparative Analysis of Existing Techniques for Energy Consumption

Author	**Algorithm**	**Technique**	**Goals**	**Tool**
Xiaodong Wu [45]	THR_MUG	By using VM consolidation, VM placement is optimized and overhead is reduced by minimizing number of VM migrations.	Reduction in overhead of live VM migration and energy.	CloudSim
Soamar Homsi [21]	GWPC	Different service requests are allocated on same VM	Improve resource utilization, power consumption	GCCP
Tanasak Janpan [22]	VM Packing	VM's consolidate and deconsolidate by web application for load balancing of CPU among PM's in acknowledge to active	CPU Load Balancing	Apache Cloud stack

		machines.		
Sara Nikzad [23]	Time series, DES	Current and predicted CPU utilization is compared with top and bottom threshold value and each host position is analyzed,	Forecast CPU utilization	Cloud 3.0.3
Jyothi Sekhar [24]	Greedy Heuristics	The workload is shared in multiple VM's and selection of least memory size leads to cost reduction.	Reduce energy, Migration cost	Ubuntu, CloudSim
Dilshad H. Khan [25]	Load Balancing Min-Min algorithm	Minimum execution time is identified, scheduled first then minimum computational time is considered, and heavy load resources are reassign with light loads.	VM scheduling at single and multiple data-center.	CloudSim
Abdul Razaque [26]	Non-linear programming model	Tasks in line examine idle VM and network bandwidth is examined prior to execution.	Task scheduling with minimum resource consumption, minimum total execution time.	Java
Ali Bagherinia [28]	Fuzzy neural network algorithm	Two-phase model for scheduling is used. First, one makes task description of VM according to resource demand. Second phase find required resources for VM in accordance with task description.	Dynamic distribution and improved utilization of resources.	CloudSim
Anusha Bamini [34]	CART,BFO modified	Comparison of: cost, execution time, throughput, number of tasks. Annova model is used.	Optimized model for allocating resource parameters.	CloudSim
Bhaskar Prasad Rimal [29]	Round robin, Genetic match making, TADCS, Memory aware	Time, power, cost, security, memory, bandwidth is compared.	Detection of energy, cost efficient, security aware scheduling algorithm i.e. TADCS	OpenNubela

Akshat Dhingra [35]	MBFD	Two phase strategy for VM allocation optimization: allocate VM to PM's then resource allocation is done.	Minimize power consumption	CloudSim

2.5 Conclusion

This chapter focuses on existing energy efficient techniques along with comparative analysis of the work done. The next chapter targets at analyzing research gaps concluded from the above study.

Chapter 3

Research Gaps and Problem Statement

3.1 Research Gaps

Cloud exhibits dynamic environment and causing increase in energy in virtualized environment results in problems. Therefore, it is necessary to address raising energy problem in software efficiently. There are various energy efficient based techniques such as task scheduling, workload consolidation, data placement etc. All these techniques suffer from various challenges such as inadequate task management, enhanced time spam and thus results in increase processing time.VM migration resolve all such issues. However, to manage energy during VM migrations is one of the major issue, which leads to problems such as increase downtime, increase in total migration time, increase overhead can rise. Existing techniques of energy efficiency are not much reliable cause low resource utilization, which results in high operational costs and degraded performance in virtualized environment. Research shows that Cloud DC can provide better energy management by using VM migration techniques for the efficient allocation and scheduling of resources.

3.2 Problem Statement

There are numerous challenges faced by Cloud Computing. Load Balancing and Job Scheduling are the critical issues, which are necessary for the maximum and efficient utilization of VM. The distribution of load is the foremost criteria followed on resource such as VM or physical machines and follows task and job sharing during processing of tasks. The real time applications need live migration in case of resource scheduling, fault tolerance, load balancing etc. The energy consumption is the issue faced in the scenario of live VM migration. Therefore, there is a need to devise efficient live VM migration approach that minimizes energy consumption [53].

3.3 Objectives

i. To explore various meta-heuristic techniques of resource scheduling and VM migration techniques for Cloud Computing.
ii. To propose a technique for efficient allocation of Cloud resources during live VM migration.
iii. To implement proposed technique on Cloud platform.

3.4 Methodology

To attain the proposed technique, the below steps are followed:

i. Understand various energy efficient techniques in live VM migration.
ii. Explore and create datacenter, brokers and multiple VM's.
iii. To execute cloudlets, Cloud environment is mandatory.
iv. The appropriate scheduling of resources and cloudlets on VM or physical machine is done by using BFO algorithm.
v. The optimal host is selected and then efficient migration technique is applied.
vi. The Post copy technique is selected for reducing time during migration process and thus energy is consumed.
vii. Compare the results of proposed technique in terms of execution time and energy with existing technique.

3.5 Conclusion

This Chapter discusses the research gaps and states the objectives and methodology followed by the proposed energy efficient technique. The next Chapter aims in detail description of the proposed technique.

Chapter 4
Proposed Live VM Migration Technique

In the virtual machine, migration process the main parameters that used to check the performance of algorithms are Energy consumption and processing time that used to calculate the delay in response time.

4.1 Description of Proposed Technique

Energy Efficient Technique: The proposed technique is divided into two parts. The first part deals with allocation of resources and the second part is deals with the migration process. Allocation process will handle with the help of BFO algorithm in which algorithm finds an optimal way to divide all the workload over VM network. It compares various parameters related to the cloudlets and VM to design the execution patterns. In this section, the load is distributed on the whole network based upon the performance of network node, so that the nodes will perform accurately and increase the throughput. This will also decrease the number of migrations.

The second phase is related to the migration of VM during peak load. The technique finds the appropriate solution to migrate VM and after selection of particular host, the Post Copy algorithm is launched for efficient migration of VM. It makes the execution process highly accurate and less time-consuming because, the proposed technique finds a most suitable place to migrate the VM and launch migration process without interrupting the execution.

In both of the phases, efficient live VM migration takes place which executes all cloudlets in least migration time. As compared to existing techniques the proposed technique manages the process efficiently and can find a better solution from the available conditions and results in efficient management of energy. It is a highly accurate technique and compares all the solutions to find a perfect match with requirements to execute smoothly. In previous management of the cloudlets and VMs, the performance degrades in heavy load because the system spread the load equally on the network having VMs with different configurations. This process makes the execution more complex while migrating VMs from one to another node repeatedly.

Table 4.1 Enhancement of Existing Technique

Description	Used Techniques	Parameters

Existing Work in Live VM Migration [53].	Equally spread load on network, Execute Migrations, Push and Pull algorithms for load balancing.	Migration Time, Throughput, Scalability.
Proposed Work of Efficient VM Migration.	BFO optimization for load balancing and VM migration with Post Copy.	Migration Time, Throughput, Scalability, Availability, Reliability.

4.2 Work Flow of Proposed Technique:

Various steps used to perform the simulation in CloudSim tool. Here the first step is to create the datacenter in the simulation environment where the system will create various virtual machines and execute workload. The system use datacenter class to create various datacenters and store the objects to load all datacenters in the execution environment. After that the system create broker to manage the execution environment and execution of various cloudlets. Broker creates various virtual machines on the datacenters with their unique id. In the last step, system generate cloudlets for the execution and simulate execution environment.

The bacterial foraging optimization process with Post Copy migration process handles all the executions in the Cloud environment. The proposed technique is used to handle load on the virtual machines and find the overloaded machines from the network. The next task is to find the optimal system where the simulation process migrates VM to reduce the load on particular system in the network. The process finds the best cost factor for the execution and migration to possess the possibilities and provide the output system in efficient manners. Now the migration process takes place with the help of second phase of the process. This phase divides all the executions in some small sub-part and check the level of execution on them. If the system need to migrate VM in the network, then the Post Copy technique does the execution without any delay in processing. The remaining execution and its previous result is transferred to the migrated environment in order to continue further processing. Rest of the data will be migrated with the help of multi-threading technique on backend.

All these parts of the processing architecture provide high speed execution within minimal energy consumption in the VM migration process. The steps obtained while following this methodology is discussed as under:

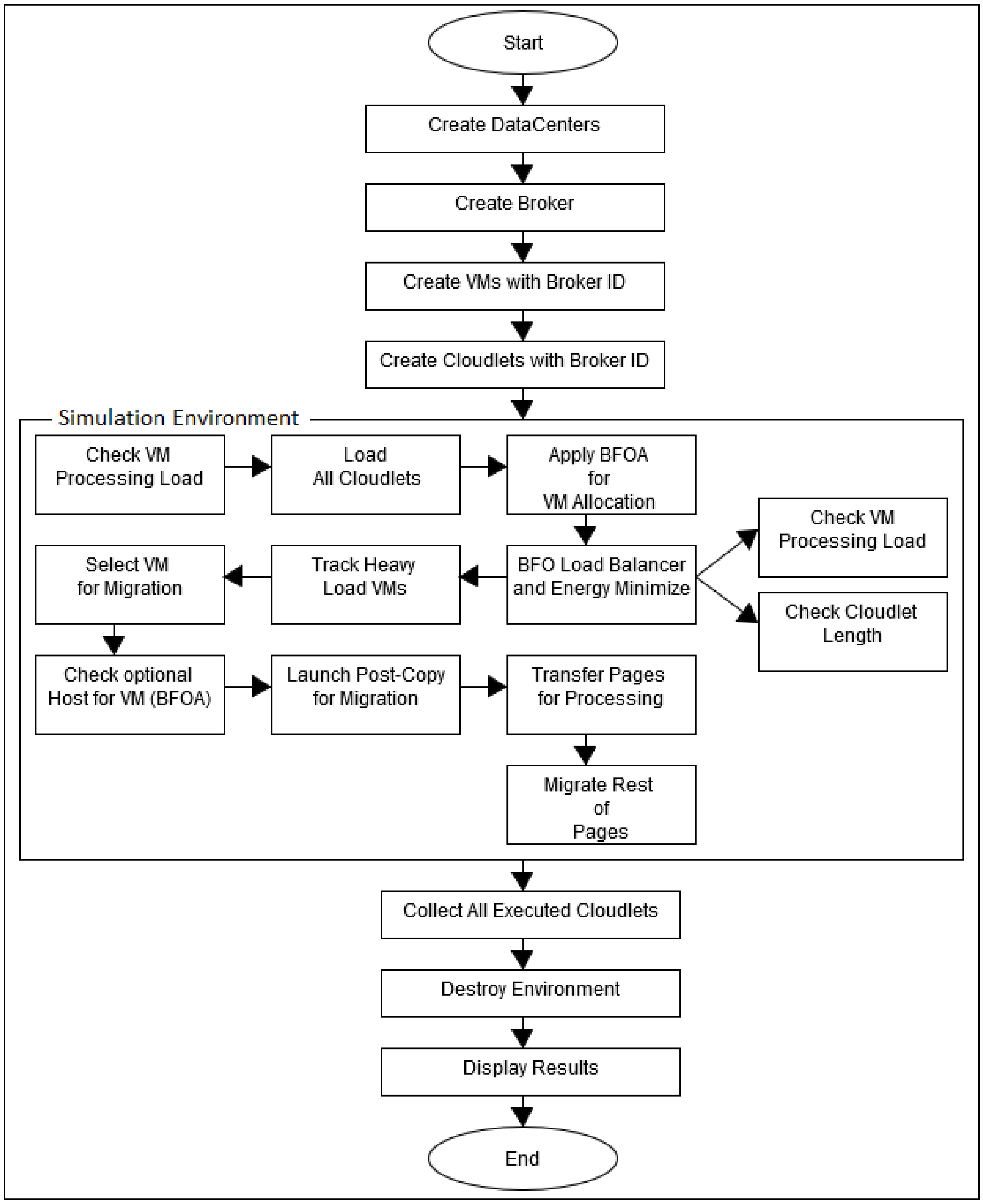

Figure 4.1 Flow chart of Proposed Technique

4.3 Conclusion

This Chapter aims to describe proposed technique and its detail methodology. The next Chapter discusses result on Cloud Platform along with the comparative analysis of existing and the technique proposed.

Chapter 5

Results and Discussion

This chapter describes the tools required for cloud environment, execution of the proposed techniques and the results examined.

5.1. Tools Required for Cloud Platform

5.1.1 CloudSim Tool

It is a set of tools that can be extended to facilitate modelling and simulating Cloud resources. It assists in experimentation of facilities in Cloud Computing and modelling of the Cloud environment. It is not necessary to highlight the low-level trivial information of Cloud-based setup and facilities as shown in Figure 5.1. It provides a boost to both behavior or and system simulation of Cloud parts like virtual systems, DC and provisioning of components [42]. Its salient features are:

i. It gives modelling support for Cloud Computing structure lying on a physical computing point.

ii. There is a hosting platform for modelling DC, scheduling, service brokers and allocation policies.

iii. It assists in modelling of energy-aware computational components.

iv. It provides support for modelling federated Clouds.

v. It provides the provision of dynamic insertion of modelling components.

vi. It gives support for modelling of the message transmitting application.

vii. It gives support for modelling of DC network topologies.

viii. It facilitates the host allocation of user-defined policies to virtual systems.

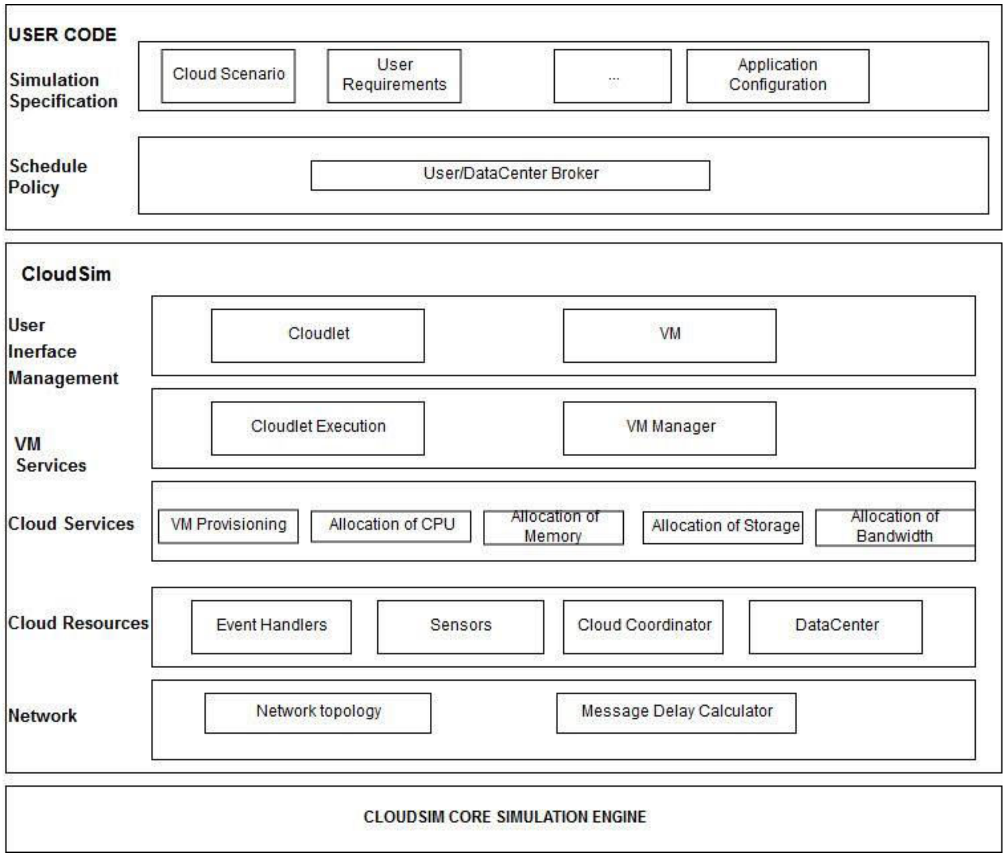

Figure 5.1 CloudSim Architecture

Eclipse is one of the most widely used and well known Integrated Development Environment (IDEs). Computer programmer for developing computer applications uses it. It is mostly used as IDE for programs written in Java language. It primarily consists of a base workspace and has the ability to extend many plug-in systems that facilitate the customization of the development environment. It has been coded mostly in Java language and its basic function is to develop applications in Java language. Due to its capability to incorporate various programming languages' plugin systems, it can be used to develop applications in many other programming languages. These list of languages include C, C#, C++, JS, Perl, Python, Ruby and many more. It can also be used to develop applications using Ruby on Rails framework. TeXlipse add-on assists in developing documents with LaTex tool and also enables the programmer to develop packages for the Mathematica Software. Various development environments in the Eclipse help to program in different languages. Some of these environments are Eclipse Java Development tools, which is used for developing the application in Java and Scala languages, Eclipse CDT used for C and C++ Language, and Eclipse PDT used for developing PHP applications. BM Visual Age released the first Eclipse's codebase. Java Development tools are the most important part of its software development toolkit that is used extensively for developing Java Applications. It enables the programmers to incorporate its capabilities by downloading plugin systems, which were written primarily for the Eclipse Platform. These plug-in systems are usually the toolkits meant for development in various languages. It offers a unique provision to end users to make and contribute their own plug-in modules. With the release of Equinox version of Eclipse, programmers can dynamically stop these plugins and are known as OSGI bundles. Its Software Development kit distributed under the terms and conditions of the Eclipse Public License. It is incongruous with GNU License. Free and open source software can be downloaded easily without any cost and gives the user an opportunity to contribute.

5.2 Implementation of Proposed Technique

This section describes the steps of implementation of the proposed technique in CloudSim toolkit:

i. Creation of VMs-The Virtual machines are created in Cloud environment as shown in Figure 5.2. The Cloud virtual machine requires some parameters such as userId, mips, vmsize, ram etc. Which are used to calculate the performance and execution speed while processing.

```
Vm[] vm = new Vm[vms];

for(int i=0;i<vms;i++){
    vmsize[i]=mips;
    vm[i] = new Vm(idShift + i, userId, mips, pesNumber, ram,
    list.add(vm[i]);

}

return list;
```

Figure 5.2 Creation of VM

ii. The cloudlets are providing some tasks for Cloud network. Tasks are anything that user want to process on Cloud server and system process that request to generate corresponding results. In Figure 5.3, the cloudlets are created in the network with some specifications. These specifications are used to process the cloudlets and select the appropriate machine in the network.

```
Cloudlet[] cloudlet = new Cloudlet[cloudlets];

for(int i=0;i<cloudlets;i++){
    cloudlet[i] = new Cloudlet(idShift + i, length, pesNumbe
    cloudletsize[i]=(int)length;
    cloudlet[i].setUserId(userId);
    list.add(cloudlet[i]);
```

Figure 5.3 Creation of Cloudlets

iii. The machines are created on hosts in the Cloud networks. The host are the main part of the execution which are created with some specification like ram, bandwidth etc. as shown in Figure 5.4 all these specifications are used to calculate the performance and speed of the particular host.

```
hostList.add(
        new Host(
            hostId,
            new RamProvisionerSimple(ram),
            new BwProvisionerSimple(bw),
            storage,
            peList1,
            new VmSchedulerTimeShared(peList1)
        )
    );
```

Figure 5.4 Creation of VM on hosts

iv. The Data Center(DC) are sub-part of the hosts created on the server and uses some parameters for simulation which are time zone, number of virtual machines, operating system and some other terms as shown in Figure 5.5. All the VMs created on it in the simulation process, deals with the execution at the end.

```
DatacenterCharacteristics characteristics = new DatacenterChar
        arch, os, vmm, hostList, time_zone, cost, costPerMem,


org.cloudbus.cloudsim.vm_migration.Datacenter datacenter = nul
try {
    datacenter = new org.cloudbus.cloudsim.vm_migration.Datace
} catch (Exception e) {
    e.printStackTrace();
}

return datacenter;
```

Figure 5.5 Implementation of Data Center

v. The Optimization process is used to balance a load of cloudlets while working with the cloud network. This optimization process in this research manages all the virtual machines. Here in the figure 5.6 some objects created to form an environment of the execution process so that the optimization process can initialize their cost functions and all to optimize and find low cost solutions.

```
BacterialForagingOptimization BFO =new BacterialForagingOptimization();
// initialize bacteria colony
System.out.println("\nInitializing bacteria colony to random positions");
// initialize a colony of bacteria at random positions (but not the costs)
Colony colony = new Colony(colonySize, dim, minValue, maxValue);
System.out.println("Computing the cost value for each bacterium");
for (int i = 0; i < colonySize; ++i) {// costs
    double cost = BacterialForagingOptimization.cost(colony.getBacteria()[
    colony.getBacteria()[i].setCost(cost);
    colony.getBacteria()[i].setPrevCost(cost);
}
```

Figure 5.6 Optimization process

vi. In Figure 5.7, the system shows some tags and events, which are used to execute the cloudlets on the VM, network in cloud simulation process. Here in case of any problem the simulation process fire some events in terms of tags like detail of cloudlets, migration process etc. all these events are used to handle the simulation process. The migration process is also one of the things in this architecture. When system want to migrate the virtual machine it fires the event in simulation process and simulation process migrate that VM on other location in the network.

```
public void processEvent(SimEvent ev) {
    int srcId = -1;
    Log.printLine("in migration process");
    switch (ev.getTag()) {
    // Resource characteristics inquiry
        case CloudSimTags.RESOURCE_CHARACTERISTICS:
            srcId = ((Integer) ev.getData()).intValue();
            sendNow(srcId, ev.getTag(), getCharacteristics());
            break;
        // Resource dynamic info inquiry
        case CloudSimTags.RESOURCE_DYNAMICS:
            srcId = ((Integer) ev.getData()).intValue();
            sendNow(srcId, ev.getTag(), 0);
            break;

        case CloudSimTags.RESOURCE_NUM_PE:
            srcId = ((Integer) ev.getData()).intValue();
            int numPE = getCharacteristics().getNumberOfPes();
            sendNow(srcId, ev.getTag(), numPE);
            break;

        case CloudSimTags.RESOURCE_NUM_FREE_PE:
            srcId = ((Integer) ev.getData()).intValue();
            int freePesNumber = getCharacteristics().getNumberOfFreePes();
            sendNow(srcId, ev.getTag(), freePesNumber);
            break;
protected void processVmMigrate(SimEvent ev, boolean ack) {
    Object tmp = ev.getData();
    try {
    @SuppressWarnings("unchecked")
    Map<String, Object> migrate = (HashMap<String, Object>) tmp;

    Vm vm = (Vm) migrate.get("vm");
    Host host = (Host) migrate.get("host");

    getVmAllocationPolicy().deallocateHostForVm(vm);
    host.removeMigratingInVm(vm);
    boolean result = getVmAllocationPolicy().allocateHostForVm(vm, host);
    if (!result) {
        Log.printLine("[Datacenter.processVmMigrate] VM allocation to the destination host failed");
        System.exit(0);
    }
```

Figure 5.7 Events and Tags

5.3 Results of proposed technique

The proposed work provides a solution to the problem of energy efficiency in Live VM migration. Particular task allotment in an efficient manner is done to each virtual machine, to achieve efficient execution and optimal load balancing of VM, which results in low response time, and hence energy efficiency is achieved. Performance of various algorithms are compared in this section for the surety of proposed results and their stable conditions. The experimental results obtained are represented below:

5.3.1 Energy Consumption and Time Consumption using 5 virtual machines

Energy Consumption: It is one of the main parameters in this research. Table 5.1 depicts the values for energy in contrast to varying cloudlets It shows the total cost of execution for the Cloud network. In Figure 5.8, the simulation process calculates various algorithms processing on different cloudlets. This section shows efficient results calculation of hybrid algorithm for all the cases. The mean that the proposed hybrid algorithm saved more execution cost than the other existing approach in VM migration process in Cloud Computing.

Table 5.1: Energy Consumption Using 5 VMs

Number of cloudlets	Knapsack Algorithm	Post Copy Algorithm	BFO Algorithm	Hybrid BFO Algorithm
10	177	198	142	90
100	1261	2425	970	679
200	1970	4925	1990	1379
500	5964	12425	4970	3479

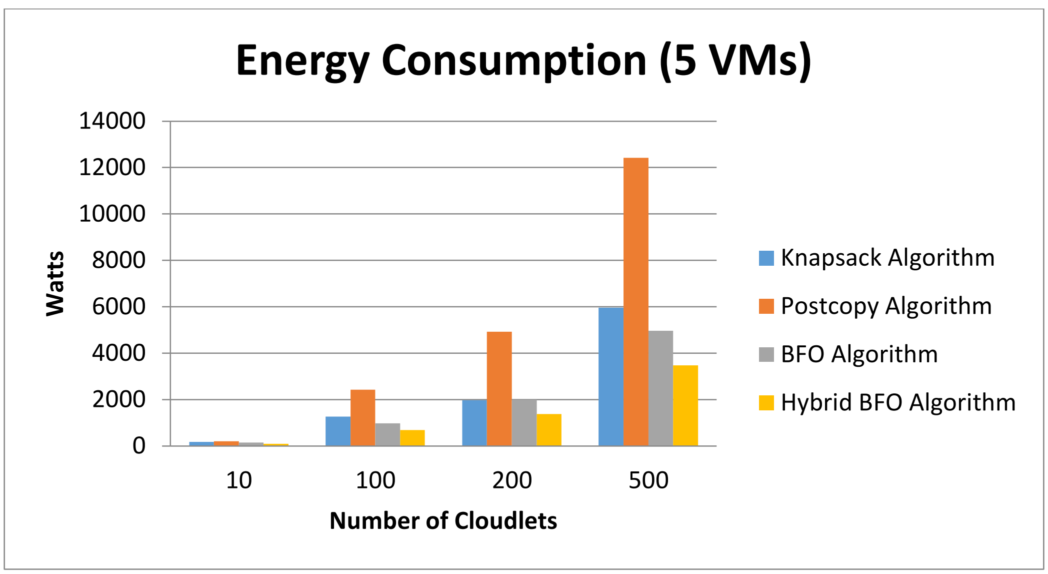

Figure 5. 8: Comparison of Energy Consumption with existing techniques using 5VMs

Time Consumption: The second main parameter is time consumption, which used to calculate the time estimation for particular execution. The Table 5.2 and Figure 5.9 represents the number of virtual machines are five and cloudlets are different for all the cases. Here the proposed architecture processes all the cloudlets on Cloud network in minimal time consumption.

Table 5. 2 Time Consumption Using 5VMs

Number of cloudlets	Knapsack Algorithm	Post Copy Algorithm	BFO Algorithm	Hybrid BFO Algorithm
10	105	126	103	84
100	1495	1843	1455	1351
200	2955	3346	2985	2561
500	6058	7946	7455	5964

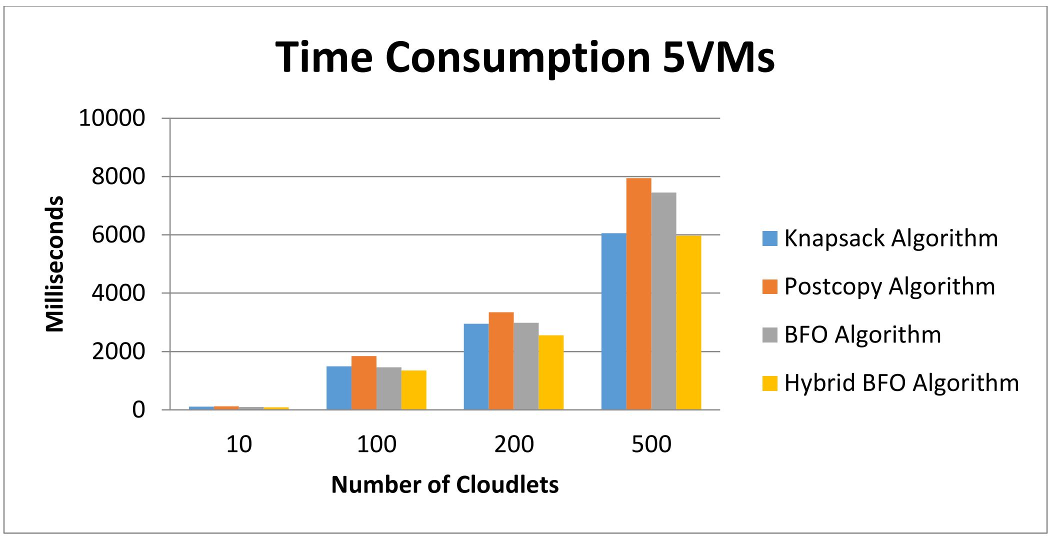

Figure 5.9 Comparison of Time Consumption with existing techniques using 5VMs

5.3.2 Energy Consumption and Time Consumption using 8 virtual machines

Energy Consumption: The energy consumption with 8 VMs is shown in the Table 5.3 and in Figure 5.10. Here the simulation process is having 8 virtual machines with different cloudlets and execute all of them on the Cloud network. After the execution process the system had shown better results for all the cases and save more execution cost than the other algorithms.

Table 5.3 Energy Consumption Using 8 VMs

Number of	Knapsack	Post Copy	BFO Algorithm	Hybrid BFO

cloudlets	Algorithm	Algorithm		Algorithm
10	153	176	125	72
100	1058	2189	807	469
200	1780	4569	1789	1158
500	5526	11925	4522	3075

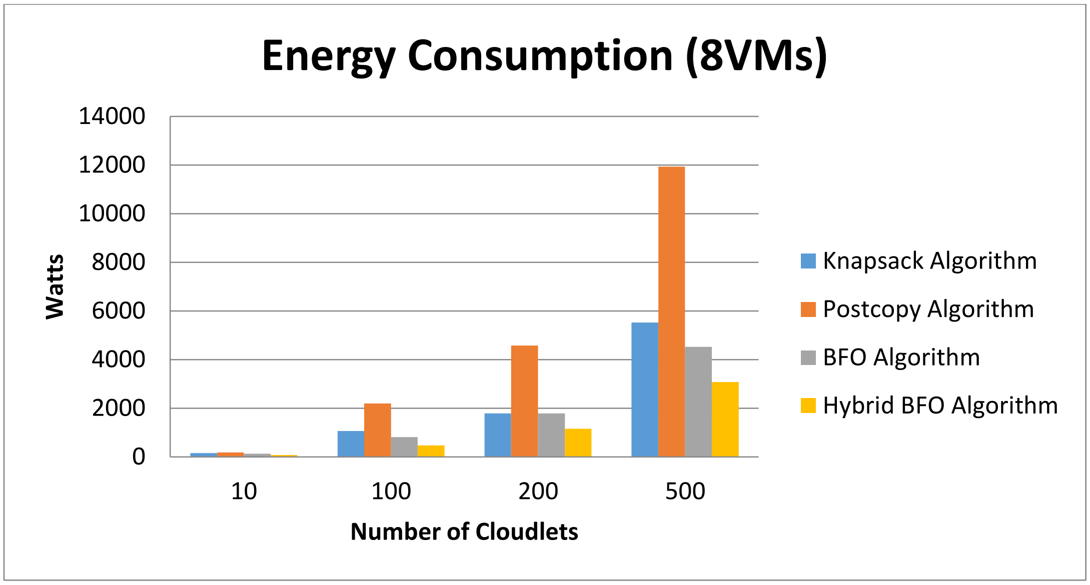

Figure 5.10 Comparison of Energy Consumption with existing techniques using 8VMs

Time Consumption: The simulation process is running for different VMs and cloudlets. Here, the number of VMs are 8 and the cloudlets are again variable as shown in Table 5.4 and Figure 5.11. This is used to check the results stability of simulation process and shows better results in all the cases and save more time than previous algorithms.

Table 5.4 Time Consumption Using 8 VMs

Number of cloudlets	Knapsack Algorithm	Post Copy Algorithm	BFO Algorithm	Hybrid BFO Algorithm
10	79	94	76	62
100	1120	1636	1008	952
200	2563	3260	2604	2252
500	5786	7695	7201	5423

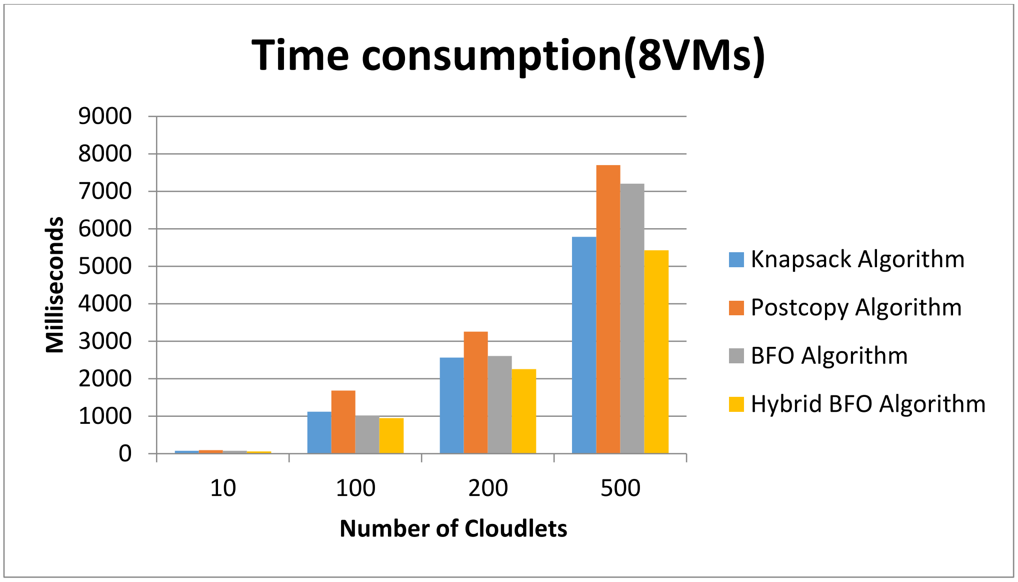

Figure 5.11 Comparison of Time Consumption with existing techniques using 8 VMs

5.3.3 Energy Consumption and Time Consumption using 10 virtual machines

Energy Consumption: The energy consumption with 10 VMs is described in Table 5.5 and shown in Figure 5.12. Here the simulation process having 8 virtual machines with different cloudlets execute all of them on the Cloud network. After the execution process, the system had shown better results for all the cases and save more execution cost than the other algorithms.

Table 5.5 Energy Consumption Using 10 VMs

Number of cloudlets	Knapsack Algorithm	Post Copy Algorithm	BFO Algorithm	Hybrid BFO Algorithm
10	142	148	102	51
100	967	1961	689	287
200	1569	4251	1599	925
500	5220	10247	4355	2789

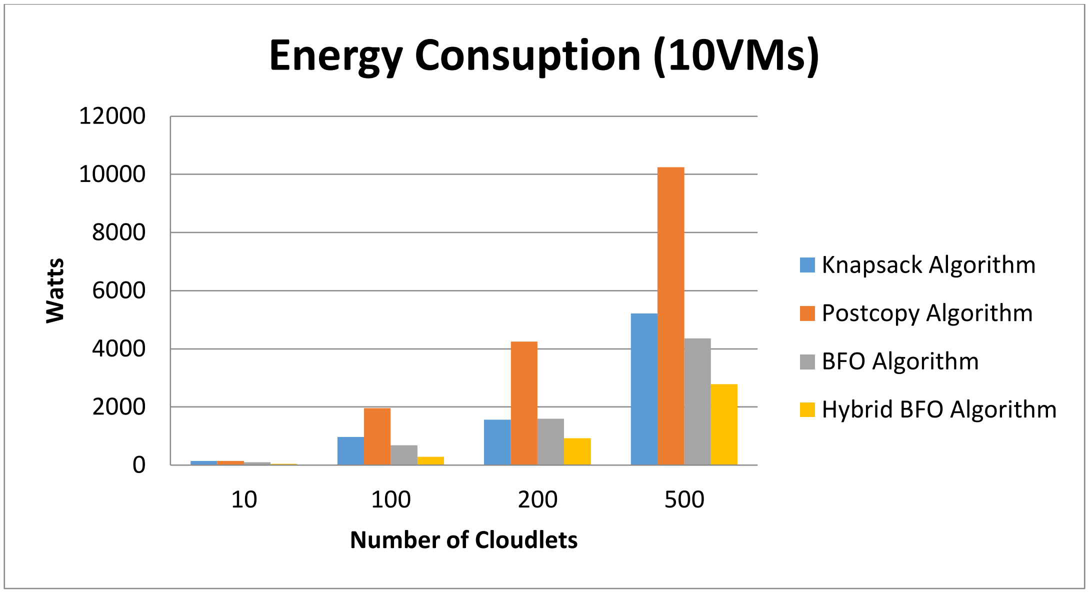

Figure 5.12 Comparison of Energy Consumption with existing techniques using 10 VMs

Time Consumption: The simulation process is running for different VMs and cloudlets. Here in these tests, the number of VMs was 10 and the cloudlets are again variable as shown in Table 5.6 and Figure 5.13. This is used to check the results stability of simulation process and shows better results in all the cases and save more time than other previous algorithms.

Table 5.6 Time Consumption Using 10 VMs

Number of cloudlets	Knapsack Algorithm	Post Copy Algorithm	BFO Algorithm	Hybrid BFO Algorithm
10	54	68	55	41
100	980	1475	924	759
200	2258	2985	2354	1989
500	5248	7365	7001	4998

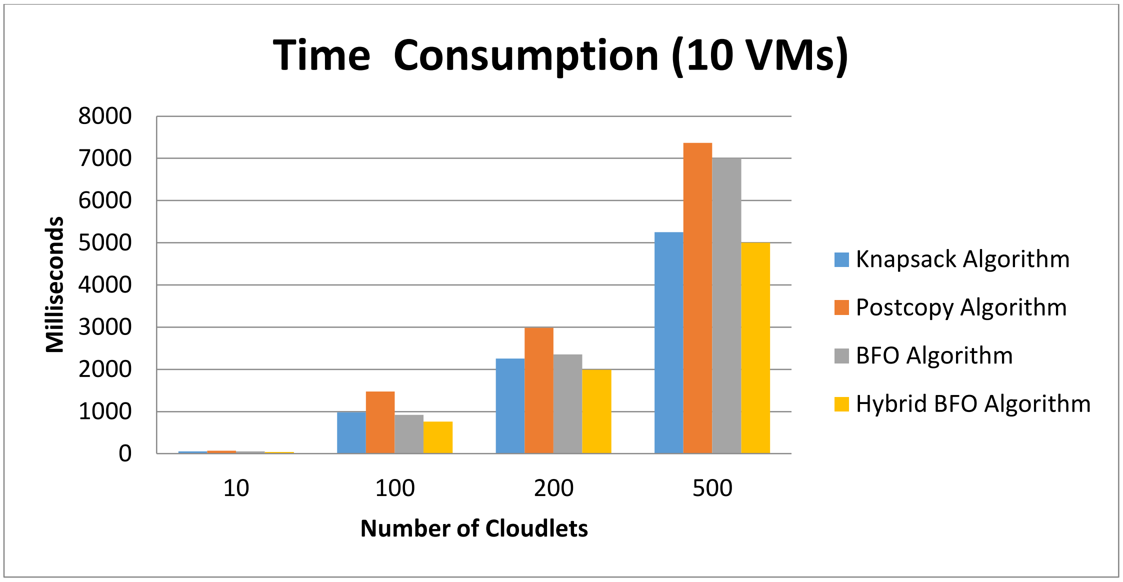

Figure 5.13 Comparison of Time Consumption with existing techniques using 10 VMs

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

The main goal of this research work is to propose an energy efficient technique for live VM migration in Cloud. The energy management approaches in the virtualized data center can be classified into static and dynamic energy management techniques. Based on the current resource requirements of the service requests, the dynamic energy management technique is the best suitable option. Identification and selection of overloaded hosts demands search time whereas transfer to under loaded host requires an additional migration time. Thus, search and transfer time are the two factors that contributes to the problem of increased energy consumption. To resolve this issue, the appropriate scheduling of resources and cloudlets is achieved through BFO and Post Copy technique is used to reduce VM during migration. All the research gaps surveyed are illustrated in the literature survey of live VM migration approaches The proposed work assures efficiency and reliability of the system where all virtual machines are dedicated to their task and minimal number of migrations will take place.

6.2 Thesis Contribution

i. This thesis provides an energy efficient technique such that there is an appropriate allocation of virtual machines to cloudlets and all tasks finish their work in an optimal time and in minimum cost so as to reduce energy consumption.

ii. This technique helps in reducing energy in Cloud environment to a large extent as it reduces migration time.

iii. This technique ensures that all machines are allocated successfully using BFO algorithm to their cloudlets and no unnecessary migration takes place.

6.3 Future Direction

i. BFO algorithm can be hybridized with other algorithms like GA (Genetic Algorithms) in future work.

ii. Based on Cloud application tasks better scheduling and migration technique can be developed.

iii. The results are obtained with Simulation and in future can be implemented in real time scenarios.

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