OPTIMIZATION OF ENERGY EFFICIENT VIRTUAL MACHINE ALLOCATION AND MIGRATION USING ARTIFICIAL INTELLIGENCE ALGORITHMS IN CLOUD COMPUTING ENVIRONMENT

A Thesis

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By

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DECLARATION

I hereby declare that the thesis entitled "OPTIMIZATION OF ENERGY EFFICIENT VIRTUAL MACHINE ALLOCATION AND MIGRATION USING ARTIFICIAL INTELLIGENCE ALGORITHMS IN CLOUD COMPUTING ENVIRONMENT" submitted by me for the Degree of Doctor of Philosophy in Computer Science and Engineering is the result of my original and independent research work carried out under the guidance of Supervisor Dr. Jimmy Singla and it has not been submitted for to any university or institute for the award of any degree or diploma.

Place : Phagwara **Signature**

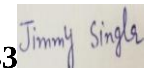
Date : 12.4.22

CERTIFICATE

This is to certify that the thesis entitled "OPTIMIZATION OF ENERGY EFFICIENT VIRTUAL MACHINE ALLOCATION AND MIGRATION USING ARTIFICIAL INTELLIGENCE ALGORITHMS IN CLOUD COMPUTING ENVIRONMENT" submitted by Suruchi Talwani for the award of the degree of the Doctor of Philosophy in Computer Science and Engineering, Lovely Professional University Punjab, India is entirely based on the work carried out by her under my supervision and guidance. The work recorded, embodies the original work of the candidate and has not been submitted for the award of any degree, or diploma of any university and institute, according to the best of our knowledge.

Place : Phagwara **(Jimmy Singla)**

Date: 12.4.22 **U.I.D. : 21733**



ABSTRACT

The concept of cloud computing is as old as 1950's while the term it was understood as intergalactic computer networks in 1960's. As the demand of online business grows exponentially the computing technology became more and more popular and the concept of virtualization found its roots in the world of internet technology. The virtualization supports running a number of Virtual Machines (VMs) simultaneously on single cloud server to parallel accomplish number of tasks. This obviously led to the rising demand of resources such as memory, storage space, power or energy to support processing in cloud computing environment. In addition to resource management, Quality-of-Service (QoS) and maintaining the overall performance are the key challenges that exist in cloud environment.

In the present study, the research work aims at Quality-of-Service aware resource allocation using concept of virtualization. In the process, comprehensive analysis of published research pertaining to VM allocation and migration was performed. So far, it was observed that artificial allocation of the resources of the cloud data centers is cumbersome task and classically high performance is attained at the cost of energy and some Service Level Agreement (SLA) violations. Modified Best Fit Decreasing (MBFD) is one of the classical technique that is popularly implemented by researchers to address challenges of VM allocation in cloud computing. However, to meet the present challenges it requires additional support to address existing computing issues. The identification and allocation of optimal VMs based on energy, number of migrations, and SLA violations was addressed in the present study using concept of Swarm Intelligence (SI) techniques. Different strategies were proposed in the present work to modify the existing Artificial Bee Colony (ABC) algorithm. Initially, the traditional ABC fitness function is modified to propose an Enhanced ABC (E-ABC) to wisely allocate optimal VMs which reduced the number of VM migrations from the overloaded hosts to the underloaded hosts. The work is simulated using various toolboxes and supported functions in Matlab. The simulation analysis demonstrated the effectiveness of E-ABC over existing Enhanced-Cuckoo

Search (E-CS),Ant Colony Optimization (ACO) and existing Artificial Bee Colony (ABC) algorithm in terms of number of VM migrations, Energy Consumption and SLA violations. This is followed by another modification in ABC where an Energy Aware ABC (EA-ABC) algorithm was designed that proved to be much effective than the existing CS, Firefly and Fruitfly optimized VM allocation work. The parametric analysis proved to achieve reduced energy consumption due to wiser allocation of VMs that required least VM migrations. Overall, the simulation studies justified the effectiveness of various modifications appended to the existing ABC. The proposed algorithm architecture utilizes Swarm Intelligence to choose the target VMs from the hotspot PM. In order to do so, a new and novel fitness function has been developed which supports bio-inspired algorithm architecture. As the selection procedure is common in a cloud network, VMs are often migrated from one end to another. This would consume so much power, and the level agreements will be violated, and Slav would increase. The proposed algorithm architecture supports the hybrid kernel oriented machine learning approach to train the system when a successful migration occurs in the network. In such a manner, the learning machine remembers which VM has been migrated to which PM and for how long. Based on the sustainability and the usage of the VM over the PM, the learning master suggests PMs for the VMs who are identified at the hotspot PM. The overall performance is evaluated based on power consumption and SLA violations and no of VM migrations. Also proposed approach is compared with some other machine learning algorithms and it proved to be effective than existing algorithms as shown by some performance measures.

ACKNOWLEDGEMENT

I wish to express my sincere thanks to my supervisor Dr. Jimmy Singla, Associate Professor, School of Computer Science and Engineering, Lovely Professional University, with immense pleasure and a deep sense of gratitude. My supervisor has given me the liberty to follow my passion for research work. The guidance, counseling, and suggestions were beneficial in completing work. It was a great privilege and honor to work and study under his guidance. Without his support, I would not have done this work with dedication.

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Date :12.4.22 **Suruchi Talwani**

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INTRODUCTION

1.1 CLOUD COMPUTING

Cloud Computing (CC) is an integration of different technologies such as service-given architecture, internet, virtualization as well as grid computing technology. Nowadays cloud computing is a very trendy technology because it has several advantages as compared to traditional technologies. Virtualization technology providesa facility to CC to deliver the on-demand computing model.[1].

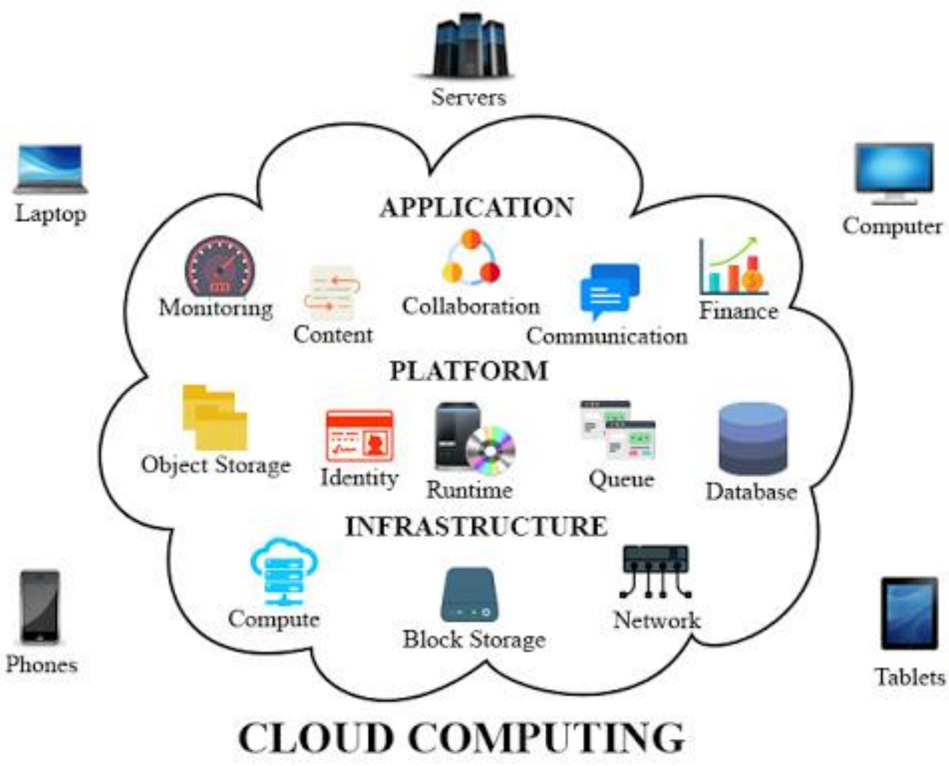

Figure 1.1 : Cloud Computing Environment

Cloud computing refers to web-based applications and online administrations such as distributed processing, machine virtualization, and secure web administrations.The difficulties vary from managing resource variety, designating resources to the user demands efficiently as well as effectively scheduling the requeststhat are planned to assigned resources, as well as managing contingencies linked with the workload and the system [2].Figure 1.1 shows the basic architecture of cloud computing environment [3].

As per NIST, cloud computing is considered as a model that allows ubiquitous, easy, and on-demand network access for sharing computing resource pools (such as servers, networks, applications, storage, and services) that may instantly allocate and publish or serve with less management effort supplier interaction [4].

1.2 EVOLUTION OF CLOUD COMPUTING

Cloud Computing concept originated in 1960. At that time, John McCarthy recommended 'national utilities' would one day be used for computer computing. Cloud computing seems like a comparatively new phenomenon. In another way, goes reverse to the early 1950s when the mainframe’s advent gave central computer access to multiple users. In the 1960s, several facts appeared that resembled what we say cloud computing today such as, the “intergalactic computer network,” concept of J. K. R. Liklider. Because of the growth in the channels of communication and the rising demand exponentially by both business users and private users for the horizontal scale of their systems of information, the cloud computing philosophy became popular in 2007.

Virtualization took the mainframe to a novel stage in the 1970s, and companies of telecommunications began contribution to provide connectivity to the virtual private network (VPN) in the 1990s. Salesforce.com became the prime company to deliver enterprise apps via a network connection in 1999. In a browser, multiple users can download these applications simultaneously at a low cost [5]. The concept of the computer cloud was later actively applied by various businesses, such as Google. The Google Docs service, which enables users to work through a browser with an official document, is the most typical example [6]. When Amazon.com, the online shopping mall, launched Amazon Web Services (AWS), which was the start of the cloud computing movement, modern 'clouds' originated in 2006 [7]. AWS gives the major range to the services like the power of computing and data warehousing, which are the leading and extremely reliable cloud web service platform infrastructure to date. Amazon.com was soon joined by Microsoft, Google, Apple, and IBM, and the market of cloud computing is growing [8].Figure 1.2 shows the evolution in cloud technology.

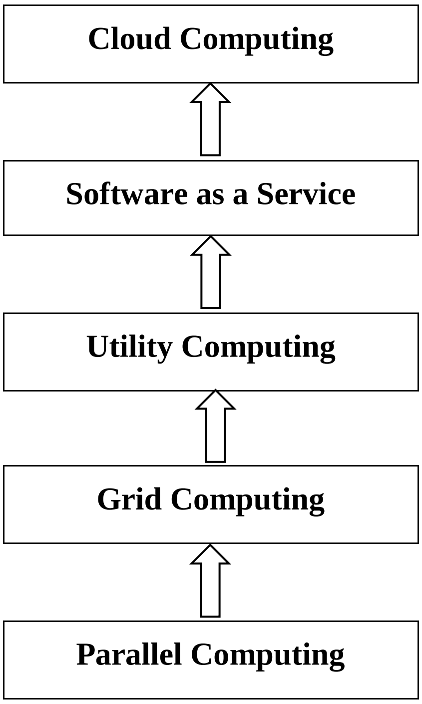

Figure 1.2 : Evolution of Cloud Computing [9]

In a 1969 forecast, Leonard Kleinrock, a leading scientist of the original Research Projects Network (ARPANET), said: networks of Computers are still evolving and their use is constantly increasing, and computer applications were expanding in the 1990s [9]

Several technologies have contributed to this era of computing, as computing of cloud environment paradigms:

• Network Computing,

• Grid Computing

• Parallel Computing,

• Utility Computing, Virtualization,

• Local Computing and many more.

The most popular technologies are discussed below;

1.2.1 Parallel Computing

It is calculated in parallel to divide the entire calculation process and to work in parallel (simultaneously). The term covers several simultaneous programming problems, as well as producing efficient implementations of existing hardware. through collaboration and communication that can solve large computer problems faster [10].

1.2.2 Grid Computing

The grid phenomenon are extremely attractive. It is no coincidence that almost all the major companies in the industry, including Hewlett-Packard, IBM, and Sun Microsystems, have turned their eyes to this technology. In general, giving different user groups ('virtual organizations') the share of geographically remote resources when they work together is the only the biggest challenge in grid computing. This implies the absence of not only a central position, but also of centralized control, and an atmosphere of confidence in working relationships in general.

The relationships between the resources of potential participants in a joint project must first be established, controlled, and used by the grid system. Interoperability in a network environment means working according to general protocols. These are the protocols, and the formation of the transmitted information, that control the interaction of the elements of a distributed system. The grid architecture is therefore primarily a protocol system that must determine the basic interaction mechanism [11].

1.2.3 Utility Computing

On-demand, the services are supplied to the user and charged accordingly. The service provider tries according to the pocket of the customer to deliver services. With the capability to request resources and provide users with a reasonable pricing system that maximizes the use of utilities and minimizes the cost of resources [12].

1.2.4 Virtualization

Virtualization is a mechanism for creating a virtual presentation of resources without being tied to hardware (in our case, software). Servers, storage, network resources, applications, and desktops can be virtualized. Virtualization is a technique of separating physical devices from each other to provide the applicant with virtual resources [13]. A typical server may host different instances of a virtual machine and make them available to users on a demand-based basis.

1.2.5 Centralized Computing

In a single place, known as Centralized Computer Systems or Centralized Computing, computer system resources such as processors, memory, and storage are fully shared and linked. In many data centers, it operates in parallel or distributed mode or is followed in architecture or cloud computing [14].

1.3 SPECIFICATION OF CLOUD COMPUTING

Every concept that belongs to cloud computing has clarified one specification. Some of its major specifications are discussed below:

1.3.1 Pool of Resources

The main goal of cloud computing is to create a resource pool.. The term resources belong to data, application, platform, infrastructure, storage, and service. These all resources are responsible to transmit the data as per the user's request. Resource pools are the concepts that multiple organizations can share the underlying physical cloud infrastructure. Virtual resources and Physical are vigorously re- distributed and allocated as per consumer demand [15].

1.3.2 On-Demand Services

Cloud service provider gives on-demand self-services like network storage and server time for its user at anytime, anywhere as required automatically with no human interaction. Users have permission to resource reserve and release as needed [16].

1.3.3 Processing Power

In cloud computing, processing power plays an important role because without power it is not possible to share the data between resources. So, the processing power that is used in CC is referred to as centralized because the number of resources easily access the power with the lowest rate of energy and cost.

1.3.4 Virtualization

Virtualization is a major service of cloud computing that is accessed by both software resources and hardware resources. This service differentiates cloud computing from other technologies [17]. The principal goal of virtualization is to balance the workload by modifying traditional computing and work in highly scalable, cost effective, and accurate way. Virtualization can be implemented in a wide variety of OS virtualization, hardware-level, and server virtualization.

1.3.5 Storage

The computational resource provided by cloud service provider is termed as storage. The major task of storage is to host different resources like applications and data. The cloud environment provides a facility to store huge data that are coming through different resources.

1.4 CLOUD COMPUTING LAYERED ARCHITECTURE

In the current scenario, cloud computing is a most demanding technology that gives a new shape to each organization to provide on-demand virtualized resources and services.Each layer of the cloud is responsible to perform any specific task. By the integration of all layers of the cloud, users can access the different services [18]. The Figure below 1.3 describes the layered architecture of cloud environment.

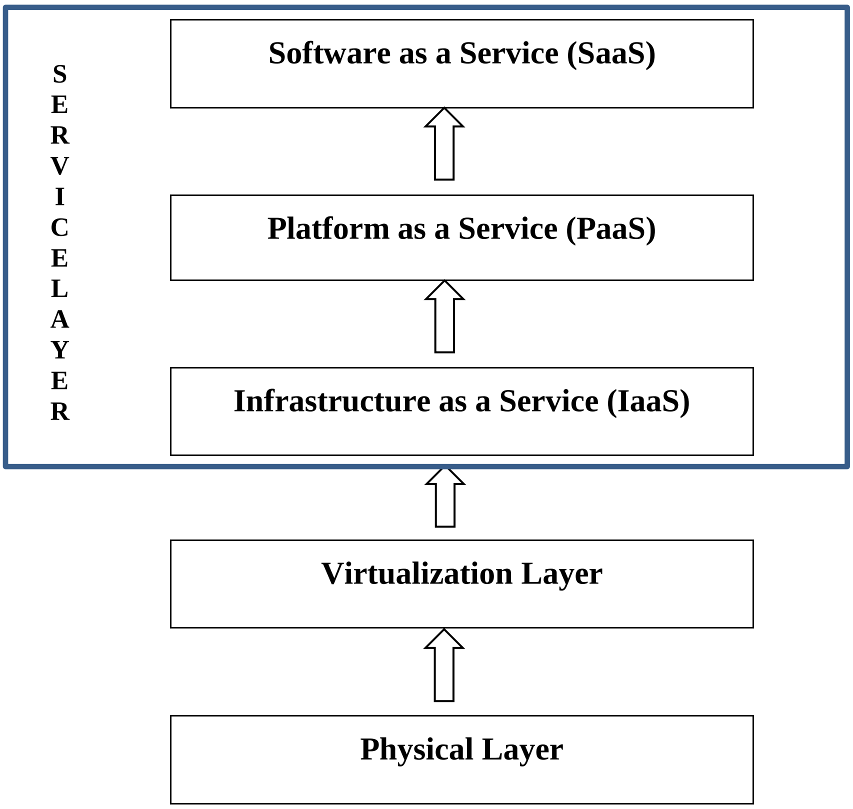

Figure 1.3 : Cloud Computing Layered Architecture [19]

1.4.1 Physical Layer

This layer is dependable for the management of cloud physical resources, with routers, physical servers, switches, cooling systems, and power supplies. The hardware layer is normally executed in the data center and is consisted of several servers being organized in a rack and integrated via routers, switches, or architectures [20]. General hardware layer issues have fault tolerance, hardware configuration, traffic management, cooling, and power resource management.

1.4.2 Virtualization Layer

This layer is responsible to creates, storing, and computing resource pools by using virtualized technologies such as Xen, KVM, and VMware to partition physical resources [21].

1.4.3 Service Layer

The service layer is laid at top of the cloud computing architecture and has real cloud applications. Unlike existing applications, the cloud applications mat take advantage of auto-scaling for enhanced availability, performance, with reduced operating costs. As compared to existing service hosting environments (like dedicated server farms), cloud computing infrastructure is considered more interchangeable. The service layer of the cloud is responsible to services that are categorized as IaaS, PaaS, and SaaS. These services are discussed in the following sub- points [22].

1.4.3.1 Infrastructure as a service (IaaS)

A cloud service is to be considered as IaaS when the cloud service provider is responsible to create a virtualization-based environment for the user. The major responsibility of the IaaS service is to manage the application's data, middleware, and runtime environment [23]. Some common examples of IaaS services are Rackspace, Digitalocean, and Amazon Web Services (AWS), etc.

1.4.3.2 Platform as a Service (PaaS)

The responsibility of the PaaS service is to provide a platform that is used to create software. This service is mostly used by web developers to launch virtual machines and provide a platform to develop applications according to their needs [24]. Some common examples of PaaS services are Google App Engine, Windows Azure, and Heroku, etc.

1.4.3.3 Software as a Service (SaaS)

This layer is the topmost service that is provided by the service layer of the cloud. The SaaS is also considered a cloud application service. The SaaS-based applications are directly executed with the help of web browsers that means users do not need to install these applications [25]. Some common examples of SaaS services are Google Workspace, Dropbox, SAP Concur, etc.

1.5 MAJOR CHALLENGES OF CLOUD TECHNOLOGY

Nowadays, Cloud Computation is an emergent technology which is used in different applications. Even though this is gaining huge achievement but still has to encounter many challenges that must be resolved [26]. The below figure 1.4 describes the major challenges of cloud computing.

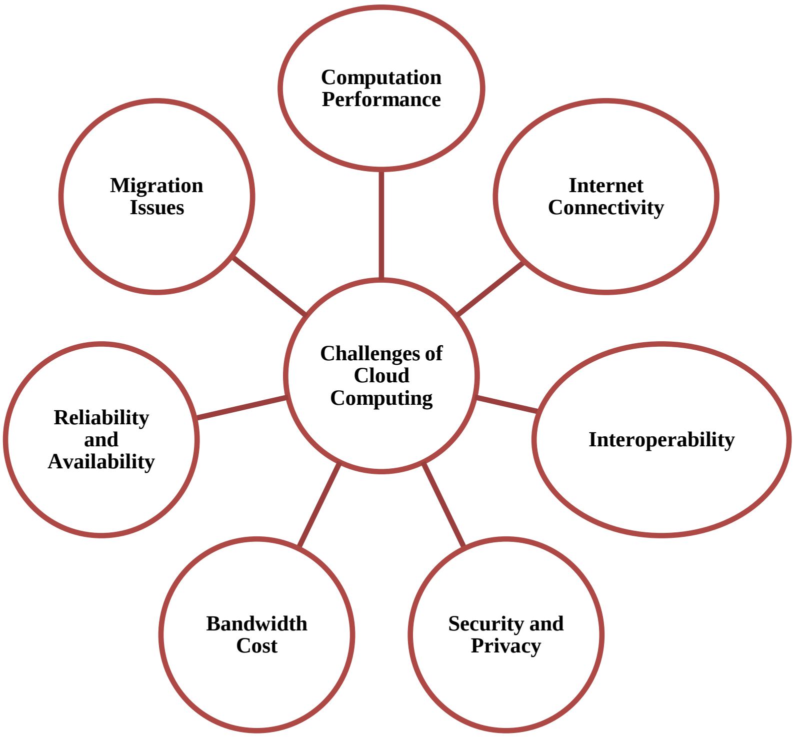

Figure 1.4 : Challenges of Cloud Technology

1.5.1 Computation Performance

Several data-intensive applications based on the cloud always require a higher speed of the network bandwidth that is also increasing the cost. So, the low bandwidth of the network is not able to meet the higher computation performance of the cloud-based application [27].

1.5.2 Internet Connectivity

The cloud applications are always accessed through the high speed of the internet connection. But some businesses are very small and always face internet connectivity issues when accessing cloud applications [28]. So, it is a major challenge in front of small businesses.

1.5.3 Interoperability

This implies that platform apps should be able to make advantage of services from several platforms. It is possible to implement this via Web services, but creating such a Web service is challenging [29].

1.5.4 Security and Privacy

While a cloud service provider holds personal data, it also means that the cloud provider has authority over a significant number of end users' security and privacy settings. It's crucial that cloud providers are aware of the end user's security and privacy concerns. [30, 31].

1.5.5 Bandwidth Cost

Data-intensive cloud apps require a lot of network bandwidth, which costs a lot of money. The processing performance of cloud computing applications cannot be met with low bandwidth. [32].

1.5.6 Reliability and Availability

Because most businesses increasingly rely on third-party services, cloud solutions must be dependable and robust. The most recent risk of employing a cloud solution for company is data availability and business continuity in the event of a lost Internet connection. [33].

1.5.7 Migration Issues

If done incorrectly, migrating data from a system to the cloud might pose a substantial danger.It is vital to establish a migration strategy that is integrated with the current IT infrastructure in order to overcome this challenge. [34-35].

1.6 RESOURCE ALLOCATION

Cloud is an assembly of computers or servers that are interconnected with each other to provide resources to customers. Therefore, resource allocation should be economical for both perspectives that are to the client as well as to the service provider. So, to obtain such a system the new approaches must provide that the system with minimum SLA [36, 37].Many computing areas, such as data centre management, operating systems, and grid computing, use resource allocation as a technique. Resource allocation entails scheduling operations as well as allocating available resources in a cost-effective manner.[38].

1.6.1 Significance of Effective Resource Allocation

Resource Allocation (RA) in cloud field is the progression of allocating accessible resources to all desired cloud applications on the web. Resource allocation comes into action for those services where the allocation is neither done nor managed properly. Resource supply solves the problem by giving service rights to the provider for supervision of the resources of each module. Resource Allocation Strategy (RAS) is the scheme to combine cloud provider performance to leverage and distribute scarce resources within the limits of the cloud environment and hence obtain the requirement of cloud applications [39]. It needs the number of resources along with the types required for each application to complete user work. The input to RAS is the time and the sequence of resources. RAS avoids the below-mentioned problems [40].

1.6.1.1 Resource contention

Resource Allocation (RA) in cloud field is the progression of allocating accessible resources to all desired cloud applications on the web. Resource allocation comes into action for those services where the allocation is neither done nor managed properly.This condition appears in the system when more than two applications intend to use similar resources in the same instance.

1.6.1.2 Resource Scarcity

Resource Allocation (RA) in cloud field is the progression of allocating accessible resources to all desired cloud applications on the web. Resource allocation comes into action for those services where the allocation is neither done nor managed properly.This happens in case when the available resources are inadequate.

1.6.1.3 Resource fragmentation

Resource Allocation (RA) in cloud field is the progression of allocating accessible resources to all desired cloud applications on the web. Resource allocation comes into action for those services where the allocation is neither done nor managed properly.This problem exists in the system, when the sources are inaccessible that means there are appropriate resources are available but are not capable to assign themselves to the required user.

1.6.1.4 Over provisioning

Resource Allocation (RA) in cloud field is the progression of allocating accessible resources to all desired cloud applications on the web. Resource allocation comes into action for those services where the allocation is neither done nor managed properly.The type occurs where the problem appears because of available resource is more than the demanded one.

1.6.1.5 Under-provisioning

Resource Allocation (RA) in cloud field is the progression of allocating accessible resources to all desired cloud applications on the web. Resource allocation comes into action for those services where the allocation is neither done nor managed properly.This problem appears when the allocated resources are less than the demanded resources.

1.7 VIRTUALIZATION IN CLOUD COMPUTING

Cloud computing allows multiple users to share the data that is available in cloud-like applications, but users share the infrastructure by using virtualization. The main target of virtualization is to run multiple operating systems through a single machine but it shares all the hardware resources as shown in Figure 1.5.

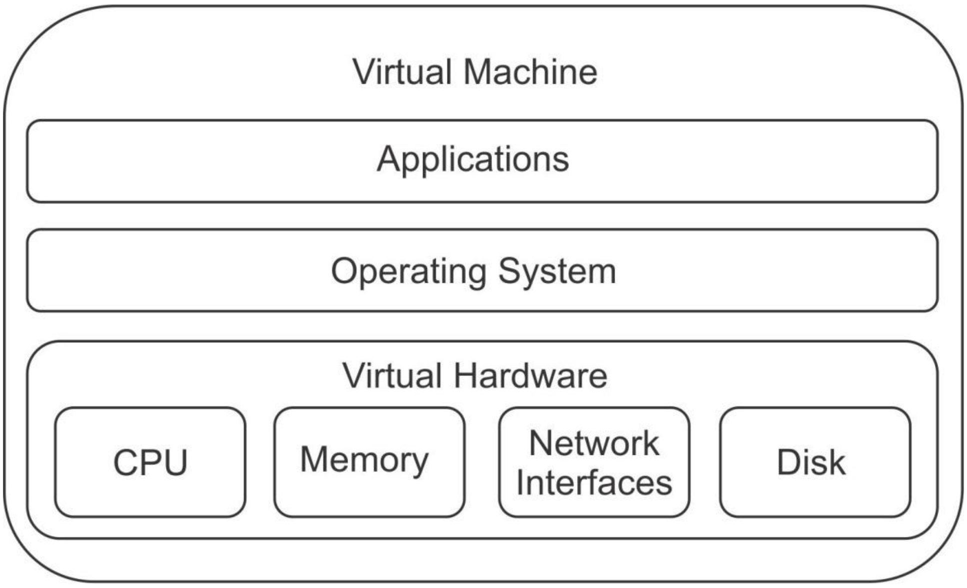

Figure 1.5 : Virtualization

Virtualization's main purpose is to handle workloads by altering traditional computing to perform in a more scalable, effective, and cost-efficient manner. Virtualization can take several forms, including OS virtualization, hardware virtualization, and server virtualization. Virtualization is a cost-cutting and energy-efficient hardware solution that is rapidly changing the way people think about computers.Virtualization technology helps to map a virtual machine (VM) with one or more physical machines (PMs) to fulfil the users requirements for different resources [41]. At the same time, multiple virtual machines can also parallelly reside on the same physical machine and each virtual machine occupies only part of physical resources, to make rational use of the resources of physical machines.

1.7.1 Virtual Machine Allocation

One of the issues in cloud computing environments, particularly for private cloud designs, is the virtual machine allocation problem.Each virtual machine is mapped into the physical host under the available resource on the host machine in this environment.Quantifying the performance of scheduling and allocation policies on a Cloud infrastructure for various application and service models while considering diverse performance metrics and system requirements is a difficult topic to solve. Nowadays, Virtual Machine (VM) are used with cloud computing for reducing the server load on the cloud data center. VM allocation is the most important technique that helps to optimize the total energy consumption held in cloud data centers. VM allocation is not an easy task that is performed on cloud computing. It is very difficult and in the current scenario, it has become a big issue in cloud environments. It is very important to map the request of the physical machine with the application that is store in the cloud data center [42].

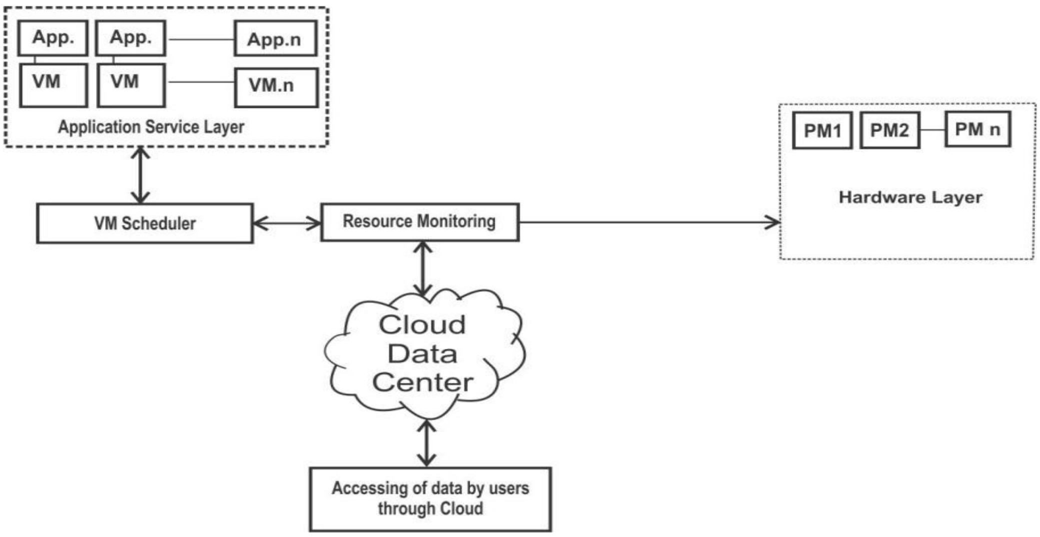

Figure 1.6 : Virtual Machine (VM) Allocation

The above figure 1.6 describes the architecture of VM allocation. The architecture is divided into two layers; the Application layer and the Hardware layer. The purpose of the application layer is used to interact the users with the cloud services by using the internet. The hardware layer provides information regarding physical machines. The cloud data center is responsible for responding to each request that is coming from the application layer. The purpose of the VM scheduler is that to arrange the number of requests that arise in the VM.

1.7.2 Virtual Machine Migration

Migrating any virtual machine is the task of shifting a virtual machine from one hardware structure to another environment. It comprises of managing the hardware v systems that are virtualized and it is a kind of service that is in high demand by providers who offer virtualization related services. Teleportation is another saying for this entire concept[41].

1.8 NEED OF VIRTUALIZATION

The virtualization is the most important technology that is widely implanted these days in order to maintain the performance of the cloud data centres [43]. The necessity and need of visualization is further discussed as follows:

1.8.1 Separation Among Users

The virtualization is the most important technology that is widely implanted these days in order to maintain the performance of the cloud data centres [43].An individual user must be isolated from another user so that he/she might not obtain knowledge about the other user's data and usage and cannot even obtain others' data.

1.8.2 Resource Sharing

The virtualization is the most important technology that is widely implanted these days in order to maintain the performance of the cloud data centres [43].Virtualization also helps to share resources by dividing a large resource into small virtual resources.

1.8.3 Active Resources

The virtualization is the most important technology that is widely implanted these days in order to maintain the performance of the cloud data centres [43].Resources reallocations like saving and computational resources are very hard but if we are using virtualization then they can be simply re-allocated.

1.8.4 Gathering of Resources

The little resources available in the system can be expanded to a great extent with the help of virtualization [44]. The most effective solution for the problems like hardware cost and IT cost is Virtualization. It is also important in power consumption minimization and also maintains a level of utilization of hardware and energy efficiency. Xen, Oracle VirtualBox, Kernel-dependent Virtual Machine (KVM), VMware ESX are with normal features but these are the highly established virtualization methods.

1.9 TYPES OF VIRTUALIZATION IN CLOUD COMPUTING

Virtualization is commonly used for cloud deployment as well as cloud services models. The main purpose of virtualization is that it provides better resource management [45]. In cloud environments, virtualization is divided into four major categories that are discussed below in figure 1.7.

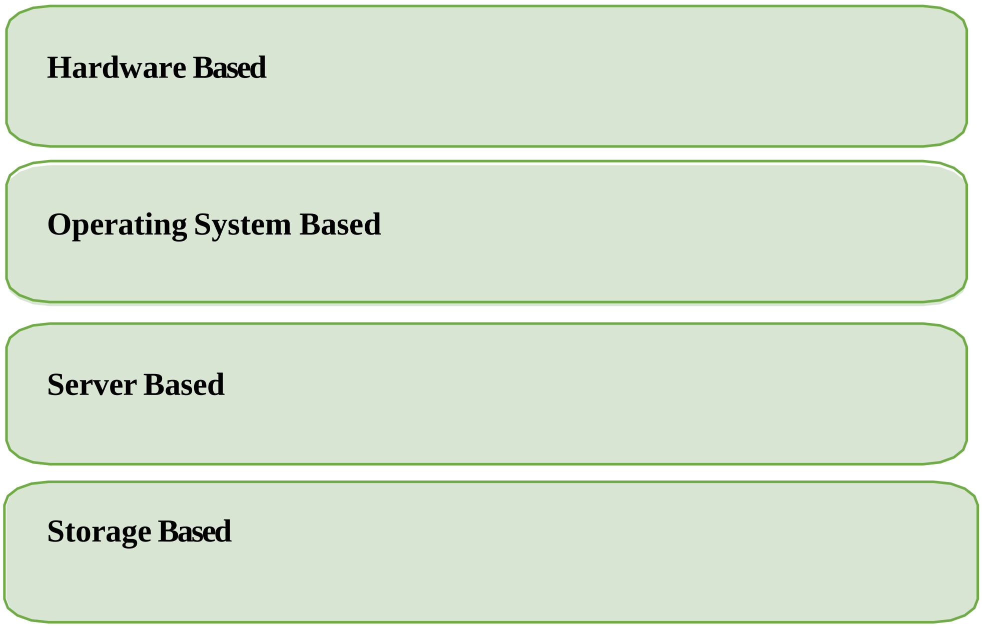

Figure 1.7 : Different Types of Virtualization in Cloud Computing

1.9.1 Hardware Virtualization

Virtual Machine Manager (VMM) software is installed on the hardware system in this sort of virtualization. The VMM is installed in the hardware device as a piece of software that enables hardware virtualization.Install a separate Operating System (OS) and run multiple programmes after enabling hardware virtualization.

1.9.2 Operating System Virtualization

The VMM (Virtual Machine Manager) or virtual machine software is installed in the host's operating system (OS) rather than the hardware in this case.This sort of virtualization is used to test different apps on different operating systems.It specifies that virtualization can be used on a variety of operating system platforms.

1.9.3 Server Virtualization

The server virtualization is applied to install the VMM directly on the server system, and further, it is divided into several servers that are based on resource usage through load balancing. The server administrator has permission to divide a physical server into a group of servers. The main target of server virtualization is to fulfill the various demands of the resources.

1.9.4 Storage Virtualization

The virtualization is the most important technology that is widely implanted these days in order to maintain the performance of the cloud data centres [43].The storage units are responsible to store a huge amount of data but it is very crucial to keep the backup and recovery of data.

1.10 GREEN CLOUD COMPUTING USING MACHINE LEARNING APPROACH

In the environment of cloud host model, recent data center runs for applications ranging from seconds running (e.g. needs for web applications as e-commerce and portals of the social network with instantaneous synthetic ANIMUS framework) to longer running applications on hardware platforms of sharing (like processing analogy or large data sets). The challenge of responding to the provision of resources on-demand and the allocation of time-changing workloads is required for managing the numerous applications in the center of data. Classically, the artificial allocation for the resources of the data center is done statically to applications based on features of peak load to maintain isolation and giving performance guards [46]. So far, high performance is the only concern in the implementation for the centers of data and this requirement is met with modest energy consumption concerns. The center of data is environmentally unfriendly and it is costly as well. Various servers are to be downloaded by the user that is offered in these data centers and cools them down. The steps for profit margins that will not be artificially minimized because of the high cost of energy must be ensured by cloud service providers. This is a challenge to reduce data center power consumption and difficult issues because applications of computer and information are produced so rapidly that bigger servers and discs are required gradually to advance rapidly over the essential period. Green cloud computing is intended not only to enable ingenious computer infrastructure processing and deployment but also to limit the consumption of energy. It is crucial to ensure that future development in the environment of the cloud is sustainable [47].

If not, cloud environment and increasing status of front-end devices for users and interaction of back-end center has shown the way for the upgrades of enormous energy. In the approach of energy-efficient to green cloud computing upgrades, resources of the data center are required to be managed to resolve this issue. In particular, it is essential to assign the cloud resources for minimizing the consumption of energy; it does not need to fulfill the requirements of QoS set through the customer via the Service Level Agreement (SLA). In industrial societies, it is portrayed and seen as the latest technique after the proposal of the computing field, but it is majorly received as a technical choice in the field of technology such as data center networks, data centers, application measurement services, etc. Green technology is the other name for it. The world experienced a computer uprising in the late 1970s, and green computers became reliable in the early 1990s. Then companies started using the eco-friendly methods to do business. Green Computing is the simple implementation and environmentally sustainable presentation in the sector of IT which may be quickly delivered with nominal administrative exertion or interaction between green vendors [48]. Alternatively, a cloud environment is a very reliable computer and data storage solution. Because it is useful for the environment, this is called green cloud computing. Now, making it economical and cost-effective is the biggest problem. To leave the section over the carbon footprints, the environment of green cloud is there. The first and most significant goal of the green cloud computing is to enhance the product's recyclability and longevity. It will have an almost negligible consequences on the design, handling, manufacturing, and use of the computers.

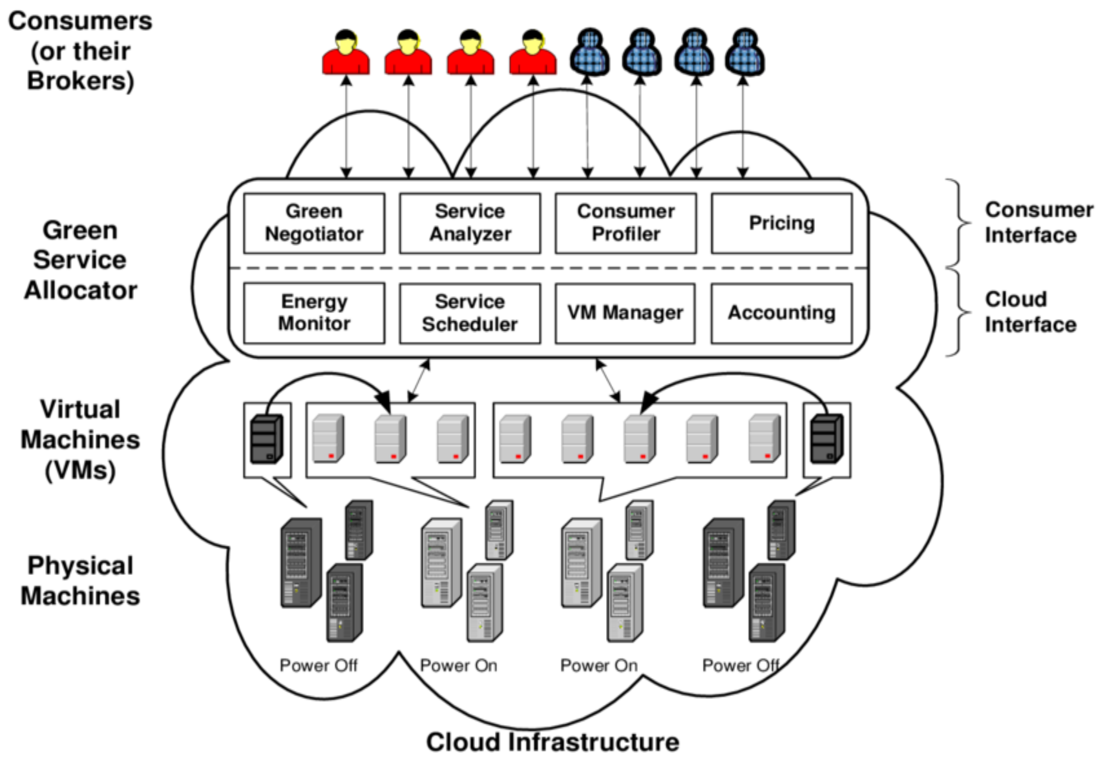

Figure 1.8 : Green Computing Environment

Normally, some data centers have become more association with environment, and data centers have become more expensive in expressions of consuming large energy and have become a problem for the environment. Due to rising energy prices, energy availability has decreased slightly [49].

Green cloud architecture and their energy centric allocated services are exposed in Figure 1.8. Generally four key entities like client/cloud interface, virtual machine, green service allocator and physical machine. The following points describe entities that are important in a green computing environment.

a) Consumers / Brokers

There are cloud computing brokers that offer requests for services worldwide. The deviation of the service users is proposed to be dealt with and the workload is dealt with in case of problems with the application being adjusted.

b) Green Negotiator

The SLA among the server and client on cloud environment is finalized by the negotiator. The cost of services and penalties among them is including the QoS requirement of the client with energy-saving schemes.

c) Service analyzer

To understand whether to go along with it or not checks the authenticity and demand of each request. It needs the latest sources of information and data because it requires the awareness of the information to analyze and interpret each application.

d) Consumer Profiler

Produced particular data from all consumers by which to get the knowledge about important or privileged customers as compared to others.

e) Pricing

It manages the contribution along with command of every resource and expedites managing service allocation in a precise manner.

f) VM Manager

It is responsible to keep track of the resource entitlement in every scenario.The migration of some or all VMs around the physical machines is the key responsibility.

g) Virtual Machines

It is the hardware on which the machine's software is implemented. VM is an entity for acomputer that works as a real computer. On one system multiple VMs can work separately. There is a server for a system that uses more than one VM and the software that helps it accomplish is hypervisor. Each VM has its own hardware including hard drives, memory space, CPUs, etc. VMs prove to be helpful in reducing each machine's need for a separate power supply and cooling device [50].

h) Physical Machines

Generate real environment for VMs so that they can work through and fulfill every needs through services. PMs helps to maintain the load as they perform load balancing.PM is used to carry out a job in a cloud environment.

1.11 INTELLIGENCE ALGORITHMS FOR GREEN COMPUTING

Many ways are being created to make the system eco-friendlier and energy savers. The methods written in this section have been run in a controlled and managed environment in data centers. The realistic method mentioned is still in the study [51, 52]. The techniques which are tested and considered here are as follows:

1.11.1 Virtual Machine Migration

All the VMs are selected; the application is then hosted by new physical machines for doing work. The hosts have permission to interchange the VMs depending on the requirements set and giving resources as output given by one another. This approach focuses on mainly saving the power. Only that VMs are selected that lead to power saving.

1.11.2 Dynamic Voltage and Frequency Scaling Technology (DVFS)

A working clock is integrated with each electronic circuit. Operating frequency has to be adjusted for the supply of the right voltage by the clock. The DVFS is dependable for the requirements, which ought to be uncontrollable. Power is also counted low whencompared to other methods and saving cost is also high. That means that there is a lesseroperating cost.

1.11.3 Intelligence Algorithms

The servers when they are in state of full CPU utilization uses 70% of power. Neural Network (NN) helps to perform dynamic workload and is found by Green Scheduling Algorithm (GSG).For lessening the number of running servers for which needles servers are considered. The energy is lowered for consumption [53, 54]. The advantage of this will be taken in all levels. The service level is ensured by the integration of all different servers for help. Saving the environment and maintaining the Quality of Service are two main concerns.The modern-day framework also includes intelligence algorithms. The intelligence algorithms are categorized as follows.

a) Natural Computing

Natural computing architecture is directly inspired by the nature. As nature dissolves what comes to it, in a similar framework, the natural computing algorithms are not distorted by the load. If the load increases, the fitness evaluator of the natural computingadjusts itself as per the background load, e.g Genetic Algorithm. From the last many decades, growing focus on research in algorithms that focus on the concept of natural evolution which is also called as survival of the fittest can be seen.These algorithms are population dependent and random search based having some heuristics. There is a set of population of individuals and each one represents research point in the area of all feasible solutions. Each one undergoes a learning phase that goes from generation to other generations. Population is initialized in a random way and then the process of selection starts, then recombination is done, mutation takes place and finally new generation is evolved towards a better region of search space. Search process is evaluated through fitness function and individuals with better fitness values are chosen.

b) Swarm Intelligence

This architecture is the behavior of the elements that exist in nature and are always in a group. The grouped behavior is classified as Swarm Intelligence, e.g Artificial Bee Colony, Cuckoo Search, Firefly.

c) Machine Learning / Brain Computing

When a machine is taught to deliver, it comes under machine learning, e.g. Support Vector Machine, Neural Networks etc. ML is a subfield of artificial intelligence that has evolved out of the need to automatically teach computers how to learn a solution from a problem automatically. ML facilitates the computers to program themselves. It is used anywhere from automating mundane tasks to offering intelligent insights. ML algorithm enables software applications to become more precise without being specifically programmed to predict performance. Its basic concept is to develop algorithms that take some raw input data and with the use of statistical analysis, they predict an outcome while updating the outputs as new data will keep on becoming available. Some commonly used ML algorithms are; Support vector machine (SVM), Naïve Bayes (NB), Random Forest (RF), and Artificial Neural Network (ANN) [55].

1.12 Support Vector machines (SVM)

In the category of supervised learning based method, Support Vector Machine comes and has become a successful approach to solve classification and regression problems now days. SVM reports outstanding results in multiple domains including fetal well-being monitoring. Researchers have mainly focused on SVM learning algorithms but now research is going on to find efficient kernel to improve accuracy. Linear, Gaussian, or polynomial are Standard kernels and are unable to take benefit from specific data sets. This has driven the research to find alternative kernels to be used in the areas of multimedia or signal processing.

A supervised learning models SVM is used to train data for classification and regression problems. Data set containing various features related to problem is categorized in to two categories defined on basis of features. SVM not only performs linear classification but also perform a non-linear classification efficiently. The concept of kernel comes in role when nonlinear classification is applied. Kernel searches for a hyperplane that can differentiate the training data by mapping the non-linear separable dataset into high-dimensional feature spaces [34].

1.12.1 Kernel

Kernel plays a significant role in the performance of the SVM and reduces the complexity of the shallow approaches as compare to deep learning approaches. Kernels are basically mathematical functions and used to take nonlinear separable data as input and transform it into linearly separable data in higher dimensional space. A "kernel," also known as a "kernel trick" in machine learning, is a method of employing a linear classifier to tackle a non-linear issue.It entails converting data that is linearly inseparable into data that is linearly separable.The kernel function is used on each data instance to translate the nonlinear observations into a higher-dimensional space where they can be separated.

1.12.2 Kernel Functions

The kernel function helps to determine the shape of the hyperplane and decision boundary. We can set the value of the kernel parameter in the SVM code. Some of the standard kernel functions are described as-

1) Linear Kernel

The Linear kernel is calculated by the inner product <x,y> plus an optional constant c.

$$K(x,y) = x^T y + c$$

2) Polynomial Kernel

The Polynomial kernel is a non-stationary kernel that works well for problems where all of the training data has been standardised..

$$K(x,y) = \left(\alpha x^T y + c\right)^d$$

Slope α, constant term classification and the polynomial degree d are adjustable parameters.

3) Gaussian Kernel

Gaussian kernel is an example of radial basis function kernel.

$$K(x,y) = \exp\left(-\frac{\|x-y\|^2}{2\sigma^2}\right)$$

4) Exponential Kernel

The exponential kernel, also known as a radial basis function kernel, is very similar to the Gaussian kernel, with the exception that the square of the norm is not included.

$$K(x,y) = \exp\left(-\frac{\|x-y\|}{2\sigma^2}\right)$$

1.13 SWARM INTELLIGENCE

Swarm Intelligence is one the most effective optimization algorithm architecture. The swarm intelligence algorithm is a behavior that is observed in a group [56, 57].From the last many years,swarm intelligence has gained a focus from research point of view in the field of optimization because of so many merits like operationally simple, fast rate of convergence and ability of global search is powerful. Different types of behaviors are observed in nature and hence different algorithms are studied and presented. Improved versions of old swarm intelligence algorithms are emerging so rapidly are are being applied in the area of optimization. Some of the popular algorithmic architectures of the Swarm Intelligence are as follows.

1.13.1 Artificial Bee Colony (ABC)

Based on the behavior of Bees which mainly comprises of three bees namely employed bee, onlooker bee, and scout bee. It is one of the newly described algorithms of Dervish Karaboga in 2005; motivation is the bee's intelligent behavior. It uses only ordinary control parameters like colony size with the maximum number of cycles. ABC offers a population-based search program with individuals referred when food locations are changed over time by artificial bees with the purpose of the bees is to find the place for the food source of high amounts of nectar and at last, found the place with more nectar. Some (scouts) randomly choose the source of food without experience. If a new source has more nectar than the precious nectar, they remember the new location and forget about the previous one. As a result, the ABC system integrates the local search approach with workers and bystander bees having a global search approach assisted with onlookers as well as scouts for balancing the exploration and development procedure [58].

1.13.2 Ant Colony Optimization (ACO)

It is defined as a population-based metaheuristic algorithm that is applied to find out the approximation of solutions to solve difficult problems. In this algorithm, a set of software agents that is called artificial ants is applied to find a best optimal solution for the given problem. These ants are responsible to build solutions by moving on the graph. The behavior of ants has inspired a lot of researchers and hence their behavior is termedAnt Colony Optimization [59].

1.13.3 Particle Swarm Algorithm (PSO)

Particle based swarm optimization is one of the heuristic optimization approach that was initially brought into practice by J. Kennedy and R. Eberhart in year 1995. It is primarily developed from the concept of swarm intelligence. It has the basis of working mechanism of bird and movement behavior of fish flock. The initial ideas on particle swarms were aimed at producing computational intelligence by using simple analogs of social interaction, rather than purely individual cognitive abilities. When looking for food, the birds either scatter or congregate before locating a location where they can obtain food.While birds are moving from one location to another in quest of food, there is always one bird that can smell the food very well, indicating that the bird is aware of the location where the food can be obtained, providing better food resource information.The birds will eventually flock to the spot where food may be found since they are continually sharing information, particularly positive information, while hunting for food from one location to another.When it comes to the particle swarm optimization algorithm, solution swarms are compared to bird swarms, with birds moving from one location to another representing the development of the solution swarm, good information representing the most optimist solution, and food resource representing the most optimist solution throughout the course. [60][61].

1.13.4 Cuckoo Search

Yang and Deb (2009) created CS, which is a meta-heuristic optimization approach based on cuckoos' obligate brood parasite behaviour.The CS technique follows three idealised rules:

1) Each cuckoo lays one egg at a time and deposits it in a nest that is picked at random.
2) The best nest is one with high-quality eggs, which will be passed down to future generations.
3) The number of available host nests is fixed, and the host bird discovers the cuckoo's egg with a probability Pa [0, 1].If an alien egg is discovered, the host bird either discards the eggs or abandons the nest and builds a new one.In a

nutshell, this rule can be summed up as the fraction Pa of bad eggs that are replaced by new eggs. [62].

1.13.5 Firefly

The author “Yang” invented the Firefly algorithm (FFA), which is a swarm-based metaheuristic algorithm. The algorithm is modeled after how planes respond to their flashing lights. This algorithm has an assumption that all fireflies present in one group are unisex that means one firefly must be attracted to another different firefly; a firefly's attractiveness is proportional to its brightness, which is computed by using the objective function of the optimization approach. The lighting of the fireflies has attracted a lot ofresearchers resulting in the firefly algorithm [63].

1.13.6 Fruitfly

Fruitfly is an insect who eats decayed plants(fruits).they gather information in the form of chemical from their local environment through their smell and taste buds that are present on their bodies and some behaviors are regulated like foraging,mating,aggregation and spawning. Olfactory has an important role in all these behaviors over short and long ranges of distances. Fruitfly Optimization algorithm(FFO) is based on simulating the foraging behavior of fruitflies and is considered to be fast and simple in structure.

1.14 OBJECTIVES OF PROPOSED WORK

- To study and review the existing research work based on energy efficient virtual machine allocation and migration techniques.
- To apply Swarm Intelligence optimization algorithms to reduce the energy consumption in VM migration.
- Prediction of optimal VM migration decision using machine learning algorithm.
- To compare the performance of proposed work with state of the art work.

1.15 THESIS CONTRIBUTION

- Live VM migrations that are highly energy efficient is performed by using Swarm Intelligence technique and machine learning classifier.Swarm Intelligence helps to find correct hotspots and machine learning classifier helps to predict the correct decision of migration in the future,
- Identifies the VMs for migration that would consume minimal expenditure of energy while not ignoring quality of service in the light of search performed by ABC and SVM approach.
- Efficient identification of hot spots minimizes the false migrations required to complete the task optimally and hence energy is saved.
- Simulation analysis conducted in Matlab shows that 40% energy get conserved with the proposed framework as compared to other existing techniques for VM migration.

1.16 RESEARCH METHODOLOGY STEPS

1) Deployment of Virtual Machines to Physical Machines based on resource availability.
2) Selection of VMs among all the VMs from overutilized hosts for migration using Swarm Intelligence Algorithm.
3) Placement of those selected VMs on a new host to minimize the number of migrations ,SLA violations and to reduce energy consumption
4) Perform post migration analysis of VMs using machine learning classifiers.
5) Result Formulation

1.17 ORGANISATION OF THESIS

Chapter 1 explains the basic introduction about the concepts related to research work, objectives of research and thesis contribution. The rest of the work is structured as follows-

Chapter 2 discusses the existing techniques of virtual machine allocation and virtual machine migration. This chapter also addresses research findings and research gaps.

Chapter 3 discusses about the problem formulation and flowchart of research methodology. This chapter helps in explaining the importance of optimization of algorithm's role in the correct VM placement so as to reduce false migrations and hence leading to saving of energy.

Chapter 4, 5 and 6 explain the detailed explanation about the research objectives.

Chapter 7 describes the results and discussion along with comparative analysis with existing techniques.

Chapter 8 discusses about conclusion of research work and future scope.

1.18 Summary

Chapter-1 summarizes the basic concept of Cloud computing, virtualization, VM allocation and VM migration along with the knowledge of Swarm Intelligence and its importance and machine learning classifier’s role in virtualization.

Chapter – 2

ANALYSIS OF EXISTING LITERATURE

With the enhancement in the field of IT sector, data processing, and computing facilitieson cloud management, cloud computing becomes one of the recent emerging trends. The prime focus of the research is to design an efficient algorithm for virtual machine resource allocation that maximizes efficiency while improving network energy saving through optimal mapping. This chapter examines in detail the latest contributions consistent with the proposed goals, with a focus on VM allocation and VM migration.

2.1 VM MIGRATION

(Fahimeh et al., 2015) proposed a distributed architecture in which the energy is savedby utilizing the concept of vm consolidation with the maintenance of required QoS. As the VM consolidation is probably the NP-hard kind of problem, to solve this problem an online optimization Meta heuristic algorithm has been used known as 'Antcolony system'(ACS). The presented work has performed improved as compared to the existing VM approach by means of a number of VM migration and energy consumption [64].

(Shaw et al., 2015) proposed the approach by considering the main cons of implementing such model that computation cost increases which puts lots of burden. So, load prediction algorithm is proposed to minimize the VM migrants and distributingthe load equally [65].

(Chou et al., 2016) proposed the dynamic allocation is described using live migration in which dynamic threshold value is used for multidimensional resources. The VM placement ensures free resource allocation using Infrastructure as a service cloud. The energy efficiency is revamped in which state of art research is focused [66].

(Kansal et al., 2016) presented approach which is due to the increase in data centers in the cloud environment. In this paper, virtual machine migration technique is proposed which is based on firefly algorithm, to reduce the workload. The developed approach doesn't efficiently balance the load and generates the unnecessary migrants which is main drawback [67].

(Zhang et al., 2016) The energy consumed by the server is reduced using the VM migration and scheduling methods. The integrated resources are balanced by consolidating VM [44].

(Sharma et al., 2016) have presented VM consolidation using GA approach with cat swarm optimization. The work has been performed to put ideal PMs on sleep mode and hence contributed to save energy and save energy upto 30000 wsec has been attained [115]

(Li et. al., 2016) took into account the typical deficient algorithms.Introduction of heuristic algorithms such as PSO, which enables efficient energy use in data centres, improves these. [116]

(Changyeon et al., 2017) proposed a machine learning-based adaptive model that predicted the key characteristics of live migration with high accuracy level.[68]

(Lin et al., 2017) compared multiple task assignment algorithms and CPU allocation algorithms by considering various parameters like time, power and SLA violations. Main Resource task balance assignment algorithm is proposed in their work that helped in increasing efficiency and throughput [117]

(Shabeera et al., 2017) devised the Ant Colony Optimization metaheuristic algorithm for picking a subset of PMs that meets the goal of decreasing data transmission time while simultaneously ensuring that the total capacity of VM allocation meets the required demand for VMs [118]

(Karthikeyan et al., 2018) proposed method to reduce the energy usage in VM migration. Artificial Bee Colony–Bat Algorithm (ABC–BA) was used to develop the Nave Bayes classifier with hybrid optimization.The proposed method was tested in CloudSim, and the results were compared using performance indicators like success and failure rates, as well as energy usage. [69]

(Kawsar et al., 2018) said that to reduce energy usage in large-scale data centres, he developed a centralized-distributed low-overhead dynamic VM consolidation technique.Using a distributed multi-agent Machine Learning (ML) based strategy, this system picks the most appropriate power mode and frequency for each host during runtime, and migrates the VMs appropriately using a centralised heuristic. [70]

(Hassan et al., 2018) proposed a machine learning technique based on adaptive prediction of utilisation threshold for VM live migrations using a changed kernel.The proposed technique's efficiency is demonstrated using various workload patterns from Planet Lab servers. [71]

(Sharma et al., 2019) have focused on failure of VMs along with the migration of VMs from overloaded to underloaded PMs. Two checkpoints are inserted to identify fault named as "VM migration", and "VM checkpoint". Using these checkpoints, the energy has been reduced upto 34 % [119]

(Li et al., 2019) have presented a host aware workload detection technique using a robust linear regression prediction model. The work is divided into four sections: (i) detection of overloaded host, (ii) detection of underloaded host, (iii) selection of few VMs from overloaded and underloaded host, (iv) plan has been made to place the selected VMs from the overloaded and underloaded hosts. Using this technique, the energy saving upto 25.43 % has been achieved with 99.16 % of SLA violation rate [120]

(Karda et al., 2019) proposed ant colony optimization (ACO) technique that was used to identify the optimal host for VM placement. The host with the fewest chances of overutilization and the fewest migrations is chosen as the ideal machine for task migration.The suggested algorithm's performance in cloudsim is evaluated in terms of energy efficiency, number of migrations, and SLA violation. [121]

(Masdari et al., 2020) introduced an extensive analysis for VM migration modified for cloud DCs. For this motive, firstly, it has given the main problems with respect to VM migration and categories on the basis of the prediction applied algorithm. Additionally, this described the applied workloads, evaluation factors, simulator, and hypervisor atmosphere, and the factor forecasted in the studied technique [72].

(Le et al., 2020) described the weak points and strong points of migration techniques of state-of-the-art life, as well as the effect of the characteristics of the workload on the appropriateness of various mechanisms for migration. The author had categorized the performance model into two parts for the migration of VM, namely, modeling of migration time cost and modeling of bandwidth allocation. Finally, the author recognized the five important problems for the migration of memory through the LAN [73].

(Naik et al., 2020) addressed VM consolidation using the Fruit fly Hybridised Cuckoo Search (FHCS) method to find the best solution using two objective functions.The suggested paper compared the Ant Colony System (ACS), Particle Swarm Optimisation (PSO), and Genetic Algorithm algorithms (GA) [114]

(Kruekaew et al., 2020) proposed Heuristic Task Scheduling with Artificial Bee Colony that is amalgamation of a Swarm based Intelligence method of an artificial bee colony with one heuristic based scheduling system (HABC) [122]

2.2 VM ALLOCATION

(Li et al., 2012) proposed two algorithms for online dynamic for resource allocation with task scheduling. The author puts forward the resource optimization mechanism in the heterogeneous IaaS combined cloud system, and achieves theschedulable task scheduling. This applies to the autonomic features of the cloud and the diversity characteristics of the VM. The presented algorithm dynamically adjusts the allocation of resources on the basis of updated information being performed by the definite task [74]

(Hameed et al., 2016) employs the process of virtualization in cloud computing data centers to distribute the workloads among smaller servers. The different workload results in different resource allocation process which reduces the carbon emission among datacentres [75].

(Khasnabish et al., 2017) proposed an efficient utilization of resources is essential to reinforce the green cloud computing environment. Khasnabish et al. proposed the tier centric resource allocation approach to overcome the limitation of resource allocation in the cloud environment [76]

(Zhu et al., 2017) presented resource model and power model. It is prepared for the physical machine. In addition, three dimension resource scheduling approach to save the energy is employed by considering three different phases. Each phase is determined by implementingthree different algorithms for each phase. The obtained simulation results ensure that virtual phases are managed efficiently [77]

(Kurdi et al., 2018) proposed model to avoid the carbon emission environment, LocustInspired Scheduling algorithm (LACE). The algorithm aids the users to allocate the VMby noticing behaviour of the locusts. LACE algorithm distributes the schedule among different servers. The developed technique is compared with other algorithms for standard results [78]

(Kaaouache et al., 2018) have designed a framework to minimize energy consumption in cloud data centre using best-fit decreasing algorithm in addition to GA approach. The work has minimized energy consumption for both PMs and networking [123]

(Wang et al., 2018) proposed trustworthy data collection approach using the cloud sensors. The developed approach acquires the confidence of the server. The various parameters such as QoS and throughput is analysed using the developed approach [124]

(Chaudhrani et al., 2019) proposes energy efficient techniques using Particle Swarm Optimization (PSO) developed to reduce the cost and load on the server. An efficient algorithm is proposed using the latest bio inspired technique. The problem of resourceallocation is sorted using the developed approach [79]

(Das et al., 2019) proposes energy aware resource allocation model for VM scheduling. It is generated to address the problem of energy consumption. The resource allocation problem is considered to reduce the energy consumption. More specifically, the data centres use the energy consumption put certain load on the server. The problem is mitigated by developing model for resource allocation [80]

(Jin et al., 2019) introduced the approach of VM allocation with speed switch and VMconsolidation in the data center of the cloud, and data center has considered the energy- efficient and the responsive in performance.Experimental consequences demonstrated that the energy-saving has an important effect with low dilapidation of retort performance when lightly used in the traffic, while the retort performance has idyllic with no serious dissipate of energy even the traffic isheavy [40]

(Jia et al., 2019) have presented the latest approach of VM allocation (SC-PSSF) with the objective of optimization of load balancing and consumption of energy to resolve the issue of security regarding VM co-residency. The energy-saving has been recognized by minimizing the numerals and processor unit of the host [81]

(Mishra et al., 2019) proposes effective and efficient algorithm for energy consumption, and increasing the throughput. An ALOLA algorithm is presented in thisresearch using a learning automata. The developed algorithm secured the resource allocation using the Cloud Sim simulator. In addition, the makespan of the developed system is evaluated for prominent results [82]

(Ruan et al., 2019) have introduced an approach for the calculation of optimized functioning utilization levels. On the real platform, the measurement has required for the performance and power data to build the practical design; authors proposed an approach named ‘‘PPRGear’’[83]

(Varun et al., 2019) proposed an enhanced version of MBFD algorithm that uses the concept of DVFS combined with location-aware algorithm. According to this algorithm, the VM located near to server executes first by measurement of distance. Performance is calculated by measuring the parameters like energy consumption and TCJ [84]

(Dubey et al., 2020) have proposed a comprehensive native circumstance based algorithm of Intelligent Water Drop (IWD) and introduced the algorithm of VM allocation that given the optimization of the execution of the task in the safe computing field.The consequences from simulation illustrate that the introduced policy of VM allocation executed greater compare to exiting approaches of VM allocation [85]

(Joshi et al., 2020) have introduced the Dynamic Degree Balance with CPU based policy of VM allocation. The introduced algorithm consists of both VM allocation and task allocation. Authors compared the algorithm with two static algorithms viz. Shortest Job First (SJF) and First Come First Serve (FCFS).The consequence of the experiment exposed that the introduced algorithm minimizes the imbalance’s degree and waiting time of a task [86]

(Liu et al., 2020) suggested strategy called Dynamic consolidation with minimal migration thrashing (DCMMT),that prioritised VMs with high capacity and considerably reduces migration thrashing [125]

(Tarahomi et al., 2020) addressed over utilization issue and discussed about live VM migrations in virtualization technology that are implemented using micro-genetic algorithm [126]

(Karthikeyan et al., 2020) have used Naïve Bayes technique in combination to integrated optimization approach ABC with Bat Algorithm (BA) to save energy in VM migration.The energy consumption upto 1200 KWh with a failure rate of 0.2 has been achieved.The classifier is trained based on the time and memory utilization of VMs and hence threshold value is set for resource uses. If the required resource is greater than the defined threshold then failure apar otherwise considered as non-failure machine [127]

(Songara et al., 2020) have presented one VM consolidation approach in CDC by considering the issues such as (i) to take decision while the system is overloaded when users demanded for multiple resources. VM selection has been performed by considering the policies of cloudsim. After appropriated selection of VMs, Particle Swarm Optimization (PSO) has been used for efficient VM placement with better energy saving [128]

(Tabrizchi et al., 2021) proposed a self-adaptive hybrid method named ICA-PSO to handle the multi-tasking scheduling issue by combining PSO and imperialist competitive algorithm (ICA) algorithms.[130]

(Li et al., 2021) proposed a modified PSO to improve population diversity using reverse learning and gene mutation methods.[131]

(Balakrishna et al., 2022) proposed the genetic algorithms that have been applied to address the cloud security related issues during virtualization.[132]

2.3 RESOURCE ALLOCATION AND VM PLACEMENTS

(Harold et al., 2009) have discussed an effective external controller issues for automatically expanding adaptability applications deploy in the cloud. Authors has recommended ratio threshold method, dependent on the accumulated number of examples of VM dynamically adjusted the objective range, i.e., low and high threshold. Thus, as the number of resources to be counted, the relative effect of the allocation of resources becomes more refined; resulting in higher flexibility and resource efficiency[87]

(Beloglazov et al., 2012) proposed the Framework of Energy - Effective Cloud Computing. The energy optimization method is categorized into two phases: 'VM placement, 'VM selection'', and the 'Modified Best-Fit Decreasing' algorithm is introduced for the VM Placement sub- stage, and the 'highest potential growth', 'random selection' Minimize the migration as the VM Selection sub-phase and compare it to the simulation result[88].

(Li et al., 2012) considers the energy consumption by suing the proposed algorithms has been reduced. Dynamic Cloud min-min scheduling perform better than Dynamic cloud list. DCMMS has the smallest execution time than DCM algorithm [89].

(Esfandiarpoor et al., 2013) have discussed four algorithms for the virtualized data center energy-aware resource management; so that the whole data centre energy consumption is lessen. The authors presented OBFD (Our Modified Best Fit Decreasing) algorithm for improving Virtual Machine placement [90]

(Patel et al., 2013) proposed a proficient resource management policy for virtualized centers while ensuring reliable QoS and reduce power consumption and delay by MBFD and Genetic algorithm [38]

(Xiao et al., 2013) proposed design and implementation of automation systems using virtualization technology. Here, the author has discussed the application process based on the needs of the dynamic allocation of data centre resources, and Green computing is supported by optimizing the number of servers used [91]

(Chiang et al., 2015) solves the problem of flexible hardware by monitoring services provided by the server. Apart from hardware, software, and network, there are various resources provided in the cloud environment such as servers, Virtual Machines, data centers, and IOT devices [92]

(Kaur et al., 2015) proposed technique that says that growth of resources puts impact on server by consuming the energy in an uneconomic way, which is very dangerous for the environment as there are large footprints of cloud data centres generated [93]

(AlIsmail et al., 2016) combined the workloads to revamp the utilization process by developing a cloud resource algorithm in the green environment. The most important problem faced by the researchers is to initiate a new VM request with low energy consumption [94]

(Han et al., 2016) proposed energy efficient VM placement. The placement is provided by Remaining Utilization Algorithm (RMU) and power aware algorithm compute the hosts not worked must be switched off. The developed technique guarantees Quality of service by meeting the customer's demand [95]

(Masdari et al., 2016) proposed different resource scheduling which is taken as a mostimportant problem in cloud environment. This is because it is very much critical for the placement of virtual machines in the cloud as physical machine detection which host the VM is difficult [96]

(Tang et al., 2017) monitored the QoS mechanisms for determining trustworthy factor. Both the factors such as feedback and QoS is combined for enhancing the trust value. Hence, trustworthy framework named as TRUSS is prepared for effective results [97]

(Han et al., 2018) presented a consolidation algorithm to prepare the energy model. The developed model provides a consolidated approach for the allocation of virtual machines. The developed model reduces the energy consumption by using constructive parameters such as Quality of Service. The consistent results are obtained using the energy model [98]

(Li et al., 2018) proposed a novel resource allocation mechanism called DPRA for decreasing the power consumption and to lower down the electricity bill of cloud data centers. The least squares regression mechanism was used for forecasting the utilization of VMs and PMs. Finally PSO algorithm is used for deploying VMs into PMs by the concept of dynamic resource allocation [129]

(Wang et al., 2019) proposes trustworthy data collection approach using the cloud sensors. The developed approach acquires the confidence of the server. The various parameters such as QoS and throughput is analysed using the developed approach [99]

(John et al., 2019) proposes the dynamic model for scalability and elasticity of resources. The model provides various benefits such as cost reduction, and remote accessibility. The major attacks like DDoS in the cloud network are diagnosed using the proposed approach. More specifically, the threats due to different attacks are solvedby Cloud security alliance model [100]

(Farahnakian et al., 2019) proposes virtual machine consolidation model that uses regression based model that helps in predicting the future CPU and memory utilization of virtual machines and physical machines. This novel approach removes the demeritsof heuristic and metaheuristic algorithms [64]

(Barthwal et al., 2019) presented a method for selecting an appropriate PM for hosting the migrated VM from an overloaded PM based on the projected value of CPU consumption.The goal of this study is to reduce electricity usage and improve service level agreements. [84]

(Xin Sui et al., 2019) proposed an intelligent VM scheduling strategy by using machine learning concepts for achieving load balancing [101]

(Kruekaew et al., 2020) proposed a hybrid ABC-Heuristic technique to improve scheduling solutions in virtual machines in homogeneous and heterogeneous cloud computing environments.[133]

(Tamura et al., 2021) introduced a modified ACO algorithm using individual memories (IM) named Ant System to solve the TSP problem that aims to optimize ant's diversity in the search space.[134]

(Zhang et al., 2021) introduced an improved ACO algorithm considering several parameters such as fuel consumption, sailing time, and navigation safety for seeking an optimal solution for ship-weather routing multi-objective optimization problem.[135]

(Jiawei L et al., 2022) proposed improved Genetic algorithm for optimal VM Placement Strategy.[136]

2.4 RESEARCH FINDINGS

- Cloud computing is becoming one of the advanced processing system architecture which is very much concerned about energy awareness.
- One of the most difficult tasks in cloud computing is to manage resources and processes in an energy-efficient manner..
- Virtualization is one of the integral part of cloud architecture which supports speed up utilization and resource sharing.
- Virtual machine allocation should reduce energy consumption on hosts.
- Virtual machine allocation has gained a lot of attention but it has issues related to energy consumption.
- False virtual machine allocation leads to migration which consumes resources and wastes time utility.
- Virtual Machine Migration should also be done effectively so that new host does not get overloaded and then again migration has to take place.

2.5 RESEARCH GAPS

- The MBFD (Modified Best Fit Decreasing) algorithm for virtual machine allocation and migration does not check the overloading of the Physical Machines that leads to higher energy consumption. So there is a scope to check overloading of the Physical Machines.
- MBFD algorithm has Border Line Problem that needs to be solved.
- Optimal VM placement and migration is still a NP hard problem.
- Still there is a need of optimizing the VM allocation and migration process so that time consumption is less and energy consumption is also reduced. There is a need of using Swarm Intelligence techniques with machine learning classifiers so that accurate VM placement and migration can take place.

2.6 DETAILED ANALYSIS OF LITERATURE SURVEY

Detailed Comparitive Analysis of existing VM Allocation and Migration Techniques is shown in Table 2.1.

Table 2.1 : Comparitive Analysis of Existing VM Allocation and Migration Techniques

Author and Year	Optimization Technique Used	Contributions	Parameters	Shortcomings and Future Scope
Fahimeh et al.(2015)	Ant Colony Optimization(ACO)	Reduced VM Migrations, Energy is saved	VM Migrations, Energy consumption	To work on other optimization techniques for finding better solutions
Shaw et al.(2015)	Load Prediction Algorithm	VM Migrations are reduced	VM Migrations	Implementationon other optimization techniques for reducing VM migrations
Kaur et al.(2015)	Resource Allocation Algorithm	Saved Energy	Energy Usage	To work on other optimization techniques for improving other performance parameters.
Chou et al.(2016)	Resource Allocation Algorithm	Saved Energy	Energy Usage	To work on other optimization techniques for improving other performance parameters.
Kansal et al.(2016)	Firefly Algorithm	Reduced VM Migrations, Energy is saved	VM Migrations,Energy consumption	To work on other optimization techniques for finding better solutions
Zhang et al.(2016)	VM Migration Algorithm	Reduced VM Migrations, Energy is saved	VM Migrations,Energy consumption	To work on other optimization techniques for finding better solutions
Li at al.(2016)	Genetic Algorithm with Cat	Saved Energy	Energy Usage	To work on other optimization techniques for

	Optimization			improving other performance parameters.
Hameed et al.(2016)	Resource Allocation Algorithm	Saved Energy	Energy Usage	To work on other optimization techniques for improving other performance parameters.
Allsmail et al.(2016)	Resource Allocation Algorithm	Saved Energy	Energy Usage	To work on other optimization techniques for improving other performance parameters.
Han et al.(2016)	Remaining Utilization and Power aware Algorithm	High Quality of Service and Energy is saved	Quality of Service and Energy Consumption	To work on other optimization techniques for improving other performance parameters.
Masdari et al.(2016)	Resource Scheduling Algorithm	Energy is saved and cost is reduced	Energy Consumption and Cost Usage	To work on other optimization techniques for improving other performance parameters.
Jiang et al.,(2017)	Ant Bee Colony(ABC)	Energy efficiency evaluation, Save energy using QoS	ESV, VM migrations, ASLAV, Energy	Finding a global energy efficiency and also find out energy level.
Moon et al., (2017)	Ant Colony Optimization(ACO)	Increase the performance of task scheduler	Preprocessing time make span	To work on heterogeneous clusters
Perumal et al., (2017)	Fuzzy ant colony cuckoo search and fuzzy firefly	Virtual machine (VMs) Placement problem	Power consumption , resource wastage	To work on other optimization techniques for finding better solutions
Changyeon et	Machine Learning Based	Reduced VM	VM Migrations	Finding a global energy efficiency

al.(2017)	VM Migration Algorithm	Migrations		and also find out energy level.
Lin et al.(2017)	Task Based Assignment Algorithm	Improved Efficiency and Throughput	Energy and Throughput	To work on heterogeneous clusters
Shabeera et al.(2017)	Ant Colony Optimization(ACO)	Minimized delay during data transfer	Delay	Implementationin a heterogeneous environment using performance based evaluation metrics
Khasnabish et al.(2017)	Centric Resource Allocation Approach	Efficient Resource Utilization	Resource Utilization	To work on other optimization techniques for improving other performance parameters.
Zhu et al.(2017)	Resource and power model	Optimized VM allocation	VM allocation	To work on other optimization techniques for improving other performance parameters.
Tang et al.(2017)	TRUSS Framework	Improved QoS parameters	QoS Parameters	To work on other optimization techniques for improving other performance parameters.
Barlaskar et al., (2018)	Enhanced cuckoo search algorithm (ECS)	VM placement based upon energy consumption	Energy consumption, SLA, VM migration	Implementationin a heterogeneous environment using performance based evaluation metrics
Ghobaei etal., (2018)	VM algorithm	Reducing energy consumption and service level agreement violation(SLAV)	Energy consumption, Total number of shutdowns, number of migrations and slav	Implementation using neural network and learning automata for achieving better efficiency in learning phase.
Karthikey	Artificial Bee	Reduced energy	Energy	To work on other

an et al.(2018)	Colony-Bat Algorithm	consumption and no of VM migrations	consumption and VM migrations	optimization techniques for improving other performance parameters.
Kawsar et al.(2018)	Multi agent Machine Learning Based Approach	Reduced energy consumption and no of VM migrations	Energy consumption and VM migrations	To work on other optimization techniques for improving other performance parameters.
Hassan et al.(2018)	Machine Learning Technique with modified Kernel Approach	Reduced VM migrations	VM Migrations	To work on other machine learning classifiers.
Kurdi et al.(2018)	Locust Inspired Scheduling Algorithm(LA CE)	Optimised VM placement	VM Placement	To work on other optimization techniques for improving other performance parameters.
Kaaouach e et al.(2018)	Framework for minimizing energy consumption	Reduced energy consumption	Energy consumption	To work on other optimization techniques for improving other performance parameters.
Han et al.(2018)	Consolidation Algorithm	Optimised VM allocation	VM Allocation	To work on other optimization techniques for improving other performance parameters.
Li et al.(2018)	Novel Resource Allocation mechanism(DP RA)	Reduced energy consumption	Energy Consumption	Finding a global energy efficiency and also find out energy level.
Zhang et al.,	State-of-the–art method (FF,	To increase the energy efficiency of a cloud data	CPU utilization, Energy, Profit	Combine dynamic voltage and frequency scaling

(2019)	MBFD)	center		methodto increase the energy efficiency for reserved cloud service request
Sharma et al.(2019)	VM Migration Framework	Reduced Energy and VM migrations	Energy Usage and No of VM Migrations	To work on other optimization techniques for improving other performance parameters.
Li et al.(2019)	Host Aware Workload Detection Technique	Reduced Energy and VM migrations	Energy Usage and No of VM Migrations	To work on other optimization techniques for improving other performance parameters.
Karda et al.(2019)	Ant Colony Optimization(ACO) Algorithm	Optimised VM Allocation	Energy,SLA Violations and No of Migrations	To work on other optimization techniques for improving other performance parameters.
Chaudhrani et al.(2019)	Particle Swarm Optimization(PSO) Algorithm	Efficient Resource Allocation	Resource Allocation	To work on heterogeneous workload environment
Das et al.(2019)	Energy aware resource allocation model	Optimized VM Scheduling	Energy Consumption	Finding a global energy efficiency and also find out energy level.
Jin et al.(2019)	VM Allocation approach	Optimised VM Allocation	Energy Consumption	Finding a global energy efficiency and also find out energy level.
Jena et al., (2020)	Modified particle swarm optimization (MPSO)	Enhance the performance of machine and balance the load of VMs, increase the throughput of VMs	makespan, throughput, standard deviation, energy utilization, load balance	Load balancingtask is performed on the basis of dependent tasks dynamically
Keller et al., (2020)	Real options analysis (ROA)	Contribution in field by provide	mean reversion speed, reference	Combine the optimization of

		guarantee cloudjob execution of variable time request in a single cloud spot	timestamp, flexibility window length	temporal and spatial flexibility
Kumar et al., (2020)	Cuckoo search firefly algorithm (CS-FA)	Perform assignment oftask and migration	Load, capacity	Implementationon other optimization techniques for migration
Sun et al.,(2020)	Convex optimization	Resource allocation for virtual machines placement in cloud data center	Resource allocation, aggregatedutility	Implementationon other optimization techniques for migration
Jangra et al., (2021)	Cuckoo search with Artificial neural network	Importance of energy savingand energy efficiency in cloud data centres	energy consumption, SLA violation, number of migrations, number of hosts, average response time	Implementationon other optimization techniques for migration
Talwani, S., &Singla (2021)	Enhanced artificial bee colony (EABC)	Reduce overall energy and migration count	Energy consumption, SLA violation, migrations	Improve performance and energy saving with thehelp of other techniques

2.7 Summary

This chapter summarizes the detail of latest contributions consistent with the proposed goals with a focus on VM allocation and VM migration in virtualization field.

Chapter – 3

PROBLEM FORMULATION

In order to meet the needs of users, cloud service givers require many physical devices or servers and in turn these servers need high electricity so that they can provide power. The concept of green computing has arised that focuses on the sustainable usage of computers so that there is decrease in consumption of power. Energy efficient algorithms have become a major point of attraction these days. On a global level also, awareness about energy related issues is accepted. In order to reduce the complexity related to computation and also to minimize the overhead or workload, virtualization concept came into picture. This concept tis primarily based on two main processes-Allocation of virtual machine(VMA) and migration of virtual machine(VMM).It provides access to multiple users to share a single entity of physical machine.

In virtualization, server or machine on which VM is made or set is called as host machine. Also that created VM is the guest machine. Entire concept of virtualization technology is split into four types-hardware, server, operating system and storage.As per the studies,VM role's come into action when any PM is overly loaded. In the cloud scenario, any cloud service giver has to create multiple quantity of VMs on one physical machine. Therefore, utilization of resources must be improved and service level agreement violations must be reduced in number. If SLA has high range of value, that means whatever the services are being given, majority are fulfilling the needs of users.[43]

The complete process of VM allocation comprises these issues-examining the load of selected host and also deciding the criteria for choosing any host so that migration of VMs from that host can take place. Also replacement of those migrated VMs onto new host is challenging because SLA violations need to be minimized as possible.

The process of allocation or placement of VM means allotting cloud resources like memory(RAM),CPU, disk storage, network etc to a virtual created machine and every PM has been assigned one or many VMs. All the assigned tasks require some VMs so that their tasks can be finished within deadlines. Many authors have already proposed much efficient algorithms that keep the SLA violations in a minimum range and also keep quality of service parameters in a satisfactory range. Also it is very crucial to keep the load of any machine balanced, therefore migration of some or all VMs from over utilized PM to underutilized PM is done.[40]

Machine Learning has been playing important role in this process of allocation and migration. It is also important that algorithms must lower no of migrations(false ones) and SLA violations. All the existing algorithms are quite complex and also time taking in terms of finding and allotting VMs to PMs. They also lack in finding correct VMs for migration. Thus in order to keep minimum SLA violations, false migrations and energy usage, Modified Best Fit Decreasing(MBFD) algorithm is used along with swarm intelligence(Enhanced-Artificial Bee Colony) algorithm and machine learning classifier(Support Vector Machine) as a complete optimized algorithm[36].

Introduction of Virtual Machines solve the issues for PM but it has its own issues as well. As per tradition, concepts a Virtual Machine is created and turned on when a PM is overloaded. Taking it as a serious issue, Dr. Buya(Co-owner Cloudsim) developed Modified Best Fit Decreasing Algorithm (MBFD) for best allocation policy and Minimization of Migration(MM) as the transfer policy of VMs. The allocation policy has a certain shortcoming like false allocations and unwanted energy consumption, which also affects the global warming issue. The aim of this proposal is to propose an optimization technique that increases the resource utilization and lower energy consumption that will help to develop the green computing environment[88].

The identification area in this proposal is to optimize the allocation policy and to cross- validate the migration system in order to optimize QoS. The parameters that would be evaluated for the performance are provided below:

i) Energy consumption

ii) Total number of migrations

iii) SLA violations

3.1 ALLOCATION PROCESS

$Definition$ 1: An allocation mechanism is a reactive architecture in cloud. An allocation A (H, A_t) where H is total number of Host and A_t.is the total allocated tasks .

$Problem\ Definition$: For A (H, A_t) , the selection of host in the A is possible only if H_{next} has enough resources for processing the incoming task and having a "μ" load utilization that must be less than that of current network utilization of load. If that parameter for utilization of load is not satisfied then searching a new node is dependent according to the following $lemma$

$Lemma$ 1: It has two elements mainly true and false and True is denoted by 1 and false by 0.

Representation of elements

1	If $f(Search_{Cost}) < f(Wait_{Cost})$
0	Otherwise

Where f is the fitness function for doing search and wait and their cost evaluation. The allocation process is largely determined by the requesting VM's resource usage. The allocation procedure follows the following set of rules:

a) Sort the VMs according to CPU utilisation requirements;

b) Check the Physical Machine (PM) for enough resource availability.

c) Assign VM to PM if Physical Machine meets resource requirements.

d) Resources of PM are reduced as per the demand fulfilled.

Border Line Problem is the one issue that is being faced by MBFD algorithm and it ultimately leads to the migration of VMs and hence energy gets consumed. So we need to reduce number of migrations and avoid false migrations.

3.2 PHYSICAL MACHINE AND VIRTUAL MACHINE

The Cloud framework uses Physical Machine (PM) to complete the incoming work. PMis the physical medium which contains random access memory, process utilities and central processing units. To support parallel processing and faster execution, Virtual Machines (VMs) are assigned to PMs based on the capabilities of the PMs. The allocationprocess is itself a load management architecture. Several computing algorithms including Modified version of Best Fit Decreasing (MBFD) algorithm is proposed for efficient allocation process. When a PM is found to be unsuitable for the assigned VM, it is migrated from one PM to another PM and it is called migration. The migration process consumes a lot of energy and hence it is aimed to reduce the migrations in order to prevent energy. Miss-allocation may also lead to migration. A well known migration prevention algorithm is termed as Minimization of Migration (MM). When a service provider fails to provide the committedservice in the set interval of time, it is said that the Service Level Agreement (SLA) is violated and it is called as SLA-V. Over exhausting load may lead to increase in SLA-V which will further result into high energy consumption. The frameworks which are produced to reduce the energy consumption are termed as green computing.

3.3 THE BORDER LINE PROBLEM

Any allocation procedure adheres to the policy of context awareness. This policy says that content awareness should ensure that the inquiring unit's demand is met, at the very least, to the base standards. For example, if a VM requires 500 MB of RAM and the host only has 520 MB, now the VM can be alloted to that host, but the host will encounter a borderline problem because it will be having remaining 20 MB of RAM. To function, the real-time simulation does not rely solely on content awareness. Run-time entities have a reputation for consuming more resources than the demand indicated at the time of allocation[88].In the research work, this problem has also been resolved by optimizing MBFD algorithm accordingly.

If the resource is currently busy with another activity, the VM will either be transferred from its current host or will have to wait for the resource to become available. This may cause unnecessary network delays and costs, which are incompatible with any processing environment.

3.4 MACHINE LEARNING BASED APPROACH FOR VM MIGRATION

The proposed algorithm naming energy aware ABC based on Machine Learning is the combination of machine learning classifier and swarm based technique. This is used for ranking the VM according to load and also considering the energy reduction as its main parameter. The VM that is most efficient is chosen further and based on the current values of load and power, decision of migration has to take place. Machine learning classifier algorithm is used to evaluate the parameters for performance of migrated VM from hotspot machine (old one) to the target PM (new one) for many simulations. Support Vector Machine (SVM) is used so that the pattern of over load and underload can be understood. The sample that has been trained is used to support the algorithm for performing better and taking right decision for migration of VM. Here SVM will analyze the data and then classify the decision of migration in two categories-Above Post Performance(APP) and Below Post Performance(BPP).If the decision is Above Post Performance, then VM is migrated from the over loaded host and reallocated to new host otherwise VM is stayed on the same host and migration does not happen. The MATLAB simulation performed shows that the proposed work illustrates a highest energy reduction of 40% by selecting appropriate hosts and minimizing the number of migrations as compared to other existing approaches for VM migrations.

3.5 FLOWCHART OF PROPOSED METHODOLOGY

Flowchart of proposed methodology is shown in Figure 3.1.

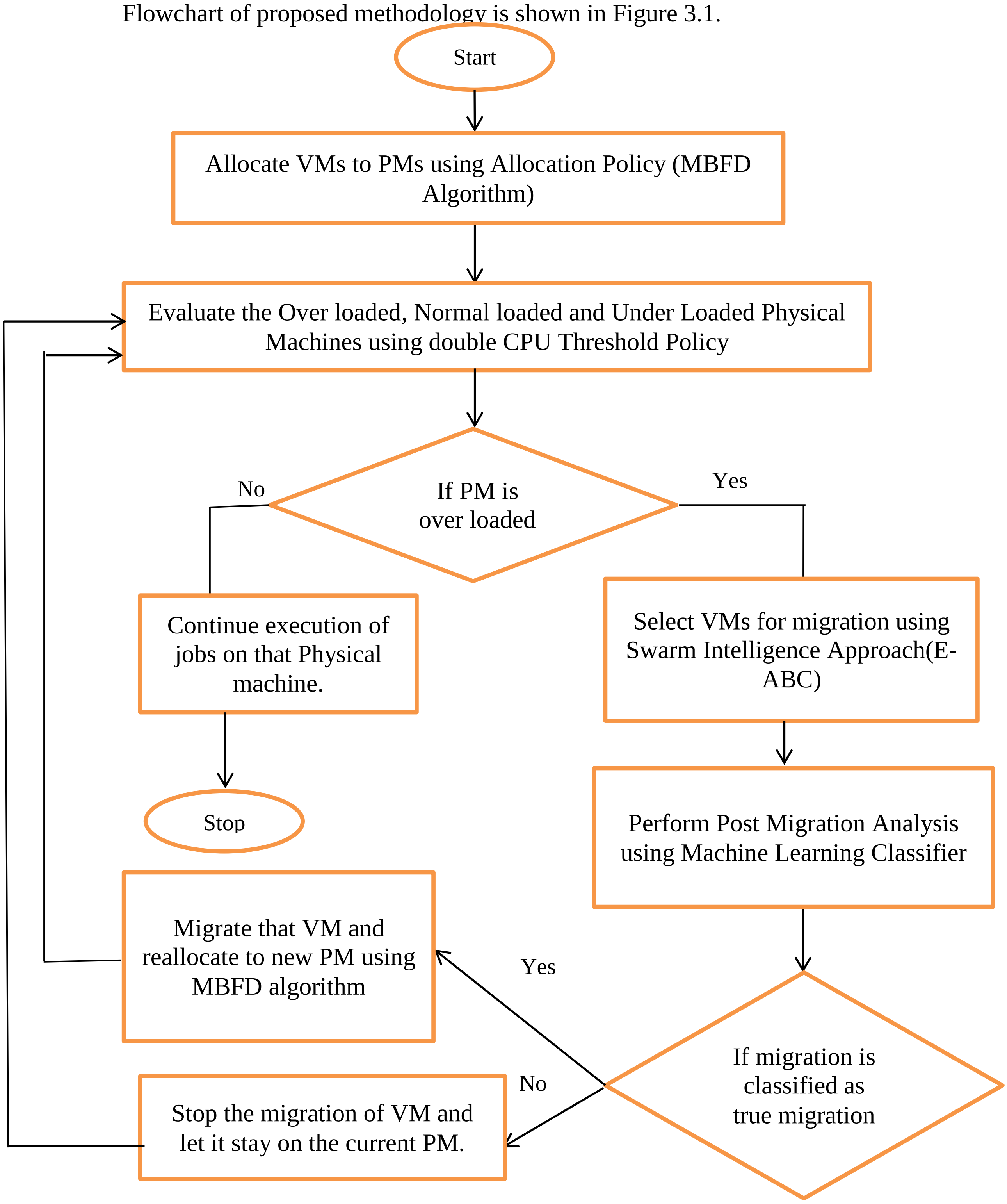

Figure 3.1 : Flowchart of Proposed Methodology

3.6 Proposed Research Methodology

Machine Learning(ML) based Artificial Bee Colony (ABC) is used to rank the VM in order to the load while considering the energy efficiency as a crucial parameter. The most efficient VM are further selected and the depending on the dynamics of the load and energy, applications are migrated from one VM to another. Machine Learning Classifier algorithm evaluates the over migration performance of the VM from the hotspot PM to the target PM during the simulation. **Support Vector Machine(SVM)** is chosen to understand the pattern of overload and underload. The trained sample is used to support EA-ABC to perform better. SVM will analyse the data and then classify the VM migration decision in two categories- Above Post Performance and Below Post Performance. If the decision is Above Post Performance, then VM is migrated from the over loaded host and reallocated to new host otherwise VM is stayed on the same host and migration does not happen. Step by Step research Methodology is shown diagrammatically in Figure 3.2.

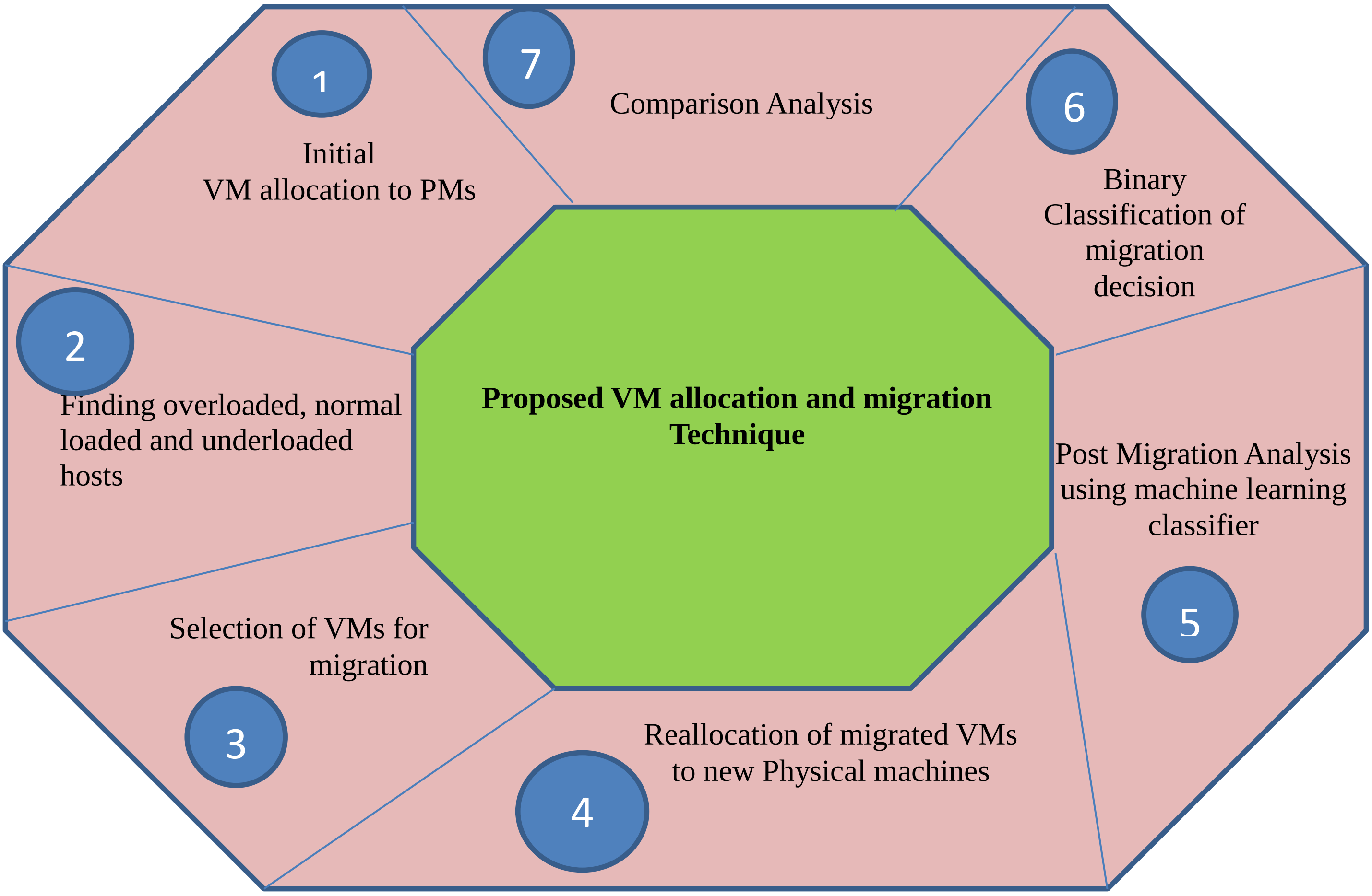

Figure 3: Steps of Research Methodology

3.7 Summary

The research methodology includes the gathering of research articles related to the area of research followed by the research articles which has to be processed further. The proposed framework is keenly interested in the utilization of the machine learning and brain mapping algorithm for both the scenarios namely allocation and migration of the workload driven based Virtual Machines.

Chapter – 4

ARCHITECTURE OF ENERGY EFFICIENTVIRTUAL MACHINE ALLOCATION AND MIGRATION IN CLOUD COMPUTING ENVIRONMENT

The energy aware VM allocation and migrating architecture can be summarized in foursubsequent steps as follows:

- Placement of the VM over a PM based on the preliminary conditions
- To support elastic computing, VMs will be migrated from overloaded PMs and hence the overloaded PMs are to be identified. The overloaded PMs are also called hotspot in the field of Cloud Computing.
- After the identification of the hotspot PM, the VMs will be selected to be migrated
- The selected VMs will be placed to the PMs that are other than the hotspot PMs of that instance.

The allocation and migration process is a compulsory repetitive procedure to prevent the systems from overload and also to minimize the power consumption as overheating consumes a lot of power. The statement becomes a paradox when the migrated VMs either don't fall on the suitable target PM or if less desired VMs are selected for the migration. False selection of the VM or less adequate placement of the VM over a PMwill also demand power and this consumption can be counted as a wastage in the powerconsumption. The logic to place a VM over a PM is simple and straight. If the PM fulfils the demand of the VM, it will be placed over the PM. Now as the power awareness has been a primary issue in the field of cloud computing since 2010 and, theproposed work also aims to lower the overall power consumed, the PM capableto handle the VM, must consume least power in competition to other PMs in the list. The process is summarised as Modified Best Fit Decreasing (MBFD) algorithm.

The primary goal that virtualization is done so that workload is handled in an effective, scalable, highly efficient as well as in a cheaper way by modifying traditional computers. In a wide range of virtualization of OS, hardware level and virtualization of server, virtualization can be enforced. The virtualization process is a reduction in maintenance costs and technology of energy-efficient, which is speedily varying the most important form of compute.Virtualization is carried out for the following reasons:

i) **Separation among users:** An individual consumer must be separated from another user so that cannot gain understanding of the other consumer's data and use and may not access the data of others.

ii) **Sharing of resources:** Virtualization also helpful in resources sharing through dividing large resources into small virtual resources.

iii) **Active resources:** The allocations of resource like saving and computational resources are challenging but if we are using virtualization then they may be simply re-allocated.

iv) **Gathering of resources:** The smaller size of resources may be enhanced up toa great extent through the assistance of virtualization.

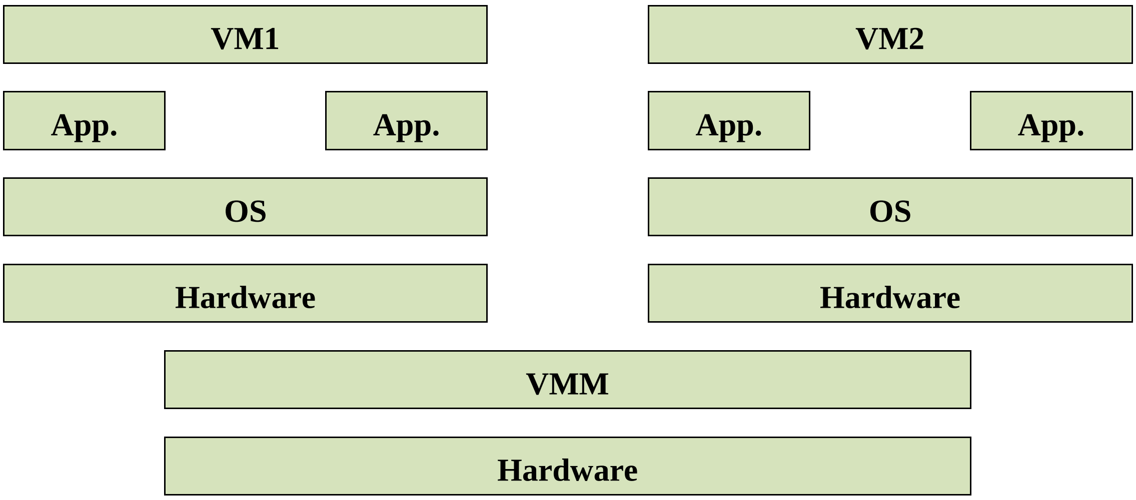

Figure 4.1 : Virtual Machine Migration Architecture of Two Operating Systems

VMs, along with one or more requests that work in a separate distribution within the computer, apply to one instance of an operating system.For VM organisations such as the MM (Minimization of Migration), which investigates the use of the host CPU according to the VM list in the descending order of use of the CPU, researchers in this field have proposed an algorithm. Algorithm execution is more reliable than other control algorithms, but the disadvantage is that when selecting a virtual machine for migration, they did not examine SLA parameters, which could be affected by live migration [103].

The above Figure 4.1 represents architecture for VM migration consisting of two operating systems. The application and the hardware used are made up of each VM. During direct migration of virtual machines, most violations occur, migration affects the different factor like accessibility, response time, throughput, bandwidth of network, and all of these parameters come under the SLA. Therefore, a new SLA-conscious energy-efficient algorithm method needs to be expanded to reduce consumption in energy for resource allotments in centres of data. In VMM, it is feasible to transfer a virtual machine among two devices without disturbing any VM operation. This migration is utilized to gain some benefits such as;

i) Energy consumption minimization

ii) Load balancing: different types of technique for load balancing with different feature and criteria for controlling the incoming request of traffic. Some load balancing techniques are:

   a) Round-robin
   b) Weighted round robin
   c) Least connection
   d) Weighted least connection
   e) Agent-Based Adaptive Load Balancing
   f) Chained Failover
   g) Least connection slow start time
   h) Fixed-weighted

i) Source IP hash

j) Software Defined Networking (SDN) Adaptive

k) Fault tolerance

l) Resource sharing

m) Mobile computing

n) System maintenance

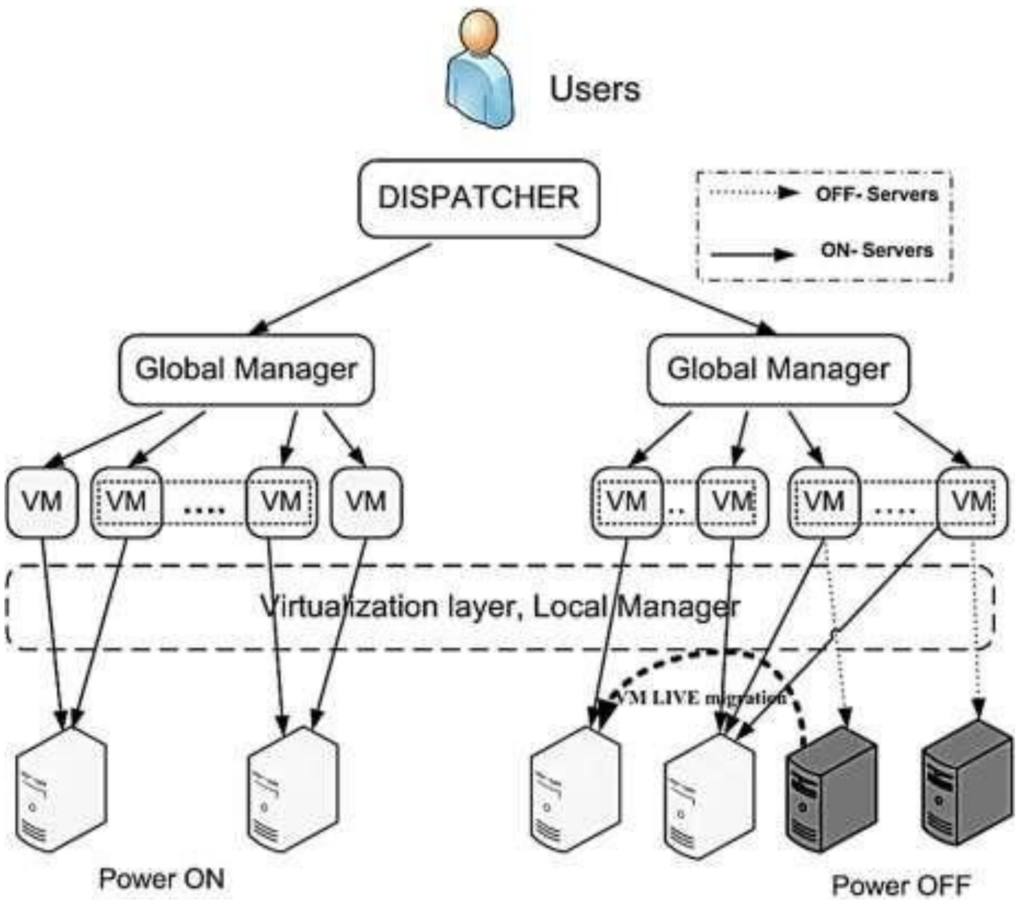

Figure 4.2 : VM Migration Process on Distributed Cloud Data Centre [104]

As given in figure 4.2 in which some VMs migrate to obtain more benefit of the resources for the efficient use of the resources from one machine to another. The local administrator checks the health of components of the system.The methods by which the VMM method works are below.

4.1 LIVE VM MIGRATION

In this, the migration takes place on the host or virtual machines in a working state without any interruption. The primary goals of this type of migration are [105]:

a) Enhancement in bandwidth utilization.
b) Optimization of application performance
c) Minimizing downtime.

The types of Live VMM scenarios are given below;

i) Pre-copy VM Migration

In this type of migration the contents of the destination's memory resources are copied to the host. The execution state is also switched between the host and the destination. The time for this migration is greater than that of other methods. The memory exchange takes a long time to switch between host and destination.

ii) Post copy VM Migration

If the migration fails in this system, the host sends the details to the destination in the execution state. To receive the more benefit of the migration time, the post-copy method migrates the minimum system state.

iii) Hybrid Method

To build full use of the resources and thus enhance performance, this scheme combines both the pre- and post-VMM. The memory pages are moved first as in the front copy and then swapped later as in the post copy.

4.2 NON-LIVE MIGRATION

In this procedure, when the machine is not alive, the migration occurs because the information is not completely reversed and works until the complete data is migrated. Before the migration is completed, the destination does not recover the complete data. If services are interrupted or the data is not fully recovered, there will be a problem in QoS due to disconnection during the migration process [104].

4.3 MODIFIED BEST FIT DECREASING (MBFD) ALGORITHM

The algorithm of MBFD is the amplified form of Best Fit Decreasing (BFD) as shown in figure 4.3. The working processes of both the algorithms are approximately same. However, the major distinction in the selection criteria of these algorithm based on selection of sever for the hosting of task. BFD choose the system which has reduce capacity of CPU.

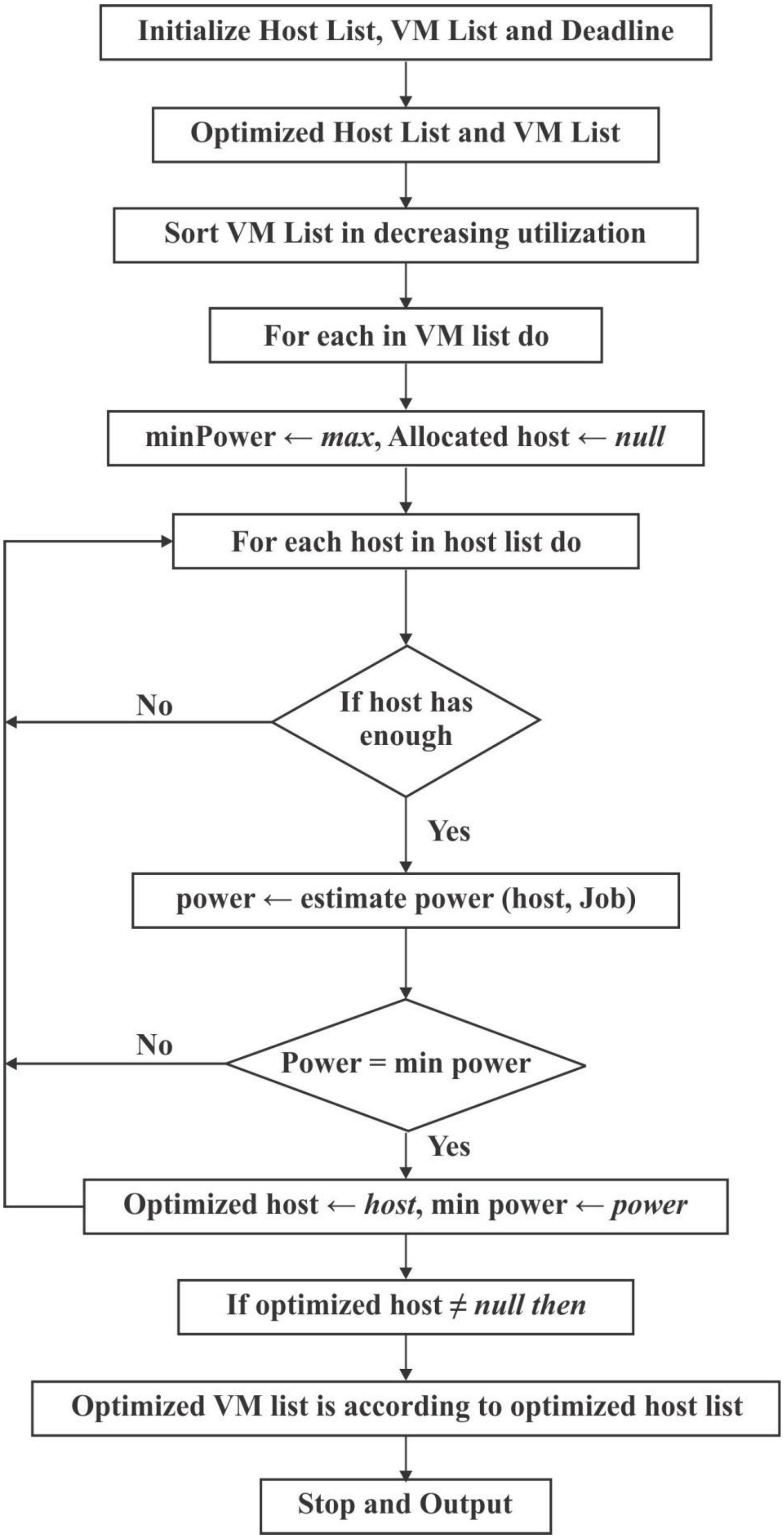

Figure 4.3 : Flow chart of MBFD

The flow chart can also be expressed using the following pseudo code.

Algorithm 1: Modified Best Fit Decreasing (MBFD)

Input: host_list, Vm_list,and Deadline

Output: Optimized host_list and Vm_list

1. Vm_list.sort decreasing utilization ( )
2. For each in VM list do
   a. minPower← max
   b. Allocated host← $null$
   c. For each host in host list do
      i. If host has enough resource for VM then

         1. $\boldsymbol{power} \leftarrow \boldsymbol{estimatepower}\ (\boldsymbol{host}, \boldsymbol{Job})$
      ii. If power<minpower then
3. Design_Fitness(Vm_Deadline,Host.Load);
4. If is satisfied Fitness
   a. Optimized host← $host$
   b. Mini power← $power$
5. End (If)

6. If Optimized host≠ $null\boldsymbol{then}$

   a. Optimized Vm_list is according to optimized host_list

7. End (If)
8. End (for)
9. Return; Optimized host_list and Vm_list
10. End (Function)

The algorithm architecture is straight and simple. Every host is checked for the fulfilment of the VM demands starting from the highest demand and going to the lowest demand. If the PM is capable of handling the VM, the total amount of power that can be consumed is calculated. The allocation process is followed by the migration process in which dual threshold policy [106]. The MM policy ensures that no PM remains under loaded and no PM remains overloaded. The overloading parameters in most of the research articles have been noted to be CPU utilization. The proposed work has implemented both MBFD, MM to understand the complexity of allocation. In addition to that, other allocation and migration policies. The study has been analysed over MATLAB development program which supports mathematical computing.

In the present work, MATLAB is used as a simulator tool to implement and evaluate the designed work. MATLAB is an easy-to-use application and is now regarded as the standard tool for most universities and industries globally. This stores the single framework in a package called the Toolbox. It has a range of features in simulation, operating environment, and computation. MATLAB is the latest programming language, it also has a sophisticated data structure including built-in debugging, editing, and object-oriented programming assistance tools. In the proposed work, the MATLAB simulator toolbox is used for implementation. There are so many inbuilt functions are in MATLAB.

4.4 SIMULATION RESULTS

The following figures represents simulation behaviour and architecture implemented over MATLAB when initially 10 hosts are given 18 VMs. Initially Host to VM ratio comes out to be 0.555.Gradually with time, as no of hosts increases, so as no of VMs allotted to them also increases. As the start of any simulation setup that relates to VM allocation and migration starts with the initialization of the VMs. When no of VMs are allocated to any host, some CPU utilization takes place. As no of VMs on host keep on increasing, so CPU utilization also increases. The CPU utilization in unsorted and sorted form is shown in figure 4.4 and figure 4.5 respectively. Figure 4.8 shows VM allocation based on MBFD. Figure 4.9 shows changed initial values for PM and VM after some iterations.

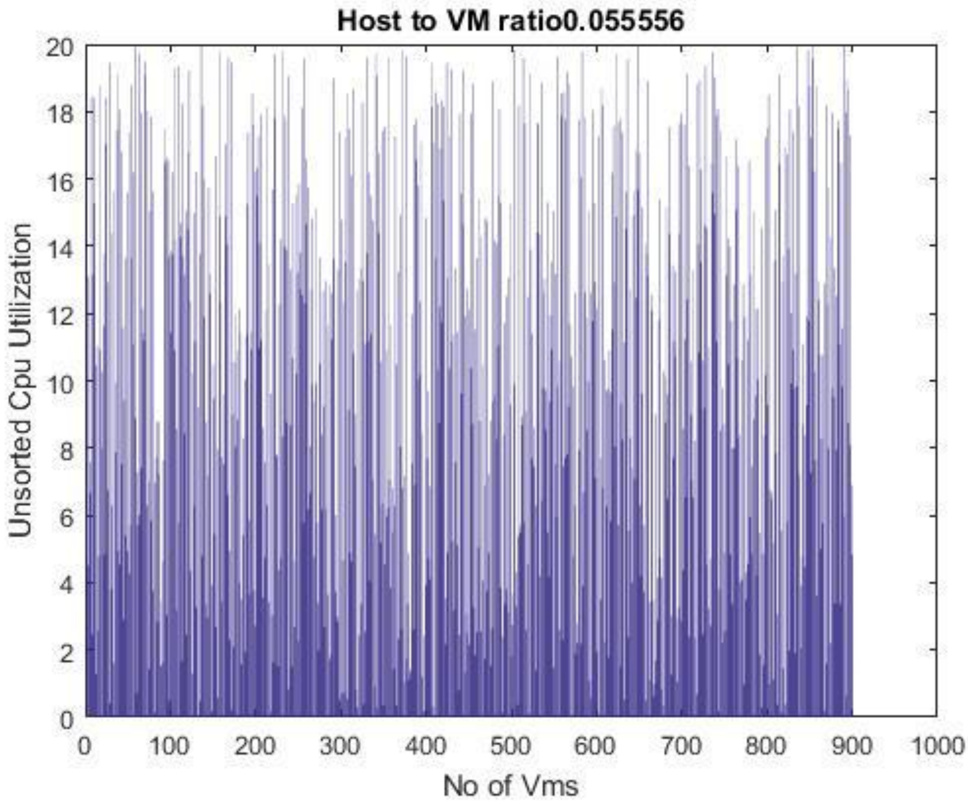

Figure 4.4 : VM initialization, unsorted CPU Utilization

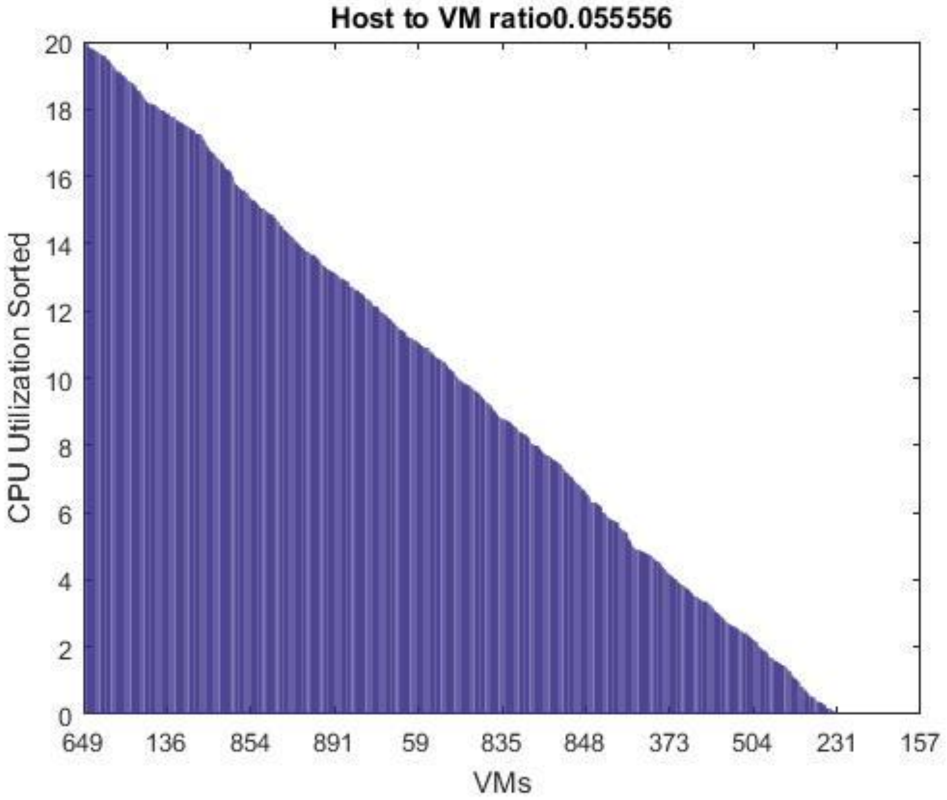

Figure 4.5 :VMs and Sorted CPU Utilization

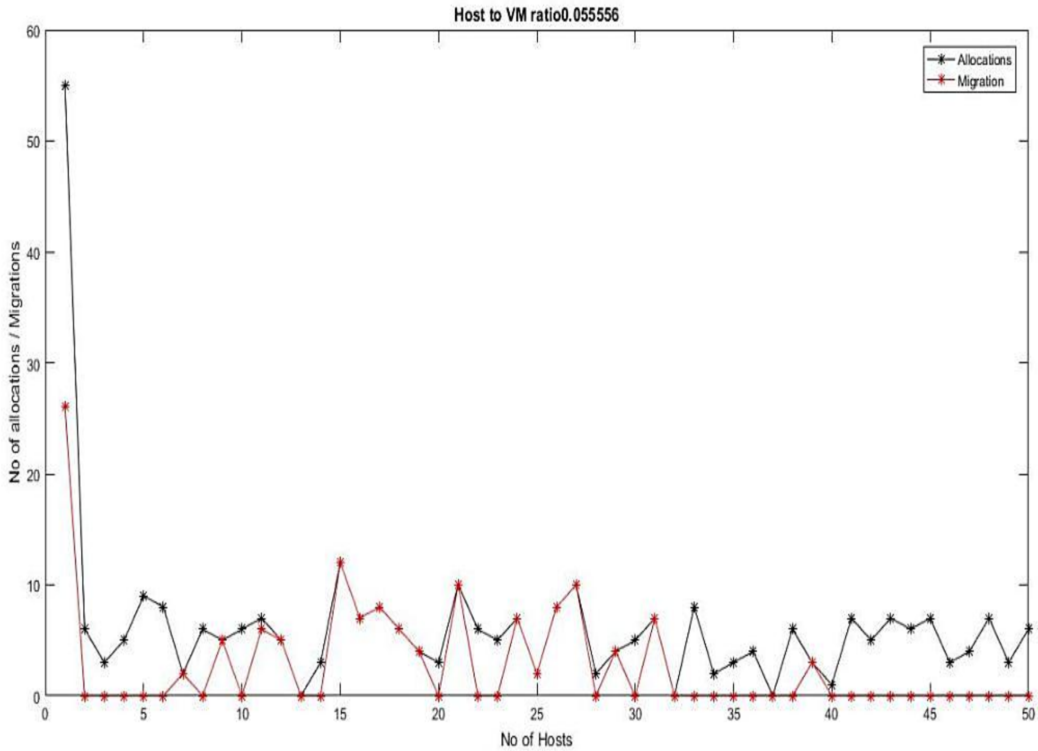

Figure 4.6 : Allocations and Migrations on hosts

Figure 4.6 shows no of allocations and migrations on hosts. This figure is representing no of allocations happening on a particular host and count of migrated VMs from that host.

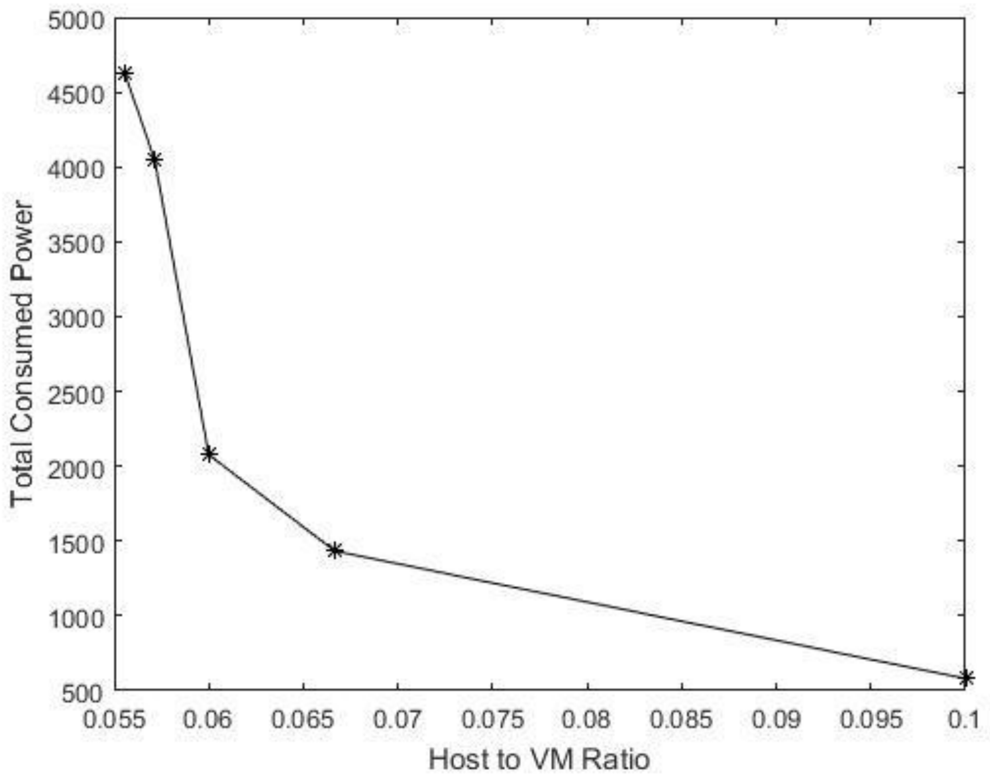

Figure 4.7 :Total Consumed power as per Host/VM ratio

Figure 4.7 shows Total Consumed power as per different Host/VM ratios.

When the MBFD is applied, the VMs are allocated to respective PM as shown in Figure4.8.

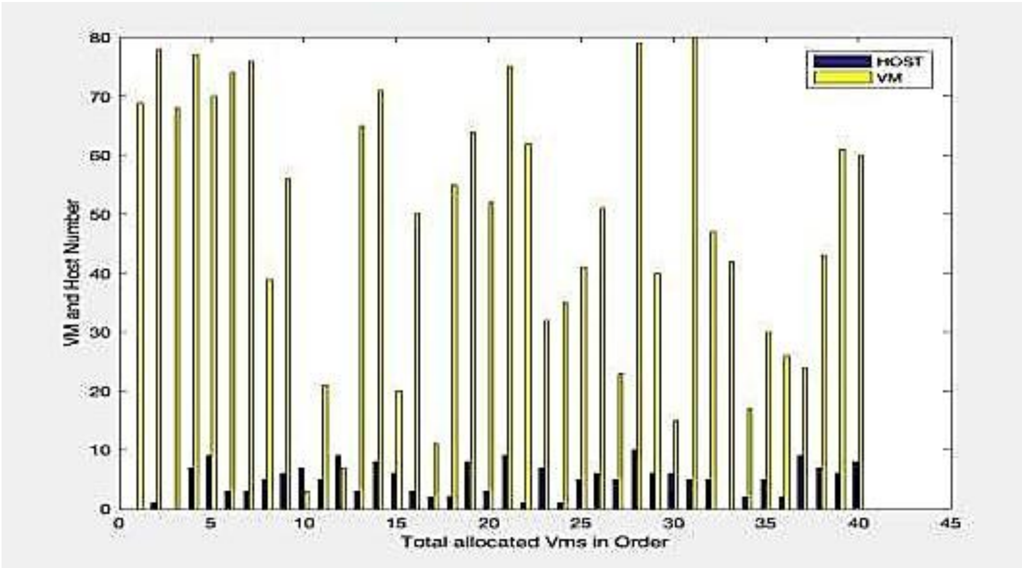

Figure 4.8 :VM allocation based on MBFD

In order to keep the proposed work dynamic in nature, the simulation environment has been kept random and after every fifty simulations setup architecture, the initialization takes place again and the VMs are allocated with new properties.

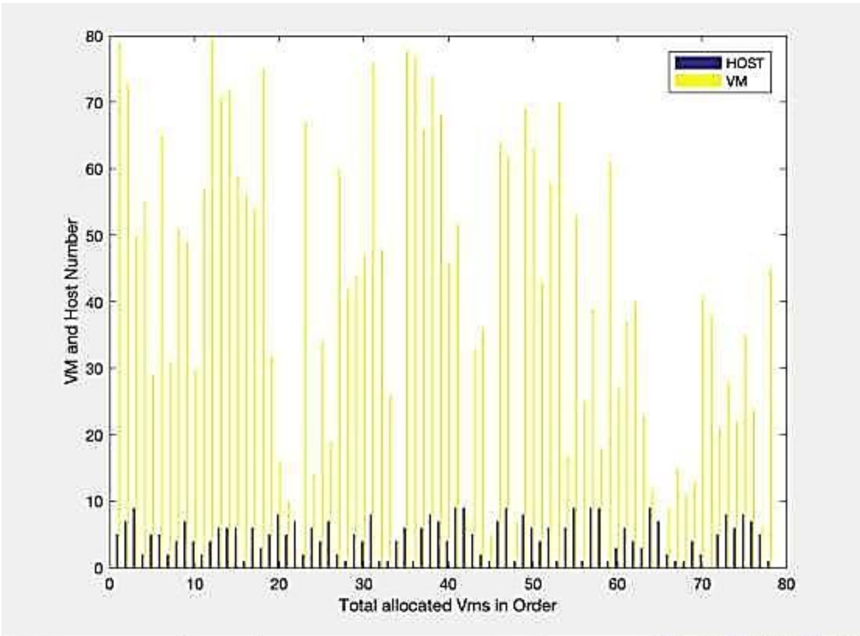

Figure 4.9 : Changed initial values for PM and VM

4.5 DOUBLE THRESHOLD CPU UTILIZATION POLICY

In order to categorize which PMs are over utilized, normal utilized and under utilized, we apply a double threshold CPU utilization policy. The basic concept is that we set the upper and lower threshold values for CPU utilization for PMs so that total CPU utilization consumed by all the VMs allotted to a particular PM remains between these lower and upper bound values. If CPU utilization value falls below the lower threshold value, then that PM is considered to be under utilized. If the CPU utilization falls above the upper threshold value, then that PM is considered to be over utilized. Else the PM is normal utilized. The lower and upper threshold values are kept to be 30 % and 70% of the total CPU utilization consumed by an idle PM running at full CPU speed.[88]

4.6 MINIMIZATION OF MIGRATION(MM) ALGORITHM

Algorithm 2 shows the pseudo-code for MM algorithm in the case of over-utilization. The technique arranges the list of VMs by CPU use in descending order. The system then loops through the list of VMs until it finds the best one to migrate from the host. A virtual computer that meets two requirements is the best. To begin, the VM's utilisation should exceed the difference between the host's current overall utilisation and the upper utilisation threshold. Second, among all the VMs' values, the gap between the higher threshold and the new utilisation is the smallest when a VM is transferred from a host. If no such VM exists, the algorithm selects the one with the highest utilisation, removes it from the list of VMs, and begins the process again. When the new utilisation of the host falls below the upper utilisation threshold, the process comes to a halt. The algorithm's complexity is proportional to the number of overutilized hosts multiplied by the number of VMs assigned to these hosts. Following is the Algorithm 2 showing the working of MM Algorithm.

Algorithm 2: Minimization Of Migration (MM)

```
Input List: Host_List Output List: Migration_List
for every host in Host_List do
VM_List←Host.get_VM_List()
VM_List.sort_Decreasing_Utilization()
Host_Util←Host.get_Util()
best_Fit_Util←MAX
while Host_Util > Thresh_Up do
for every VM in VM_List do
if VM.get_Util() > Host_Util − Thresh_Up then
t←VM.get_Util() – Host_Util + Thresh_Up
if t < best_Fit_Util then
best_Fit_Util←t
best_Fit_VM←VM
else
if best_Fit_Util = MAX then
best_Fit_VM←VM
break
Host_Util←Host_Util – best_Fit_VM.get_Util()
Migration_List.add(best_Fit_VM)
VM_List.remove(best_Fit_VM)
if Host_Util < Thresh_Low then
Migration_List.add(Host.get_VM_List())
VM_List.remove(Host.get_VM_List())
return Migration_List
```

4.7 Summary

This chapter summarizes the algorithmic explanation of the base algorithms that are being used in the proposed research work and also this chapter describes about the simulation results that have been achieved while doing simulations.

Chapter – 5

SWARM INTELLIGENCE ALGORITHMS FOR REDUCING ENERGY CONSUMPTION IN VM MIGRATION

As illustrated earlier, there are four major segmental steps in appropriate VM allocation technique. The first two steps that is placement of the VM to a suitable PM, and identification of the hotspot have got so much focus and update from around the world of the research industry [107].

The other two steps that is selection of the VM and replacement of the VM to a PM are still a piece of work in progress. The proposed work, initially utilizes MM, for the selection of the VMs to be migrated to PMs and then aims to apply re-allocation policy with the utilization of meta-heuristic oriented Swarm Intelligence algorithm architecture. The ordinal measures of Swarm Intelligence has already been illustrated in the introduction chapter. The proposed work has used ABC and Cuckoo Search for the implementation of the selection of target PM. However, this research work does not ignore the importance of the selection of suitable VMs from hotspot PM and hence employs an optimized VM selection policy in the proceeding chapters.

5.1 ARTIFICIAL BEE COLONY

The algorithm was implemented by Karaboga and is based on how honeybees collect nectar from flowers [108]. The objective is to identify such flowers having maximum nectar amounts or with an optimal solution. To accomplish this, bee swarm is divided into three parts: employed ,onlooker and scout bees. Here each group tries to find the best food source, it followed by another bee to achieve the best location. It also deals with the memory for storing private and best possible location.

A bee goes to a new location and compares with the previous visited best location. If the new location is found to be better than the old one has to forget and the new location has to be memorized. If this is not the case, then, the memory state remains unchanged.

The location of a food source represents a possible solution to the problem in the ABC algorithm, whereas the nectar quantity of a food source represents the quality of the linked solution.Because each worker bee is linked to a single food source, the number of employed bees equals the number of food sources.

i) Initialization

ii) Repeat

a) Place employed bees on the food sources.

b) Place onlooker bees on the food sources

c) Send scout bees to continue with the global search.

iii) Until the condition satisfy

At the initialization phase, scout bees initialize the population of the food source. Then at the employed bees phase, fresh food sources possessing more nectar are searched by the employed bees within the vicinity of the food source according to their choice. After that, the fitness of the new food source is calculated, and a greedy selection is implemented among new food sources and its parent. Then by dancing on the dancing area, employed bees distribute the information of their food source to onlooker bees.

At the onlooker bees phase, which based on the information provided by the employed bees previously, the onlooker bees pick their food sources for which a fitness-based selection method, i.e., roulette wheel selection method can be applied. Firstly we have to choose the food source then calculate the fitness value of its neighbourhood source. Finally, a greedy selection method is implemented within these two sources.At the scout bee's phase, employed bees become scout bees as solutions of employed bees cannot be modified over a set amount of probations, so they are abandoned. Scout bees randomly begin to search for fresh alternatives afterward. Later sources are left originally poor or totally drained, and adverse reaction behaviour ascends to equip the beneficial reaction.ABC is used in Rough Set Theory (RST) hybrid for optimization. First, RST analyzes the characteristics of each individual dataset class. The salient characteristics are mentioned to identify the individual classes. Then, ABC is introduced to the collection of features that discarded the key reduce. The combination of key reduction and the characteristics chosen by ABC is the ideal feature subset that results.

The proposed work has incorporated two types of architecture and structure for the employment of ABC algorithm. The first architecture system aims to reduce total number of false migrations that can occur during a migration process. And hence the first algorithm architecture is for the selection of the VMs that are being falsely migrated to some PM based on the over utilization and underutilization policy. To validate the method, the proposed ABC is being classified using Support Vector Machine. This section of the work is illustrated in two different sections. The first section mimics the behaviour of the MBFD algorithm and places the VM over the PM based on the CPU utilization. In order to compute so, the proposed algorithm computes Host Load (HL) and Average Host Load by equalizing the following mathematical expressions.The second section shows how proposed ABC is being classified by SVM into two classes and categorize the migration into true and false.

HL= Total Executed Jobs/ Total Supplied Jobs

Input: VM List(VML) , Host List (HL)

SECTION I.

Step 1. SVML = Sort(VML. VM. CPU_Utilization)//

Sort VMs as per the decreasing order of CPU utilization //

Step 2. For each VM in the SVML

a) Possible List = [ ]

// For every vm in the list, there is a possible list of hosts where the // vm is to be allocated //

Step 3. CPU_Utilization = VM.

CPU_Utilization (); // Identify the current demand of the cpu//

Step 4. AHL_current = HL. AHL() // Calculate AHL using (2)

Step 5. Foreach host in HL // Identify each and every host //

Step 6. HL_host = Host. Load();

//Extract the current load over the host by using (1)//

Step 7. If $_1$HL_host ≥ AHL_current // If host is overloaded

Step 8. // do nothing, pick next host //

Step 9. Else 1

1. If 2 host. resource( ) − .15(host. resource) > VM. demand( ) // Applying border line portion //
2. Evaluate Power_Consumption ( )
3. Add host to Possible List.

Step 10. End If 2

Step 11. End If 1

SECTION II

Step 1: Calculate the power consumption at every section

Step 2. Start Execution of jobs over the host until time t_execution

Step 3. Activate ABC( ) // Activate ABC definition

Step 4. Definition ABC ( )

Step 5. Bee_index= Overloaded_Hosts // Identify all hosts that are overloaded/

Step 6. Employed_Bee = Bee_index. VM. Index

// Identify the VM in the overloaded list //

Step 7. Onlooker_Bee= Scanned bees till now.

Step 8. Onlooker_Food = $\int^{vm_{allocated}} pdt$

// Total consumed power by other bees in the list //

Step 9. Travel_degradation = Heterogeneous

//The travel variation is considered to be hetrogenous in nature//

Step 10. If Employed_Bee. Bee_food ∗ Travel_degradation < Onlooker_Food

Step 11. False migration + +

Step 12. Else

Step 13. True migration + +

Step 14. End If

The proposed ABC algorithm also incorporates the employed and the onlooker bee as each bee is going to participate only once in the activity, the role of scout bee is almost negligible as shown in Algorithm 3.

Algorithm 3: Enhanced-Artificial Bee Colony

1. **Input: Number of user requests, Number of VMs, VM properties (**N_{PROP}**), Number of servers**
2. **Defined ABC Parameters:** Population of Bee (B) //Number of user's requests
   i) Employee bee // used to update servers features (memory, CPU utilization)
   ii) Fitness Function: $(f) = \begin{cases} 1; & if\ VM_{PROP} < Th_{PROP} \\ 0; & Otherwise \end{cases}$
3. Determine size of VMs in terms of row and columns (R, C)
4. Start feature selection
5. **For i = 1 $\rightarrow$ R**
6. **For j $\rightarrow$ 1 to C**
7. Bee_E= Employed Bee (i, j) //update server features
8. Bee_{On} = Respective Bee (i, j) // select PM with higher quality
9. $F = define_{fitness} function$
10. Fitdata=ABC ($F(f)$, Feature of VMs)
11. **End**
12. **End**
13. **Returns:** Create an optimized VM list

The proposed ABC algorithm utilizes employed and onlooker bee in the following manner. The role of ABC is to find out the false migrations made by MM algorithm if only MM is considered.Hence the onlooker bee and the employed bee considers the power consumption as the primary food source. Figure 5.1 represents the reduction in energy consumption by E-ABC algorithm.

In the similar fashion, Cuckoo Search has also been implemented as an alternative to ABC algorithm and also to validate the results of ABC algorithm as shown in Algorithm 4.. Under the similar setup condition, CS has been implemented. In order to accomplish the results, the following simulation architecture parameter has been organized. A sample set of collected data is presented in the table 5.1.

Algorithm 4: Enhanced Cuckoo Search

1 **Input:** Selected VMs, number of servers

2 **Initialize CS operators** – Iterations (ITR)

– Number of Egg (E_N)// number of VMs

– Number of Variables (Nvar)// Number of servers

3 Calculate VM size $P_i \leftarrow$ Size (VM)

4 Fitness function, f_{fit}

$$fn_{fit} = \begin{cases} \text{True ;} & \text{if attained superior quality egg } (fe > fth) \\ \text{False ;} & \text{otherwise} \end{cases}$$

Where fe is the random change in egg and fth is the threshold which should be achieved by host birds

5 **For each ITR & P_i in respect of j**

6 $fe = \sum_{j=1}^{p} VM\ energy = P_N$

7 $fth = \frac{\sum_{i=1}^{p} power\ (VMs)}{P_j}$

8 $VM_{allocation} = CSO(P_N, Nvar, fn_{fit})$

9 **End**

10 **Return:** Allocated VMs

11 **End**

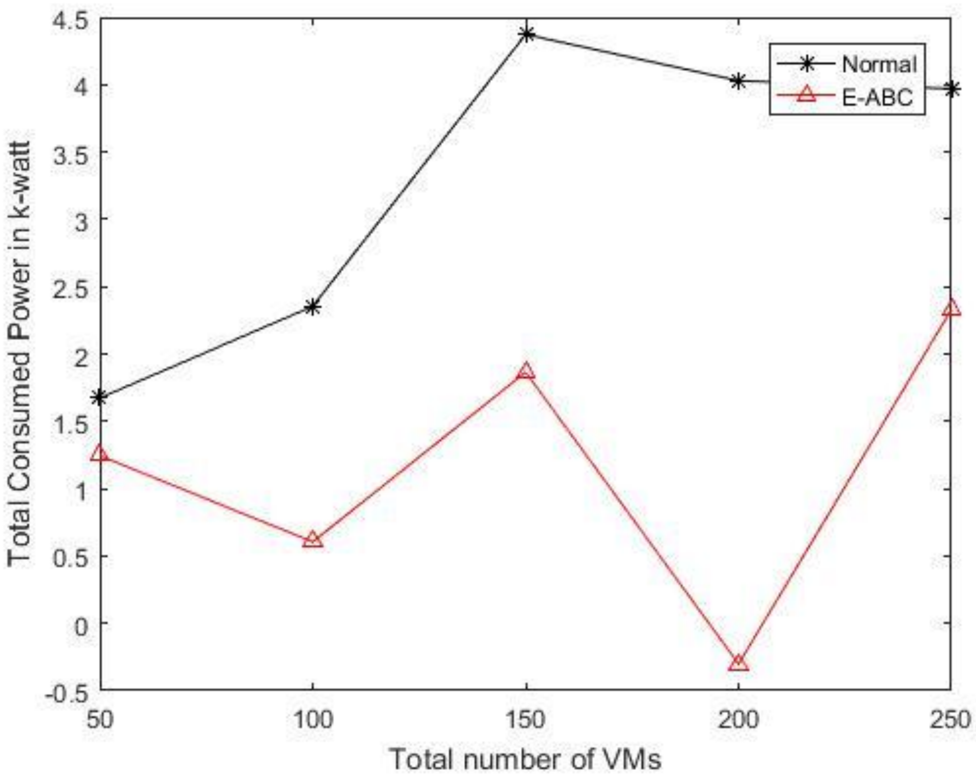

Figure 5.1: Energy Consumption by ABC and E-ABC Algorithm

For the first set of scenario, the proposed algorithm utilized Support Vector Machine as a validator to the passed architecture set attained from ABC algorithm. The point to be noted in this context is that, SVM can simplify the ground truth based on two classes only. The question is, how multiple VMs are going to be considered if there are only two classes. There were two ways to address this problem. The first architecture was the establishment of two classes only viz valid and non-valid. If the proposed work has to be done in that way, a machine learning approach was additionally needed to generate the ground truth. Rather than putting ML into action, each VM was trained against its similar power consumption and utilization value under the hood of the name which is the identity of the VM. The proposed algorithm architecture tried both the ways to train and classify the SVM.

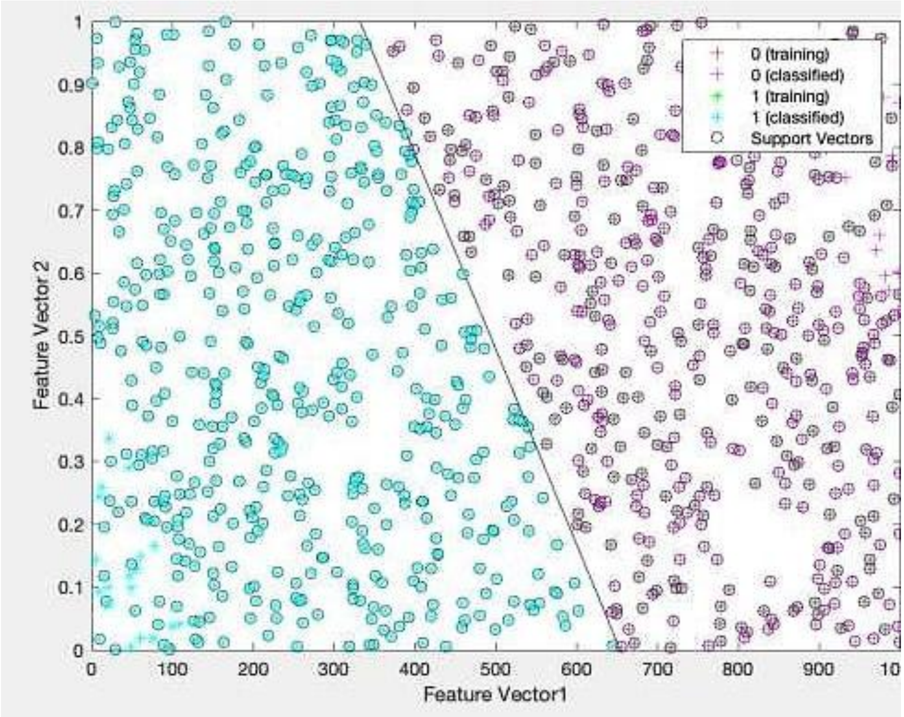

Figure 5.2 : SVM placement with certainity

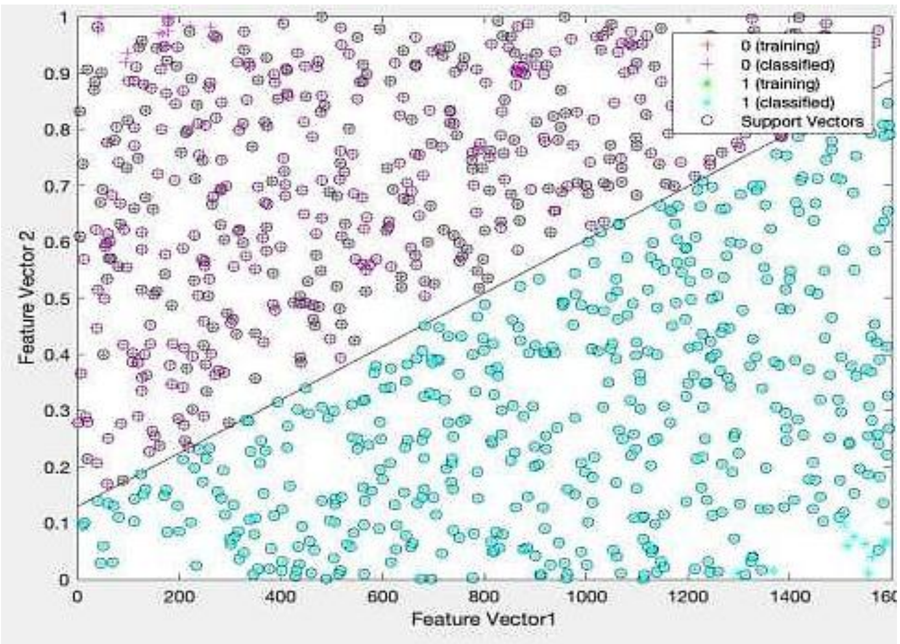

Figure 5.3 : SVM placement with uncertainty

Figure 5.2 and Figure 5.3 show SVM placements with and without certainity respectively. The key idea is to do dropout at both training and testing time. At test time, prediction is repeated a few hundreds times with random dropout. The average of all predictions is the estimate. For the uncertainty interval, we simply calculate the variance of predictions.In context to avoid the uncertainties in the data, the proposed work algorithm also opted alternative kernels to justify the proposed work but seemed that the distribution of the data was not linear and the method to implement this architecture did not get significant results as expected. Hence, second way of identifying the VMs were opted that is training the selected VM as sole candidate in comparison to other candidates in the same list.

5.2 Summary

This chapter summarizes the usage of two swarm intelligence algorithms for reducing energy consumption in VM migration process. The proposed work, initially utilizes Swarm intelligence algorithms for the selection of the VMs to be migrated to PMs. The ordinal measures of Swarm Intelligence has already been illustrated in this chapter. The proposed work has used ABC and Cuckoo Search for the implementation of the selection of target VMs for migration.

Chapter – 6

PREDICTION OF OPTIMAL VM MIGRATION DECISION USING MACHINE LEARNING CLASSIFIER

The proposed algorithm naming energy aware ABC based on Machine Learning is the combination of machine learning classifier and swarm based technique. This is used for ranking the VM according to load and also considering the energy reduction as its main parameter. The VM that is most efficient is chosen further and based on the current values of load and power, decision of migration has to take place. Machine learning classifier algorithm is used to evaluate the performance metrics of migrated VM from hotspot machine(old one) to the target PM(new one) for many simulations. Support Vector Machine(SVM) is used so that the pattern of over load and underload can be understood. The sample that has been trained is used to support the algorithm for performing better and predicting right decision for migration of VM in future. Here SVM will analyze the data and then classify the decision of migration in two categories-Above Post Performance(APP) and Below Post Performance(BPP).If the decision is Above Post Performance, then VM is migrated from the over loaded host and reallocated to new host otherwise VM is stayed on the same host and migration does not happen. The MATLAB simulation performed shows that the proposed work illustrates a highest energy reduction of 40% by selecting appropriate hosts and minimizing the number of migrations as compared to other existing approaches for VM migrations.The proposed architecture system majorly focuses on the development of the selectionpolicy of the VM. The proposed algorithm is inspired by the architecture of the Artificial Bees and the ordinal measures of ABC algorithm are already illustrated in theupper sections of this report. The proposed algorithm architecture will be applied to thehotspot PMs that are over-utilized in terms of CPU utilization. Overall, the proposed solution is divided into three significant phases illustrated as follows.

6.1 STAGE 1

This stage significantly focuses on the identification of the hotspot and applied MM algorithm for the selection of hotspot PMs. It is to be noted that the MM algorithm has also been used earlier in the preliminary objective sections. To be on fact, CPU utilization has been used for the selection of the hotspot PM. The remaining hosts, that are not identified due to the under load identification policy [109] follows the followingpolicy architecture defined in Stage 2 of this section.

6.2 STAGE 2

The evaluation parameters for the setup will be a set of 5 metric system and each metric will have significant possible food sources that are collected to judge the VMs. The VMs are judged based on Completed MIPS(C- MIPS),Million Instructions Per Second (MIPS),), Most Utilization Time (MUT) ,Consumed power (Cp) and Least Idol Time (LIT).

The following algorithmic architecture is employed to execute the proposed algorithm design where vmcount variable shows the count of total number of vms in the current hive under Ih. Variable rnd is storing random value between 0-1 and k is total number of hives.

Calculate $T-MIPS=\frac{C-MIPS}{MIPS}$ (6.1)

Calculate $T-Cp=\frac{Cp}{\frac{\sum_{i=1}^{n}Cpo}{n}}$ (6.2)

where Cpo is the power that is consumed by other VMs of another hives with approximately same MIPS.

$$T-MUT=\frac{MUT}{\frac{\sum_{i=1}^{n}MUTo}{n}} \quad (6.3)$$

Where MUTo is most idol time taken by VMs of other hives with almost same MIPS.

Calculate $T-LIT=\frac{LIT}{\frac{\sum_{i=1}^{n} MITo}{n}}$ (6.4)

Step 5 : Calculate $f\text{-}onlooker=\frac{T-MIPS}{(T-Cp)}\times\left[(T-MUT)-(T-LIT)\right]$ (6.5)

I. First fly variation(fv) is initiated by calculating average factor of every metric in Bf and varying it by taking the difference of maximum and minimum value of each attribute, multiplied to a random value ranging from 0 − 1.

$$Fv=\int_{i=1}^{k}\sum_{j=1}^{vmcount}\frac{Bf_{attribute_i}}{vmcount}-\left[\max\left(Bf_{attribute_i}\right)-\min\left(Bf_{attribute_i}\right)\right]\times rnd \quad (6.6)$$

II. Repeat step 5 for every step.

III. 4 flies are considered, and therefore a Pre − Judgement Metric(P − JM) is created containing 4 ∗ vmcount[Fv] values and also f −onlooker value is calculated for each bee and for every fly position.

IV. For each fly position, calculate its average threshold(at).

V. A judgement metric(jm) is created containing 4 ∗ vmcount[Fv] number of zeros.

VI. For every position in the fly table, check if bfv value of current fly is greater than at, then mark 1 in jm for that current fly.

VII. After completion of all the flies, 1s and 0s for every VM are calculated in the hive. Now,if 1s are greater than 0s, it means VM has performed well inspite of having major load.The VM needs some change to avoid over-utilization and should be migrated if required.

6.3 Pseudo Code for Proposed Methodology

Step 1: Begin

Step 2: Apply MBFD for deployment of VMs.

Step 3: Apply thresholds minimum and maximum thresholds for CPU utilization.

Step 4: Get a list of over utilized host, underutilized host, and normal utilized host using CPU Threshold Policy.

Step 5: Select VMs to migrate from overutilized host by Swarm Intelligence Algorithm(Enhanced-ABC).

Step 6: Selected VM list is feed to machine learning algorithm for performing post migration analysis .

Step 7: For all VMs that needs to migrate from Overutilized hosts.

Step 8: Find its post migration performance of VMs using SVM (Support Vector Machine)classifier using RBF Kernel.

Step 9: Continue execution of tasks on Normal Utilized Hosts

Step 10: Migrate all VMs from underutilized hosts and switch off the hosts.

Step 11: For post migration analysis , Train SVM for data for 1000 simulations .

Step12: SVM will create a repository for two categories- Above Post Performance and Below Post Performance.

Step 13: If post migration analysis for a selected VM comes as Above Post Performance Then

Step 14: Reallocate that VM to new PM using MBFD algorithm.

Step 15: Else

Step 16: Let that VM stay on the current PM and continue its execution and stop that VM from migration.

Step 17: End If

Step 18: After Training SVM, Test SVM with validation ratio of 0.15, 0.30 and 0.50.

Step 19: End

6.4 Workflow of Proposed E-ABC+SVM Algorithm

Figure 6.1 illustrates the diagramatic workflow of proposed algorithm.

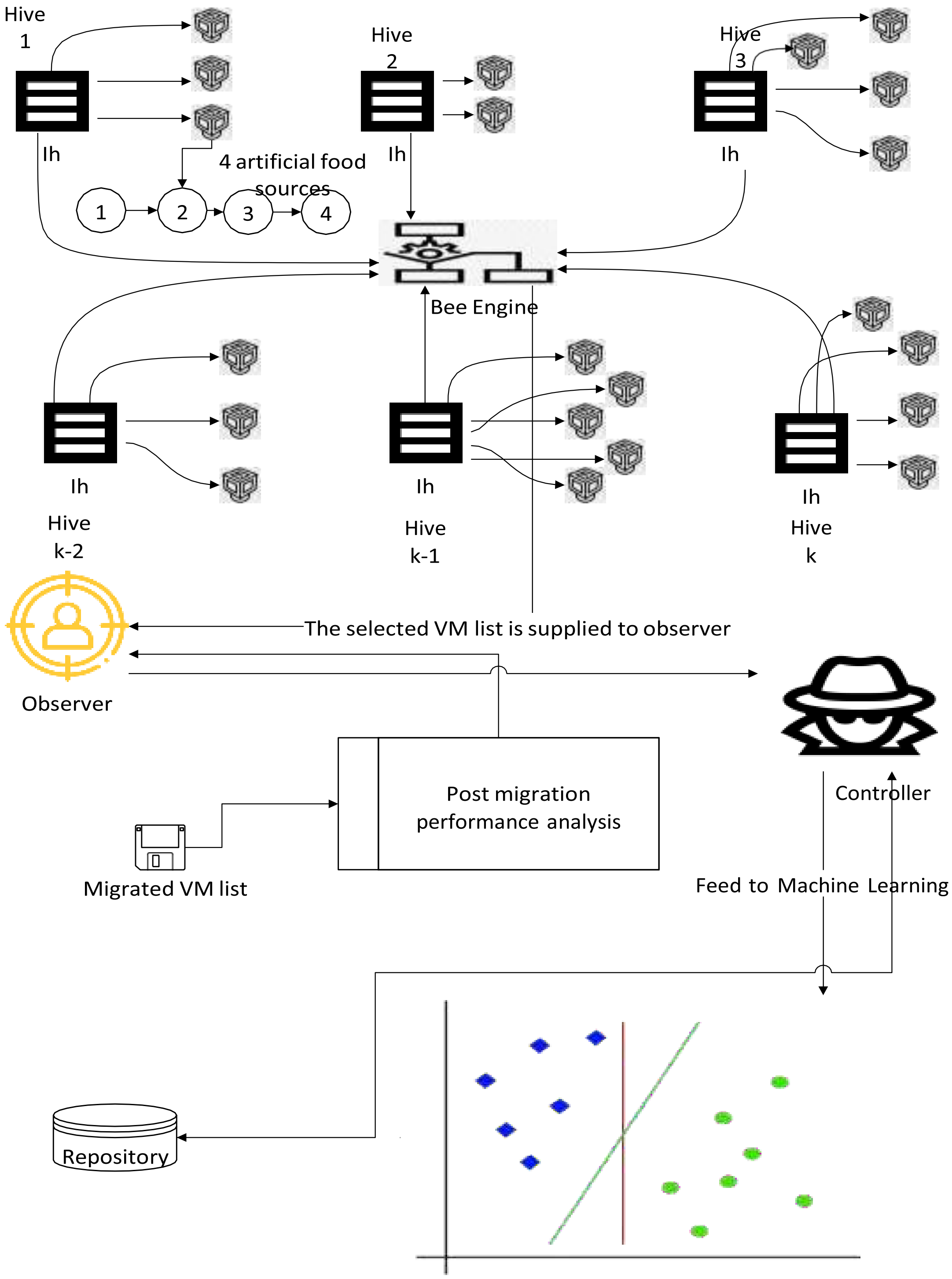

Figure 6.1 : The Work Flow of SVM+E-ABC Algorithm

The proposed algorithm naming energy aware ABC based on Machine Learning is the combination of machine learning classifier and swarm based technique.This is used for ranking the VM according to load and also considering the energy reduction as its main parameter.The VM that is most efficient is chosen further and based on the current values of load and power, decision of migration has to take place. Machine learning classifier algorithm is used to evaluate the performance metrics of migrated VM from hotspot machine(old one) to the target PM(new one) for many simulations. Support Vector Machine(SVM) is used so that the pattern of over load and underload can be understood. The sample that has been trained is used to support the algorithm for performing better and taking right decision for migration of VM. Here SVM will analyze the data and then classify the decision of migration in two categories-Above Post Performance(APP) and Below Post Performance(BPP).If the decision is Above Post Performance, then VM is migrated from the over loaded host and reallocated to new host otherwise VM is stayed on the same host and migration does not happen. The MATLAB simulation performed shows that the proposed work illustrates a highest energy reduction of 40% by selecting appropriate hosts and minimizing the number of migrations as compared to other existing approaches for VM migrations.The proposed architecture system majorly focuses on the development of the selectionpolicy of the VM. The proposed algorithm is inspired by the architecture of the Artificial Bees and the ordinal measures of ABC algorithm are already illustrated in the upper sections of this report. The proposed algorithm architecture will be applied to thehotspot PMs that are over-utilized in terms of CPU utilization. As described earlier, the proposed ABC algorithm is an energy centric algorithm and hence power consumption and utilization becomes a serious issue here. The proposed EA-ABC algorithm utilizes energy model based on the following architectural assumptions.

Improving energy efficiency is the main concern intended for cloud data-centers. It's necessary to eliminate the inefficiency and waste of power delivery to compute the resources, and then how the resources are being utilizes to the workloads of service application. It may be achieved via improvement of the data center's physical infrastructure with the algorithms of resource allotment and management. From all angles, the problem of energy-efficient data centers is

a) Energy-efficient hardware architecture

b) Virtualization of computing resources

c) Energy-aware Job scheduling

d) DVFS

Energy data center consumption increased by 56% worldwide from 2005 to 2010, representing 1.1% of total power in 2010 to 1.5% [111]. The server's dynamic power range is narrow and the low server utilization problem is getting worse: thorough idle servers have consumed around 70% of peak power consumption.

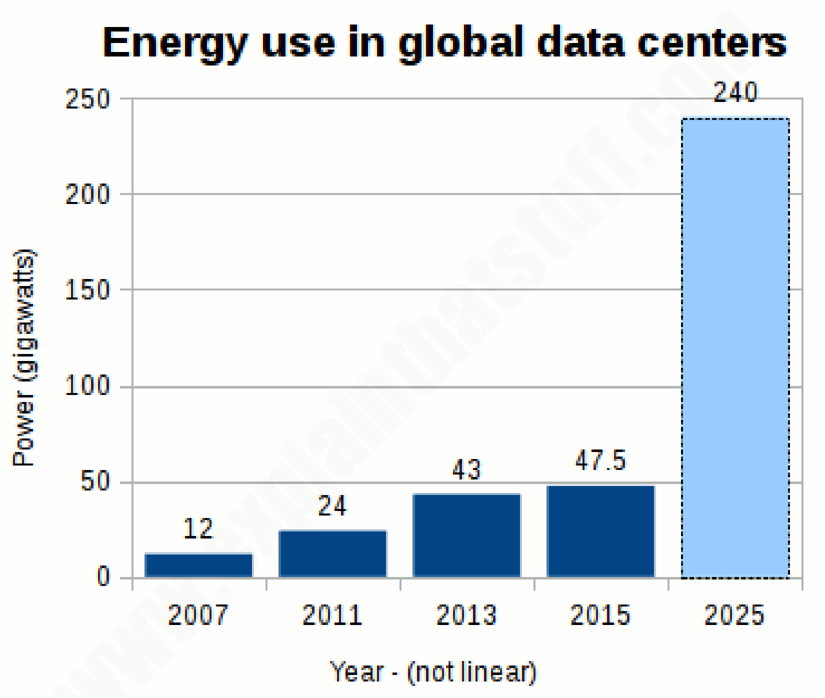

Figure 6.2 : Energy Consumption in Data Centers Worldwide[112]

Figure 6.2 shows year wise energy consumption in cloud data centers worldwide. In fact, cooling equipment consumes energy comparable to the IT system itself. Ranganathan argues that each dollar being spent on a huge data center is spent on electricity costs and another dollar for refrigeration [112].

Table 6.1 : Percentage of Power Consumption by Each Data-enter Device [112]

Cooling device (Computer Room Air Conditioning, Chiller, (CRAC))	33% + 9%
Information Technology Equipment	30%
Electrical Equipments (Power Distribution Units (PDUs), UPS, Lighting)	28%

The selected VMs requires validation and hence Support Vector Machine (SVM) has been used for the validation. The ordinal measures of SVM as follows.

Figure 6.3 shows different types of kernels that can be used with SVM classifier.

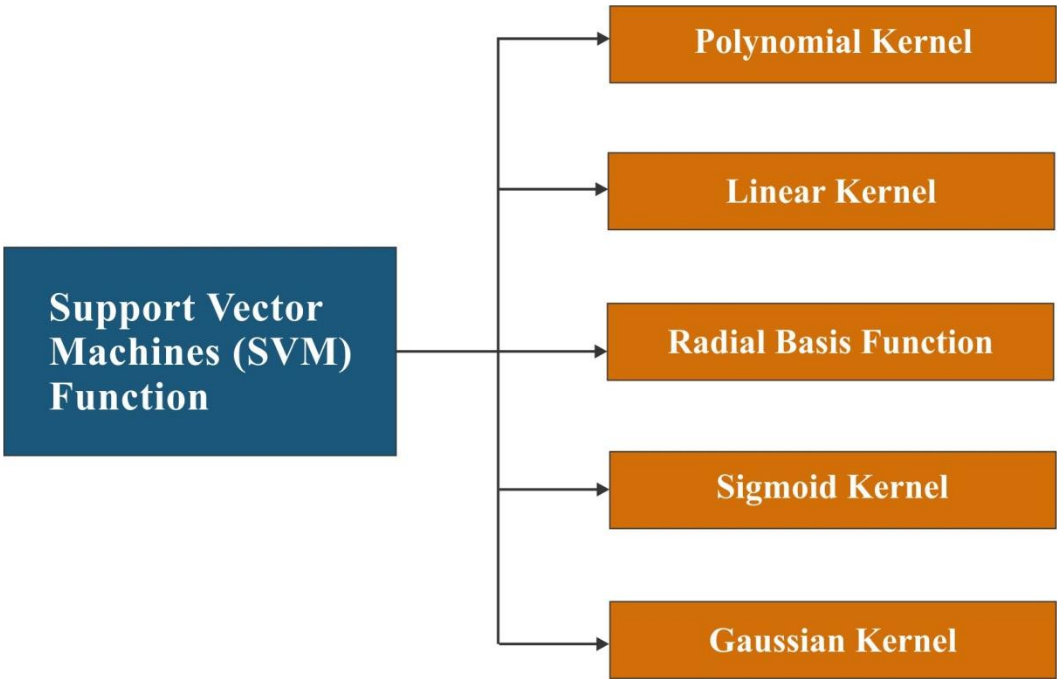

Figure 6.3 : Types of Kernel Functions in SVM

6.5 SVM Classification with Different Kernels

SVM Classification with Linear, Polynomial and RBF Kernels is shown in Figure 6.4, 6.5 and 6.6 respectively. The best separation is attained with RBF kernel. Therefore RBF kernel is chosen to check for various validation ratios.

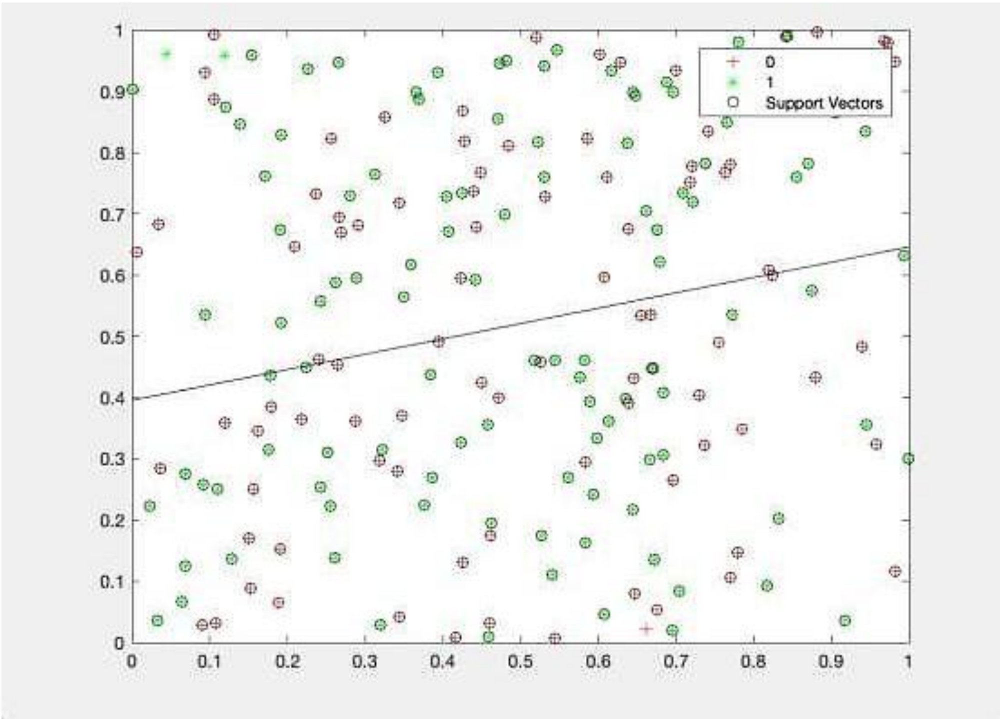

Figure 6.4 : Linear Kernel Derivation and Propagation

As it is clear from the figure 6.4, there are anonymous number of components that falls into other region and hence a clear separation is missing. To investigate it further, polynomial kernel is implemented as shown in Figure 6.5.

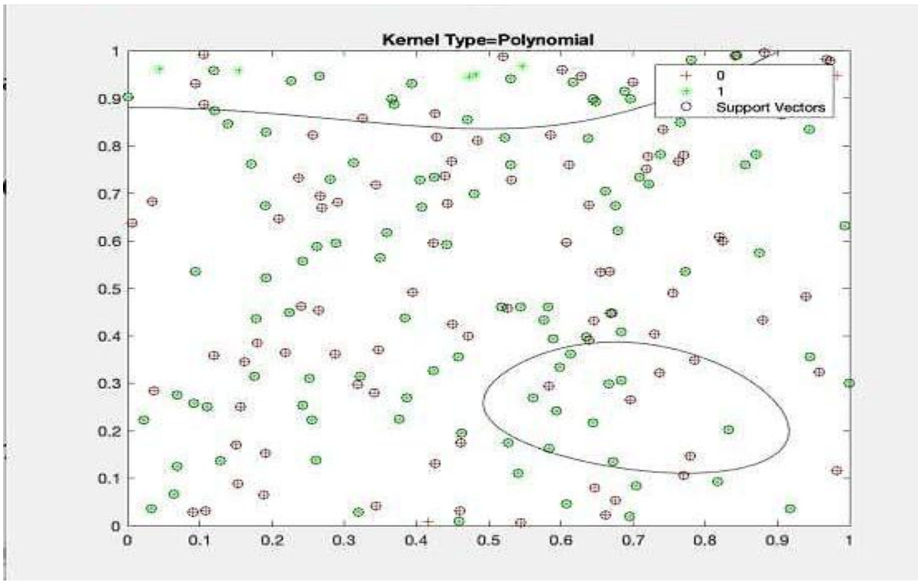

Figure 6.5 : Polynomial kernel separation

The major separation has been attained utilizing polynomial kernel which provides appreciation for the usage of RBF kernel as shown in Figure 6.6.

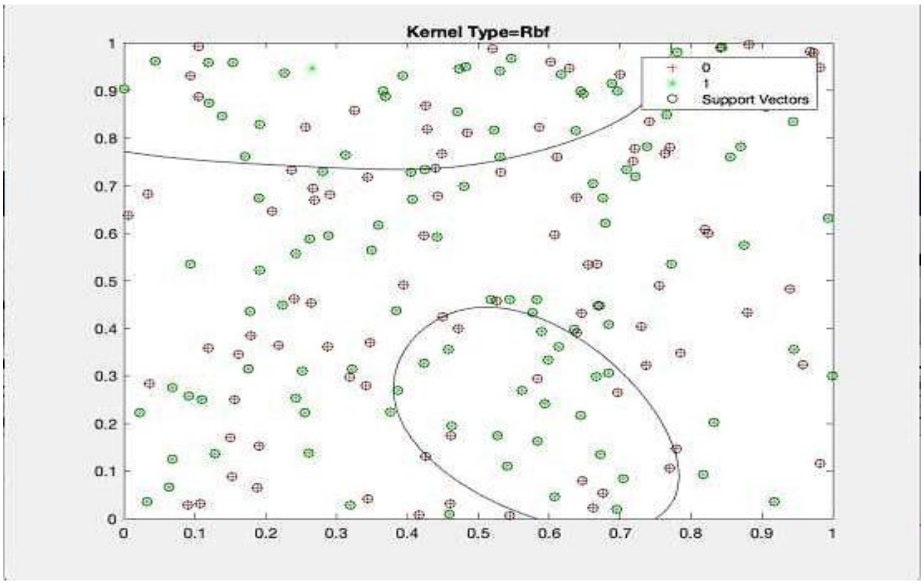

Figure 6.6 : SVM with RBF kernel mode

6.6 Analysis of Result of SVM Classification with Different Validation Ratios

Figure 6.7, 6.8 and 6.9 represent SVM Validations with RBF Kernel having 0.15, 0.30 and 0.50 validation ratios respectively. The best classification is achieved with 0.50 validation ratio.

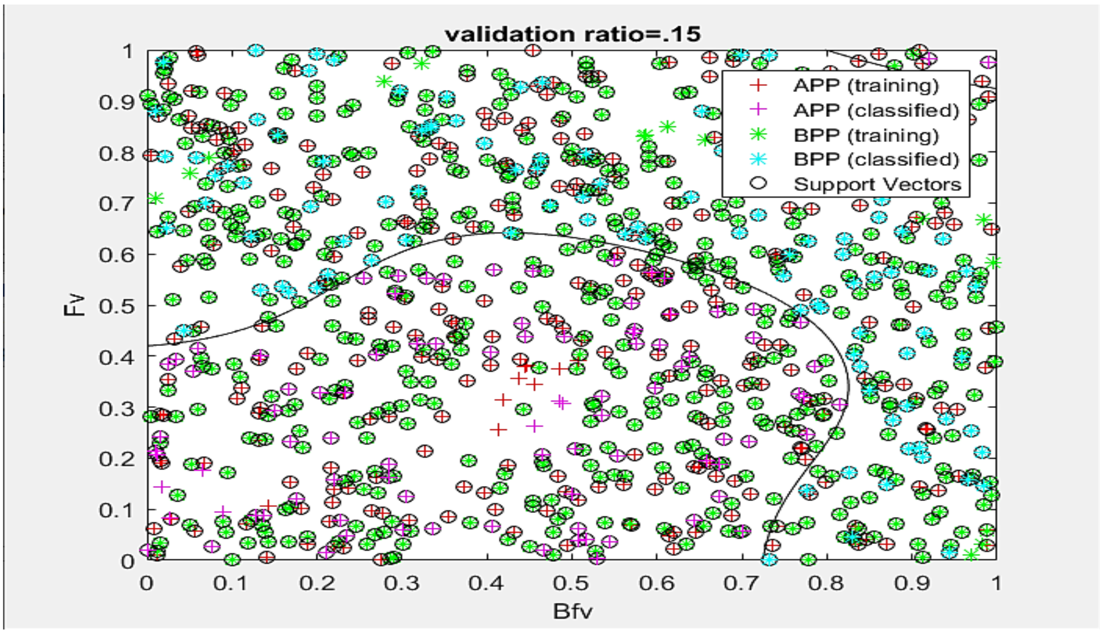

Figure 6.7: SVM Classification with 0.15 validation ratio

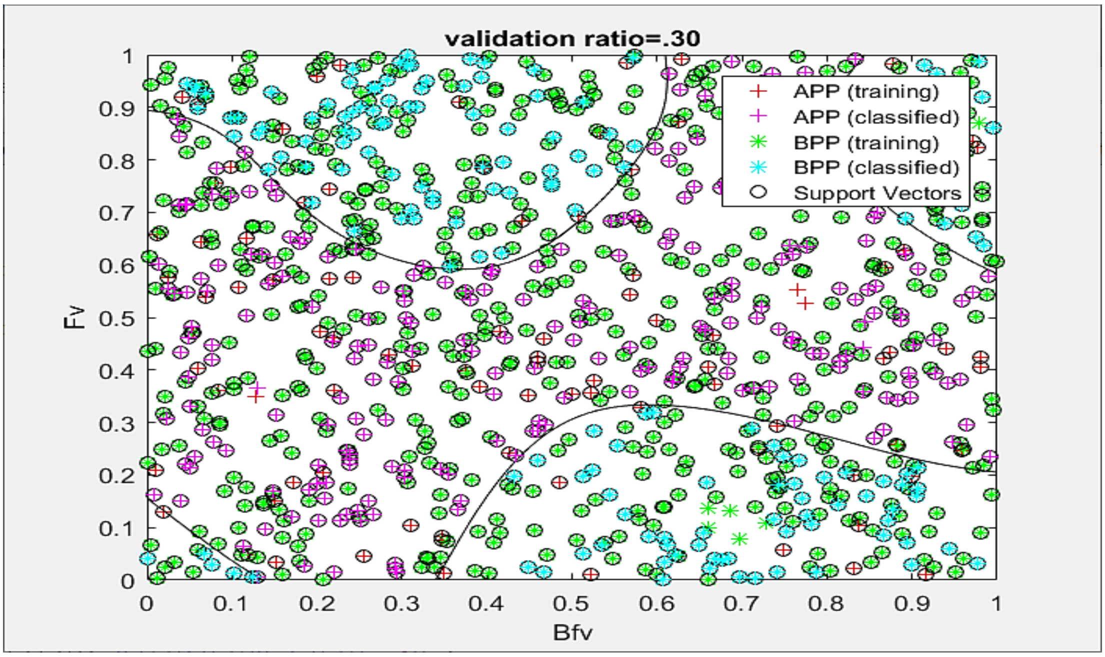

Figure 6.8: SVM Classification with 0.30 validation ratio

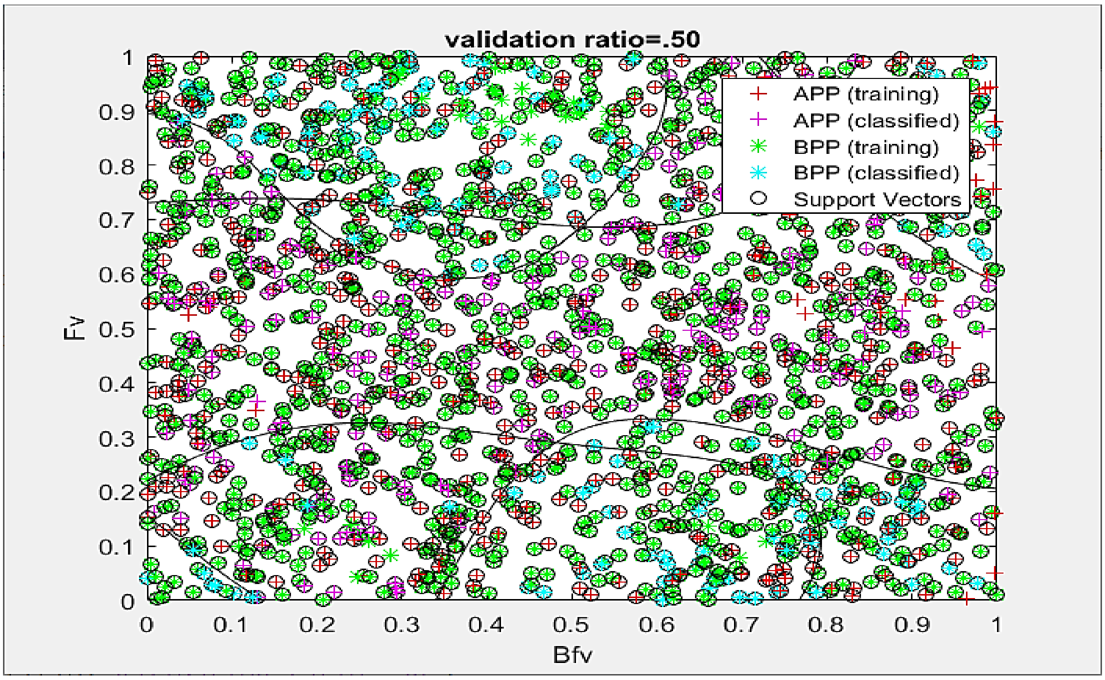

Figure 6.9: SVM Classification with 0.50 validation ratio

6.7 Summary

This chapter summarizes the utilization of proposed algorithm naming energy aware ABC based on Machine Learning in predicting the correct VM migration decision for future so that false migrations are avoided and hence energy consumption will be reduced. The combination of Swarm Intelligence and machine learning classifier is proposed here.

Chapter 7

TO COMPARE THE PERFORMANCE OF PROPOSED WORK WITH STATE OF THE ART WORK

The chapter discusses the proposed mechanisms against the existing state of art works.

7.1 ENHANCED BEE COLONY APPROACH FOR MONITORING VIRTUAL MACHINES IN CLOUD ENVIRONMENT

In this section , the suggested work E-ABC algorithm ‘s performance was shown in the first part, and it was compared to the E-CS, basic ABC, and CS algorithms, respectively. In the second section, a comparison was made with previous work by [113]. The work was done with the MATLAB toolset, and the tests were done with the optimization tool. The system's performance is measured in terms of energy usage, migration counts, and SLA violations. A few assumptions have been made in order to conduct the experiment, as shown in table 7.1.

Table 7.1 : Required Parameters for Simulation

Number of VMs	800
Number of Hosts	300
VMs CPU utilization	500,750,1000,1250
Hosts CPU Utilization	2000,3000,4000
Number of CDC	1
Hosts memory capacity (MIPS)	2000
VMs memory capacity (MIPS)	200

The test is run using the above input parameters listed in Table 7.1, i.e. 300 hosts and 800 virtual machines. Table 7.2 shows the acquired findings for the various parameters.

Table 7.2 : Computed Parameters

Number of VMs	Energy Consumption (KW-h)				SLA Violation				Number of Migrations			
	ABC	CS	E-ABC	E-CS	ABC	CS	E-ABC	E-CS	ABC	CS	E-ABC	E-CS
50	5.27	5.46	0.45	1.02	1.14	1.93	0.52	0.63	31	33	22	28
100	6.43	7.11	1.31	1.31	1.81	2.21	0.81	1.1	41	47	29	34
150	7.83	8.13	1.83	2.13	2.4	3.71	1.1	1.31	62	65	52	62
200	9.41	8.81	1.89	2.19	3.7	4.81	2.21	2.91	75	83	61	73
250	10.21	9.41	2.19	2.59	8.5	5.61	3.41	4.71	91	93	77	83
300	10.41	9.81	2.49	2.89	8.6	7.81	4.61	5.12	97	101	81	89
350	10.43	10.73	3.13	3.73	9.92	8.92	6.91	7.21	99	110	91	98
400	10.83	11.03	3.73	4.83	10.31	9.21	8.21	9.91	119	125	101	113
450	12.07	12.37	4.31	5.01	11.5	10.7	10.7	12.31	131	137	117	128
500	12.47	12.77	4.51	5.71	12.8	12.6	10.8	13.7	141	149	121	135
550	12.77	13.47	6.01	6.31	13.89	14.62	11.92	14.2	151	153	130	140
600	13.17	13.77	6.77	7.47	14.6	16.3	12.3	15.6	152	153	133	142
650	13.03	13.83	6.89	7.39	15.23	18.22	14.53	16.72	159	161	138	147
700	13.53	13.93	7.39	9.09	16.29	20.21	15.23	17.22	161	163	144	155
750	13.83	14.69	7.59	9.69	19.67	22.78	17.89	18.66	186	201	189	193
800	14.03	15.03	9.13	10.43	21.3	16.19	18.67	19.34	225	249	208	237
850	13.73	15.33	9.73	11.03	24.6	27.31	19.22	20.51	260	263	247	258
900	14.13	16.27	10.27	11.57	27.34	30.51	20.42	22.43	271	272	252	270
950	14.43	16.77	10.67	12.77	28.6	32.99	22.23	25.3	291	296	274	287
1000	14.93	17.03	11.03	13.73	30.21	34.59	22.7	25.2	301	313	290	297

The tests were run on up to 1000 virtual machines, and the simulation was run ten times. Table 7.2 lists the computed parameters for four different techniques: simple ABC, Simple CS, E-ABC, and E-CS.

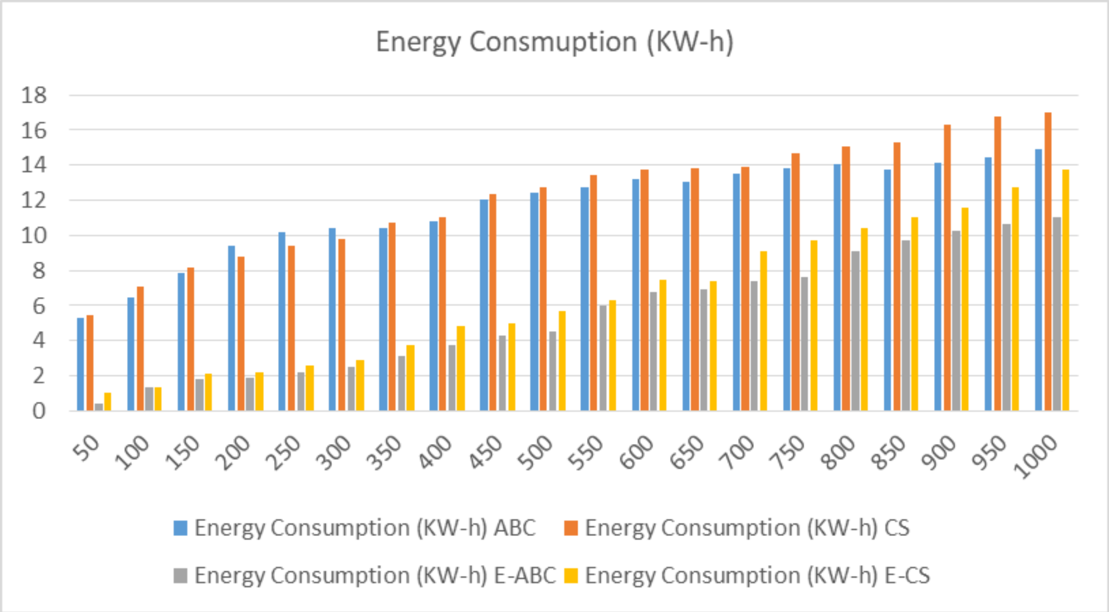

Figure 7.1 : Energy Consumption

The comparative graph for consumed energy with four different techniques ABC, CS, E-ABC, E-CS for different count of VMs is shown in Figure 7.1. During the experimental process, it must be noted that how much hosts are required by the VM to complete the user request with minimum energy. To prevent most hosts from sitting idle.Since, the number of hosts sitting idle consume unnecessary energy, which will violate the criteria of minimum energy demand. After the detection of idle hosts, it is switched to sleep mode. From the experiments it has been observed that E-ABC technique consumes less energy compared to E-CS, ABC and CS approach. This is because, E-ABC runs using artificial bee colony optimization algorithm that helps in selecting an appropriate node for VM allocation with less searching time. The enhancement in the ABC approach (E-ABC) utilized resources in a well-managed manner and hence reduced the number of VM migrations, which minimized the energy consumption and hence save energy.

The energy saving can be calculated by first determining the average energy consumed by E-ABC and E-CS approach, which was observed as 5.335 KW-h, and 6.31 KW-h respectively. Therefore, the energy saved around 15.31 % has been achieved using E-ABC approach against E-CS.

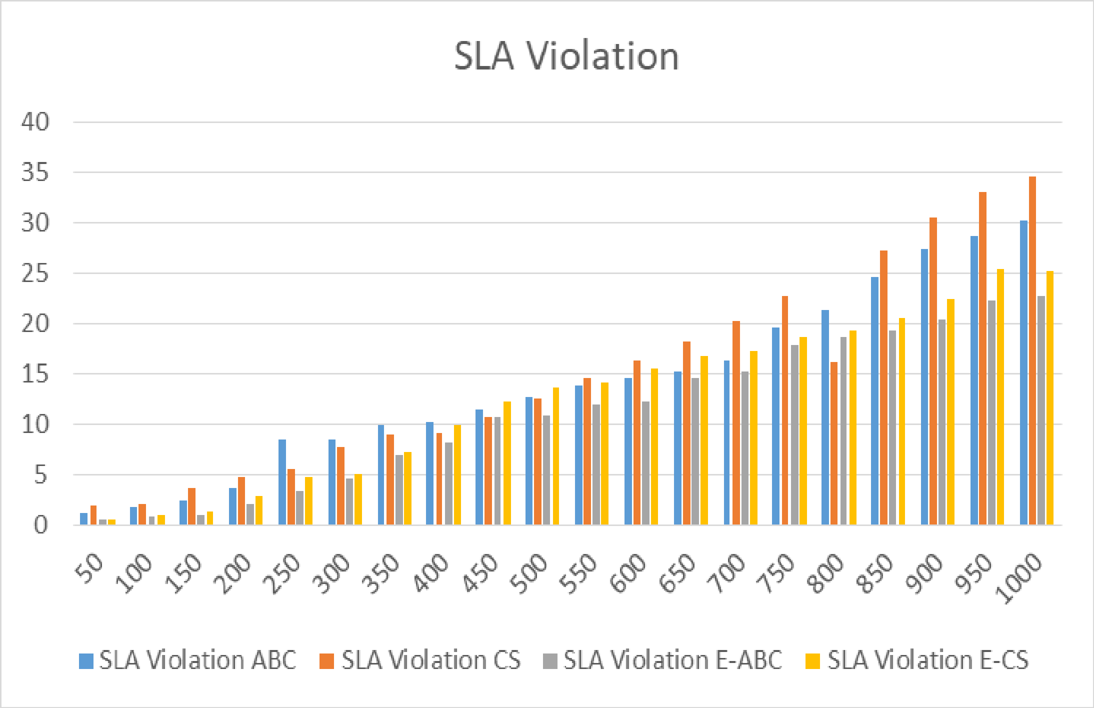

Figure 7.2 : SLA Violation

The examined values for SLA violation for different number of VMs is shown in Figure 7.2. From the graph it is concluded that E-ABC approach is performed better with minimum violation followed by E-CS, ABC, and CS i.e. maximum violation has been observed using simple CS approach.The minimum and maximum SLA violation observed for 50 and 1000 number of VMs using proposed E- ABC approach is 0.5, and 22.8 respectively. Also, the average SLA violation analysed for E-ABC, E-CS approach is 11.185%, 14.69 % respectively. Therefore, the percentage reduction in SLA violation using E-ABC approach is 23.86 % against the E-CS approach. Therefore, E-ABC has performed well among all the three approaches. This is because, bees search for an appropriate host with minimum searching time.

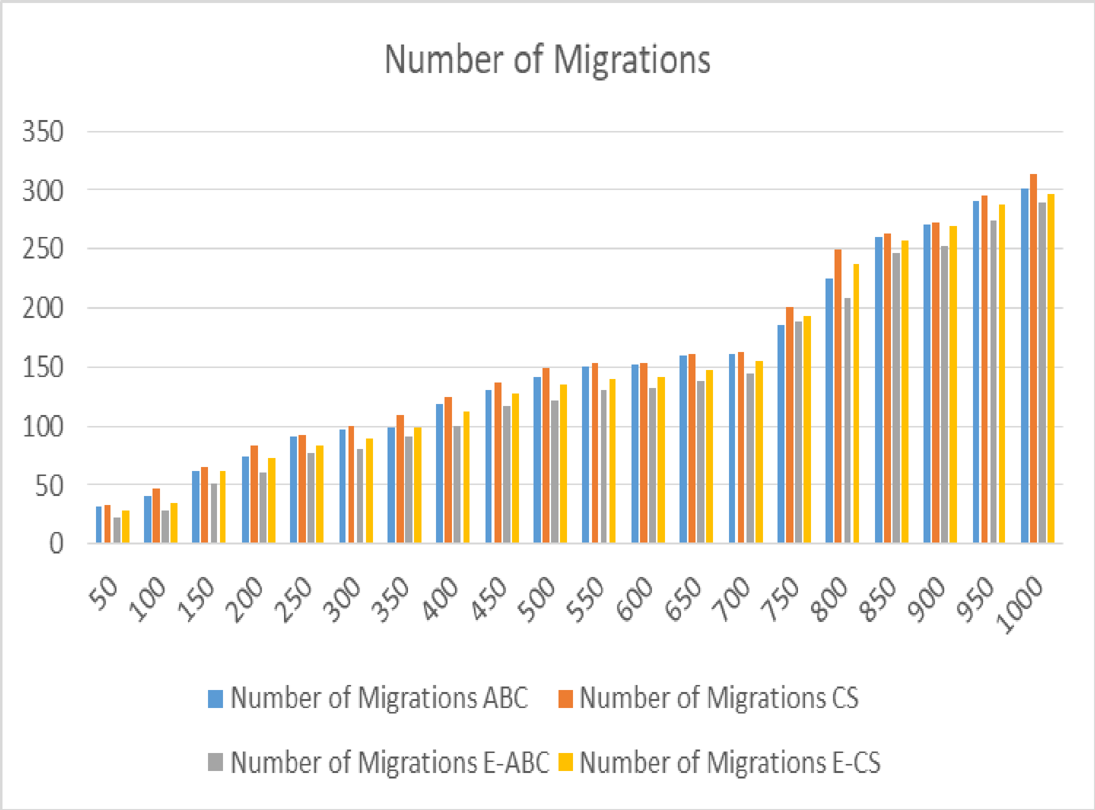

Figure 7.3 : Number of Migrations

Number of migrations observed by four different approaches is shown in Figure 7.3. From the graph it is observed that proposed E-ABC approach utilized a smaller number of hosts and hence results in lesser VM migrations compared to existing E-CS, ABC, and CS approach. The VM migrations has been affected by the ability of E-ABC approach to actively find out the best host without compromising on energy consumption. When a new workload arrives, the overall energy consumption in the CDC is the optimal, because nodes work on threshold-based energy consumption. This is because, all the incoming requests from the users has been performed or allocated to the hosts by considering the threshold value of energy consumed by each request. Therefore, while performing workload distribution based on energy constraints, the demand for causing more and more VM migrations is low. From experiment the average number of migrations examined using E-ABC, E-CS approach are 137.15, and 153.94 respectively. The percentage reduction in the VM migration using E-ABC approach is of 10.91 % has been observed against E-CS approach.

7.1.1 Comparative Analysis

In the last couple of years, a number of researchers have used biologically-inspired optimization approach to deal with heterogeneity and the growing energy crisis in CDC. In this research, we have also used swarm inspired approach to minimize the energy consumption in CDC. To show the enhancement of our work against the existing work comparative analysis has been performed. The analyzed parametric values are listed in table 7.3.

Table 7.3 : Comparative Analysis

Energy Consumption (KW-h)				**SLA Violation (%)**				**Number of Migrations**			
E-ABC	**E-CS**	**ACO Karda et al.(2019) [113]**	**ABC**	**E-ABC**	**E-CS**	**ACO Karda et al.(2019) [113]**	**ABC**	**E-ABC**	**E-CS**	**ACO Karda et al.(2019) [113]**	**ABC**
5.339	6.36	6.49	5.50	11.23	14.769	14.6	12.24	137.22	154.1	154.67	145

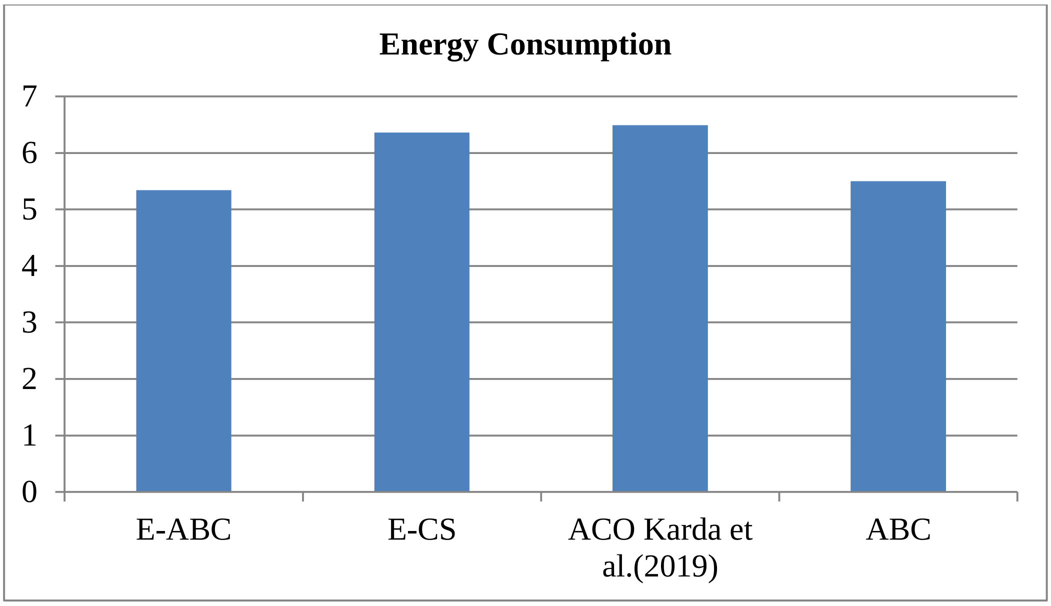

Figure 7.4 : Comparison of Energy Consumption

The comparison for energy consumption using E-ABC (proposed approach) has been performed with E-CS and ACO[113] and ABC approaches. The values of energy consumption correspond to E-ABC, E-CS, and ACO and ABC have been represented. The average values of energy consumption observed for E-ABC, E-CS, and ACO are 5.335 KW-h, 6.31 KW-h, and 6.43 and 5.50 KW-h respectively. Therefore, energy saving of 15.45 %, and 17.03 % and 3% has been obtained using E-ABC approach compared to E-CS and ACO and ABC approaches. This is because, in CS, due to randomness initialization of cuckoo egg population, the fluctuation in population is significantly more than ABC and it creates a poor convergence.

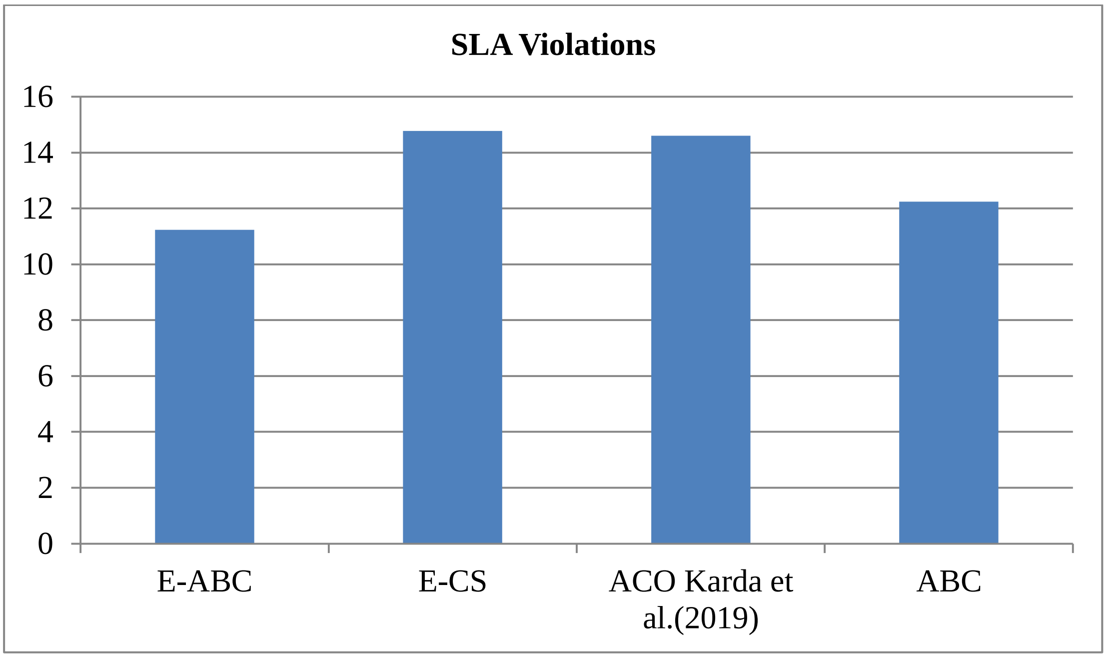

Figure 7.5 : Comparison of SLA Violation

In the same way, comparison for SLA violation and number of migrations with the existing technique ACO [113], and E-CS and ABC is shown in Figure 7.5, and Figure 7.6 respectively. From Figure 7, the percentage minimization in SLA violation against E- CS and ACO and ABC is obtained about 23.86%, and 22.86 % and 8.26% respectively. Also, the reduction in number of migrations using E-ABC approach against E-CS, and ACO and ABC approaches has been obtained as 10.91%, and 10.67 % and 5.04 % respectively.

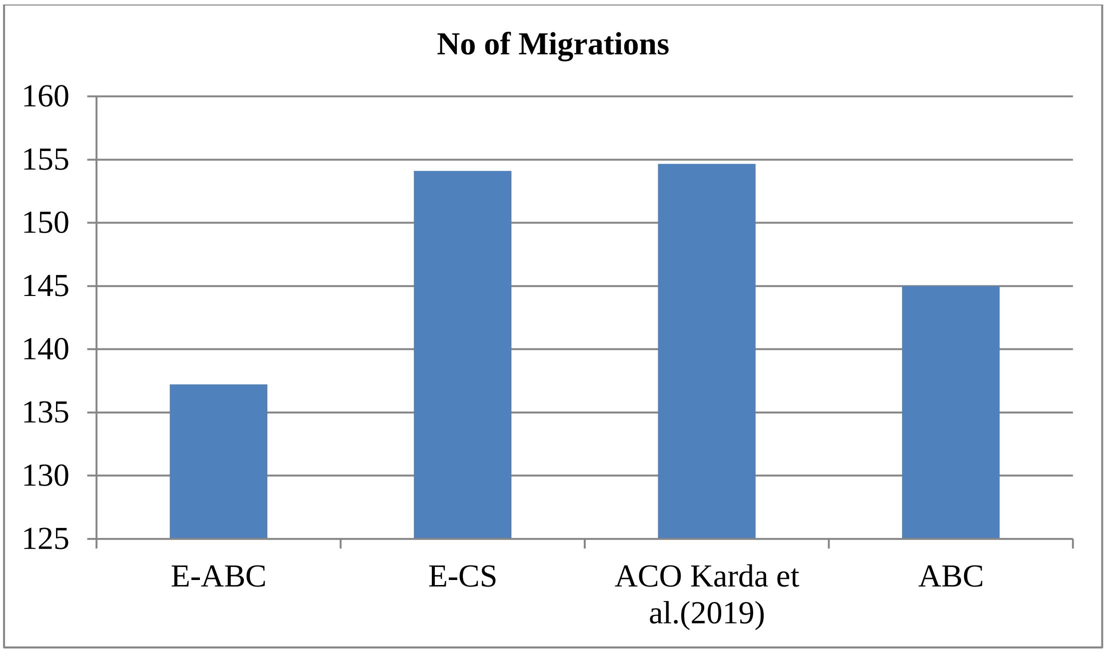

Figure 7.6 : Comparison of Number of Migrations

7.2 A NEW VM MIGRATION ALGORITHM ENHANCING MACHINE LEARNING ARCHTIECTURE FOR REDUCED POWER CONSUMPTION

The experimental analysis for the proposed technique is performed using Matlab. In the simulation study,original behaviour of algorithm is illustrated. The parametric description having specification details is mentioned in Table 7.4.

Table 7.4 : Simulation Parameters

Parameter	Description
VM Count	10-200
Host Count	10-200
Bandwidth Used	2.5Gbps
Host Types	2 Types
VM Types	4
Primary Host Memory	4
GB Secondary Host Storage	1 TB
Primary VM Memory	1 GB to 4 GB
GB Secondary VM Memory	2.5 GB
Simulator	Matlab2016a

The energy consumed by reducing false VM migrations has been the major parameter which is being analysed in the proposed work. Proposed work achieved 97% accuracy in identifying and allocating better VMs. The comparative analysis is listed in Table 7.5. The comparative study involves comparison of proposed work with two SI techniques ABC and CS against two already existing work done by Kansal and Chana, 2016 [67] and Naik et al., 2020 [114].

Table 7.5 : Analysis of number of host and migrations

Numberof VMs	Number of Hosts			Number of Migrations		
	EA-ABC +SVM	Kansal and Chana, 2016	Naik et al., 2020	EA-ABC +SVM	Kansal and Chana, 2016	Naik et al., 2020
10	8	9	9	1	2	1
20	10	11	10	1	3	1
40	14	20	17	3	5	2
60	21	27	25	3	7	3
80	25	38	30	4	9	4
100	31	42	39	4	10	5
120	35	53	48	6	12	7
140	43	66	61	7	13	8
160	53	83	74	8	16	9
180	74	94	84	11	18	12
200	90	124	102	13	22	14
220	99	139	114	14	23	15
240	108	152	134	16	24	16
260	129	165	147	18	27	19
280	140	173	160	19	29	20
300	151	179	165	20	32	21

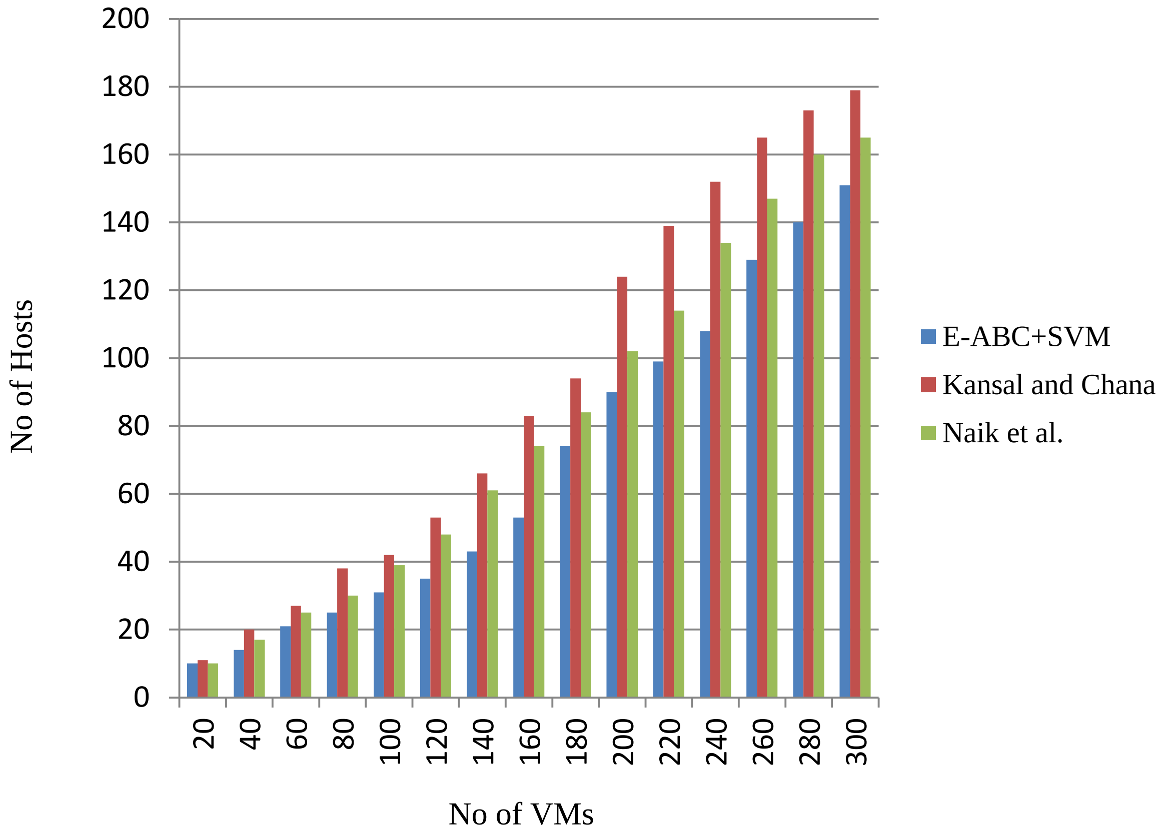

Figure 7.7 : Analysis of No of Hosts Versus No of VMs

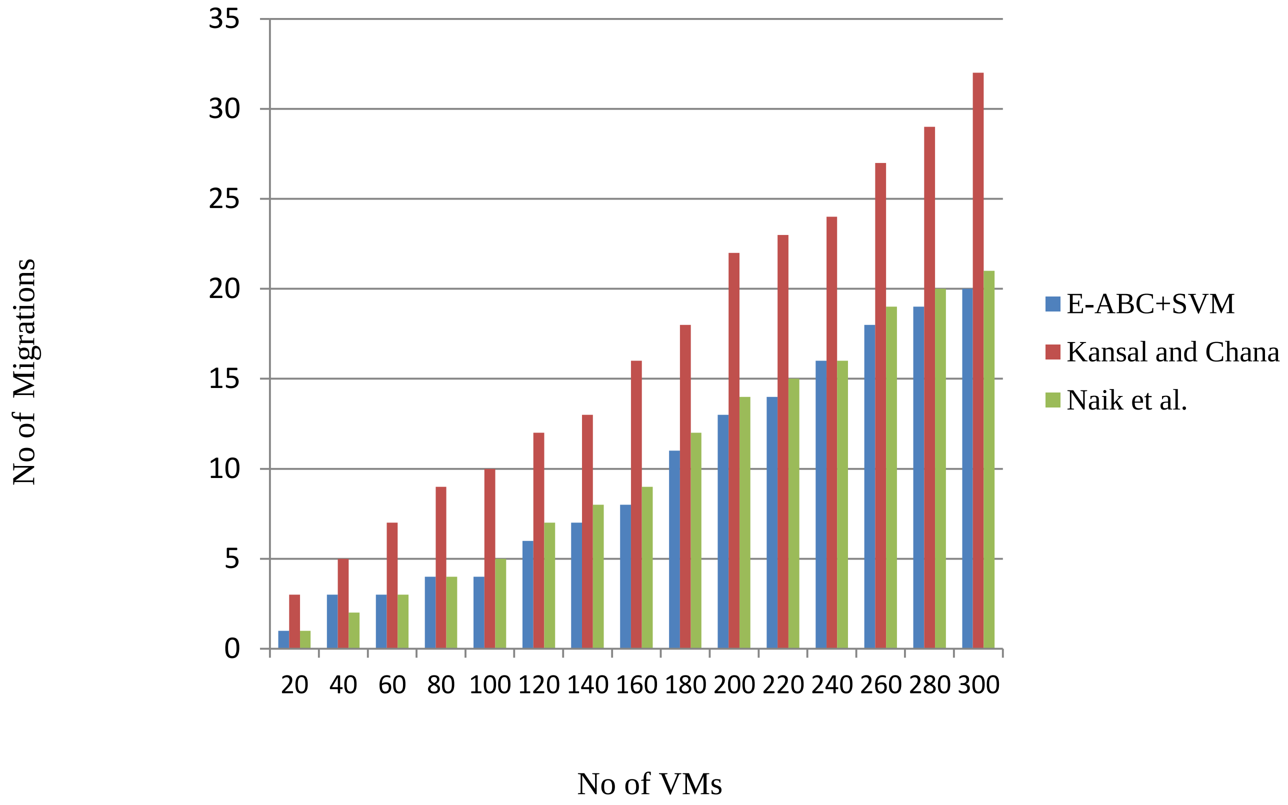

Figure 7.8 : Analysis of No of Migrations Versus No of VMs

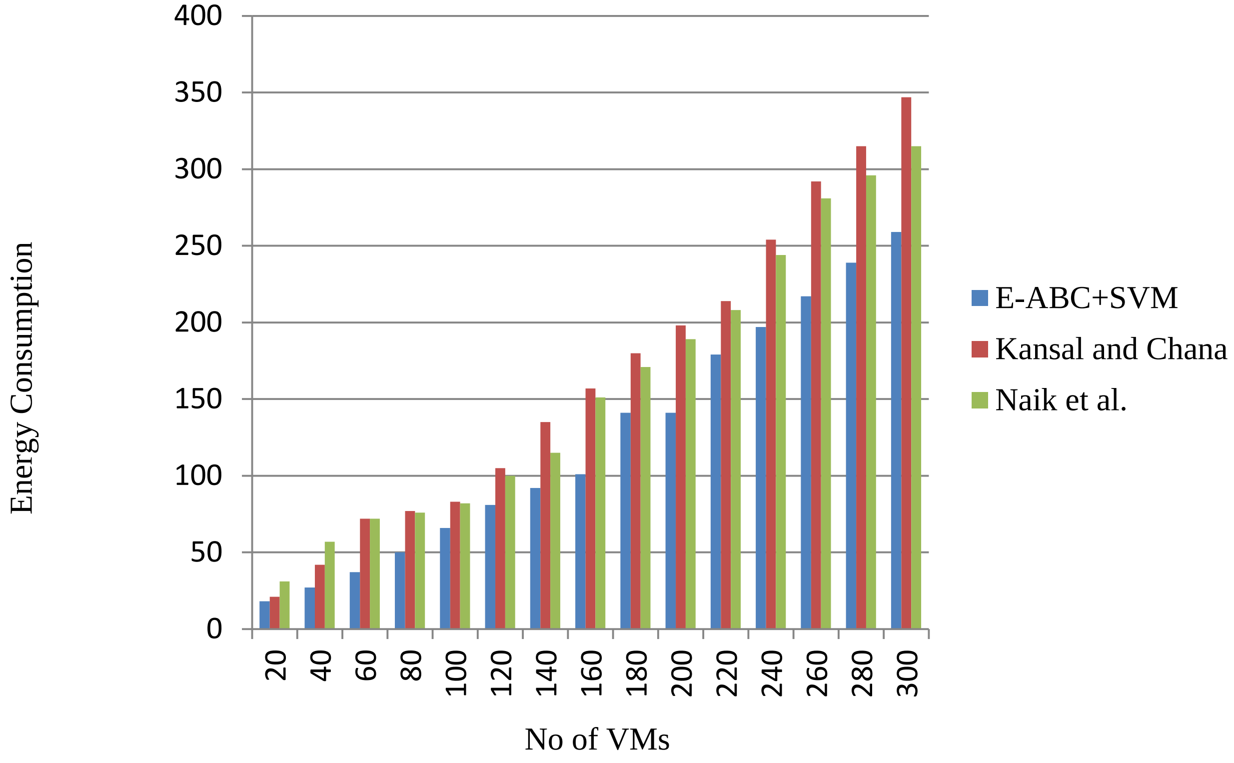

Figure 7.9 : Analysis of Energy Consumption Versus No of VMs

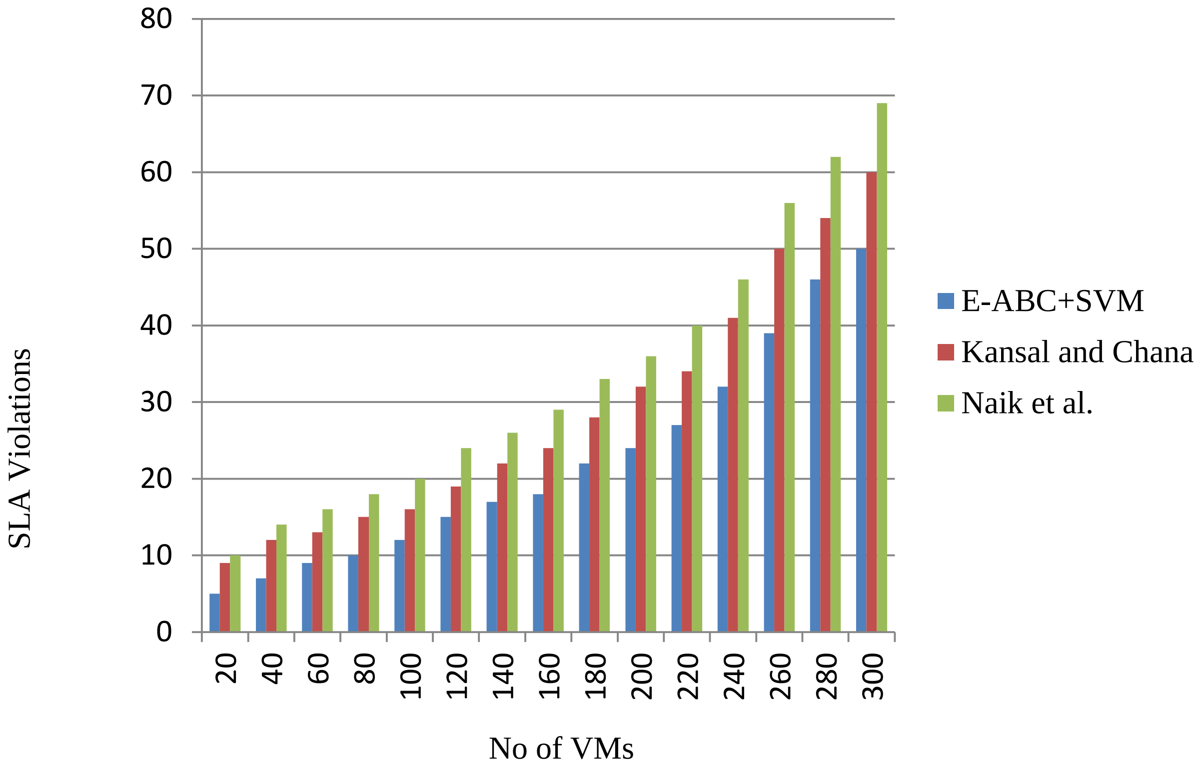

Figure 7.10 : Analysis of SLA Violations Versus No of VMs

It's critical to keep track of how many active hosts there are so that instances where hosts are idle and spending needless energy can be avoided.As a result, the proposed work is compared to the number of active hosts in two other efforts.The proposed optimization methodology's architecture has resulted in a significant reduction of active hosts.It's also worth noting that as the number of VMs grows, so does the number of hosts and migrations. When comparing the VM count of 10 to 300, the improvement study given in Figure 7.8 demonstrates a 10% to 30% improvement in the number of hosts.In other words, compared to Naik et al. and Kansal and Chana's studies, there are fewer active hosts.

The reason for this is that ABC and CS chose more accurate hosts for the VM allocation procedure with reduced discovery time due to their identifying global optimization with rapid coverage speed.

The improvement in resource utility resulted in reducing the number of false migrations that helped in avoiding wastage of energy resources. In Table 7.5, change in migration count with respect to VM count is also summarized. As we increase number of VMs, ultimately there will be increasing migrations. As compared to Naik et al. and Kansal and Chana work, however, the count of migrations took with the proposed work are very less. The improvement is seen for the proposed work in is illustrated in Figure 7.11 and in Figure 7.12. It is shown in the simulation analysis of our research that EA-ABC +SVM does very less VM migrations in comparison with FHCS (Naik et al.) and Firefly (Kansal and Chana). The improved ability for searching and allocating the best VM for minimizing the number of wrong migrations is also proved.

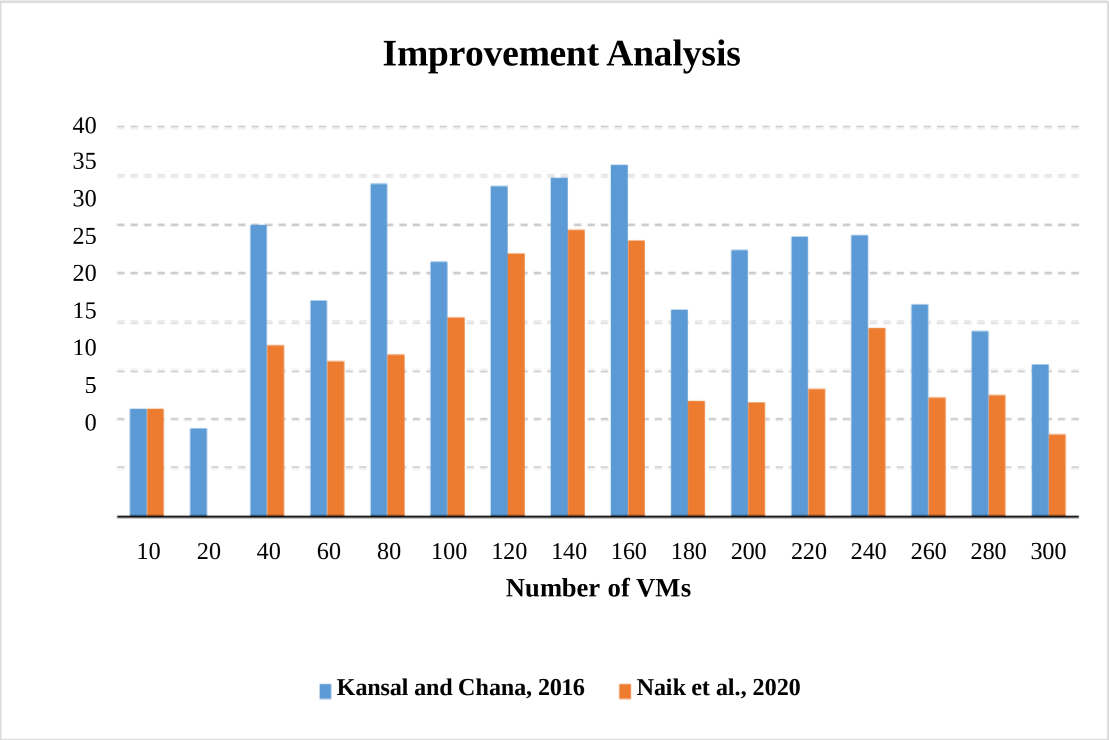

Figure 7.11 : % Improvement in terms of number of hosts

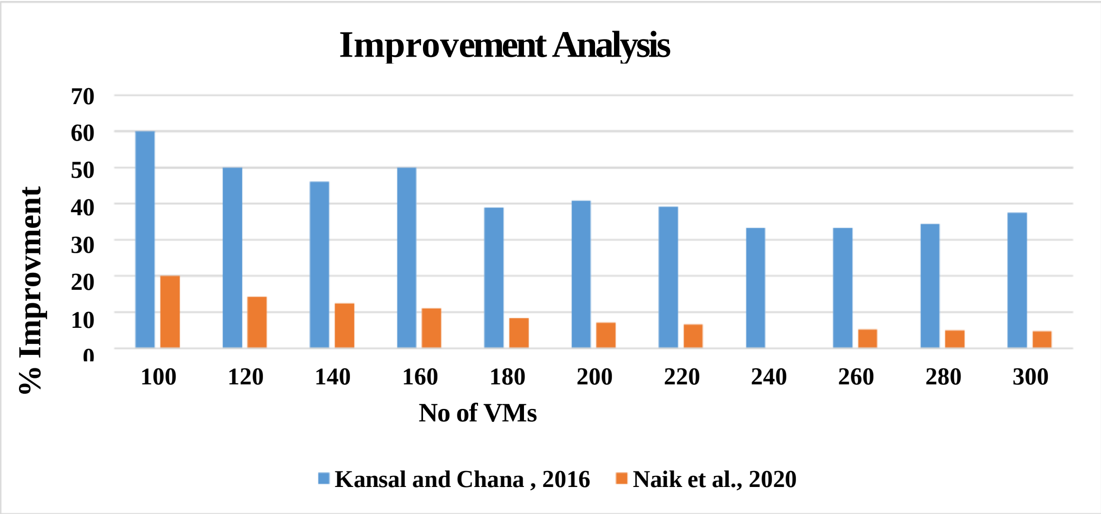

Figure 7.12 : % Improvement in terms of number of migrations

The capacity of EA-ABC +SVM to actively search for and allocate the best possible VM is also assessed in terms of energy consumption and SLA violation count.Table 7.6 shows the energy consumption and SLA breaches that occur as the number of virtual machines grows.

Table 7.6 : Analysis of energy consumption and SLA violations

Number of VMs	Energy Consumption (KWh)			SLA Violation		
	EA-ABC +SVM	Kansal and Chana, 2016	Naik et al., 2020	EA-ABC +SVM	Kansal and Chana, 2016	Naik etal., 2020
10	16	19	18	4	6	8
20	18	21	31	5	9	10
40	27	42	57	7	12	14
60	37	72	72	9	13	16
80	50	77	76	10	15	18
100	66	83	82	12	16	20
120	81	105	100	15	19	24
140	92	135	115	17	22	26
160	101	157	151	18	24	29
180	114	180	171	22	28	33
200	141	198	189	24	32	36
220	179	214	208	27	34	40
240	197	254	244	32	41	46
260	217	292	281	39	50	56
280	239	315	296	46	54	62
300	259	347	315	50	60	69

Figures 7.13 and 7.14 show how the suggested work can be significantly optimised in terms of optimum allocation and migration architecture for VMs while consuming the least amount of energy and exhibiting the fewest SLA breaches.

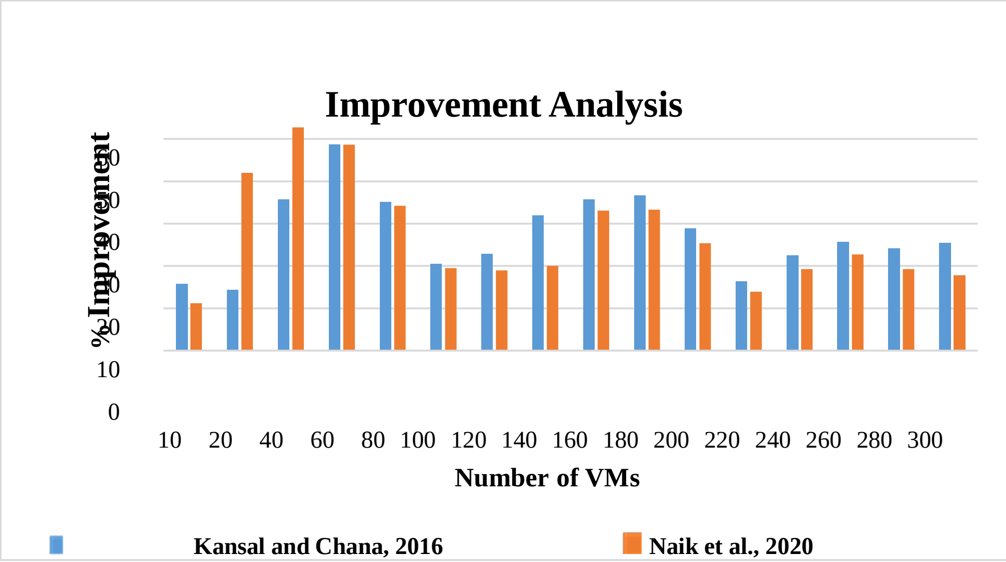

Figure 7.13 : % Improvement in terms of energy consumption

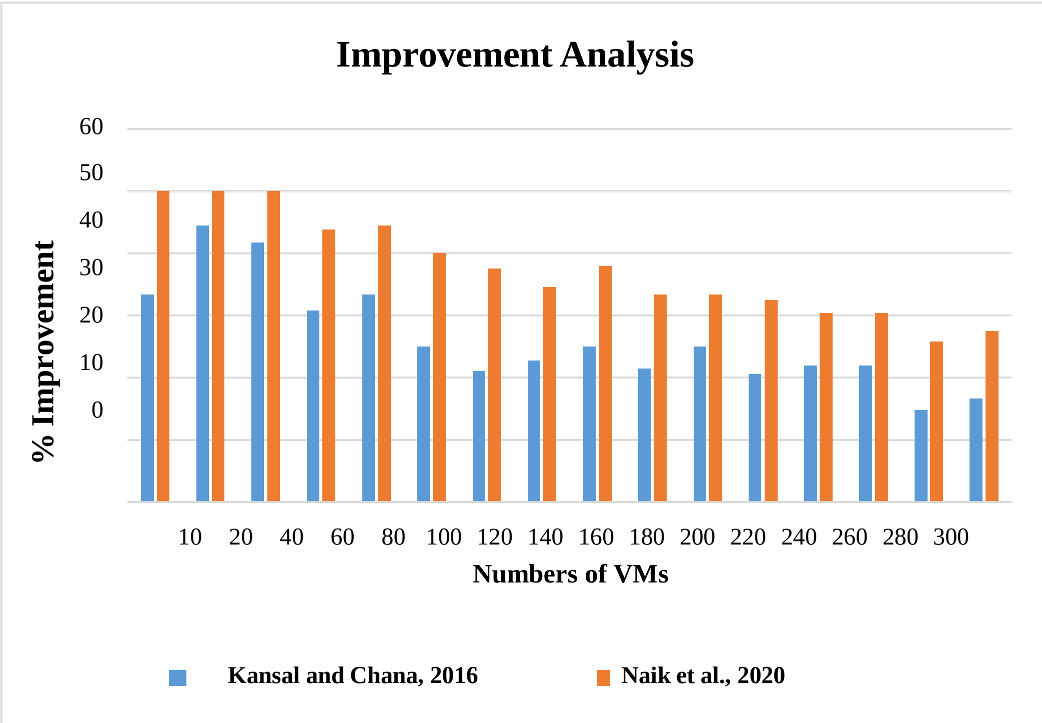

Figure 7.14 : % Improvement in terms of SLA violations

7.3 COMPARISON OF PROPOSED ALGORITHM IN TERMS OF CONFUSION MATRIX WITH KNN AND DECISION TREE ALGORITHM

Table 7.7 : Confusion Matrix for E-ABC + Decision Tree Approach

Accuracy	Precision	Recall	F-Measure	TP	FP	TN	FN	Class
87.80	1	0.947	0.96	36	0	2	3	1
4.87	0.6	1	0.57	2	3	36	0	2

Table 7.8 : Performance Parameters for E-ABC + Decision Tree Approach

Overall Accuracy	Overall Precision	Overall Recall	Overall F-Measure
92.67	0.800	0.9735	0.765

Accuracy of machine learning model is calculated by dividing the number of correct predictions (the corresponding diagonal in the matrix) by the total number of samples. Accuracy tells how many times the machine learning model was correct overall. For 41 samples taken,using decision tree with E-ABC gives an accuracy of 92.67.

Precision is one indicator of a machine learning model's performance that tells quality of a positive prediction made by the model. Using decision tree with E-ABC gives a precision of 0.800. The precision for machine learning model is calculated as:

Precision = TruePositives / (TruePositives + FalsePositives)

The recall measures the model's ability to detect positive samples. The higher the recall, the more positive samples detected. Using decision tree with E-ABC gives a recall of 0.9735. The recall for machine learning model is calculated as:

Recall = TruePositives / (TruePositives + FalseNegatives)

F-Measure allows a model to be evaluated taking both the precision and recall into account using a single score, which is helpful when describing the performance of the model and in comparing models. Using decision tree with E-ABC gives a F-Measure scorel of 0.765. The higher the precision and recall, the higher the F1-score. F1-score ranges between 0 and 1. The closer it is to 1, the better the model.F measure is calculated as follows:

F-Measure = (2 * Precision * Recall) / (Precision + Recall)

Table 7.9 : Confusion Matrix for E-ABC + KNN Approach

Accuracy	Precision	Recall	F-Measure	TP	FP	TN	FN	Class
73.17	1	0.81	0.895	30	0	4	7	1
9.75	0.363	1	0.53	4	7	30	0	2

Table 7.10: Performance Parameters for E-ABC+KNN Approach

Overall Accuracy	Overall Precision	Overall Recall	Overall F-Measure
82.92	0.6815	0.905	0.7125

Accuracy of machine learning model is calculated by dividing the number of correct predictions (the corresponding diagonal in the matrix) by the total number of samples. Accuracy tells how many times the machine learning model was correct overall. For 41 samples taken,using KNN with E-ABC gives an accuracy of 82.92.

Precision is one indicator of a machine learning model's performance that tells quality of a positive prediction made by the model. Using KNN with E-ABC gives a precision of 0.6815. The precision for machine learning model is calculated as:

Precision = TruePositives / (TruePositives + FalsePositives)

The recall measures the model's ability to detect positive samples. The higher the recall, the more positive samples detected. Using KNN with E-ABC gives a recall of 0.905. The recall for machine learning model is calculated as:

Recall = TruePositives / (TruePositives + FalseNegatives)

F-Measure allows a model to be evaluated taking both the precision and recall into account using a single score, which is helpful when describing the performance of the model and in comparing models. Using KNN with E-ABC gives a F-Measure score of 0.7125. The higher the precision and recall, the higher the F1-score. F1-score ranges between 0 and 1. The closer it is to 1, the better the model.F measure is calculated as follows:

F-Measure = (2 * Precision * Recall) / (Precision + Recall)

Table 7.11 : Confusion Matrix for E-ABC + SVM Approach

Accuracy	Precision	Recall	F-Measure	TP	FP	TN	FN	Class
95.122	1	0.975	0.98734	39	0	1	1	1
2.439	0.5	1	0.66667	1	1	0	39	2

Table 7.12 : Performance Parameters for E-ABC + SVM Approach

Overall Accuracy	Overall Precision	Overall Recall	Overall F-Measure
97.5610	0.7500	0.9875	0.8270

Accuracy of machine learning model is calculated by dividing the number of correct predictions (the corresponding diagonal in the matrix) by the total number of samples. Accuracy tells how many times the machine learning model was correct overall. For 41 samples taken,using SVM with E-ABC gives an accuracy of 97.5610.

Precision is one indicator of a machine learning model's performance that tells quality of a positive prediction made by the model. Using SVM with E-ABC gives a precision of 0.7500. The precision for machine learning model is calculated as:

Precision = TruePositives / (TruePositives + FalsePositives)

The recall measures the model's ability to detect positive samples. The higher the recall, the more positive samples detected. Using SVM with E-ABC gives a recall of 0.9875. The recall for machine learning model is calculated as:

Recall = TruePositives / (TruePositives + FalseNegatives)

F-Measure allows a model to be evaluated taking both the precision and recall into account using a single score, which is helpful when describing the performance of the model and in comparing models. Using SVM with E-ABC gives a F-Measure score of 0.8270. The higher the precision and recall, the higher the F1-score. F1-score ranges between 0 and 1. The closer it is to 1, the better the model.F measure is calculated as follows:

F-Measure = (2 * Precision * Recall) / (Precision + Recall)

7.4 Summary

The chapter discusses the proposed research mechanism against the existing state of art works. Also major reduction in energy is shown by the proposed algorithm against existing research work.

Chapter – 8

CONCLUSION

8.1 CONCLUSION

The study aims to address the VM allocation and migration issuers in cloud computing environment using Swarm Intelligence. MBFD forms the basic VM allocation technique along with the ABC based optimization strategies. In the initial stages, comprehensive survey is conducted to analyse the existing works in terms of energy efficiency and migration cost. It involved survey study of live VM migration literature while evaluating existing mechanisms aimed at efficient resource management. In the process, a number of shortcoming of the existing works are enlisted to guide the reliability enhancement work proposed in the current study. It was concluded that number of researchers had taken advantage of Artificial Intelligence technique to guide the VM allocation and migration for reducing the number of wrong migrations that effectively reduced the computation cost as well as energy consumption.

Firstly, the traditional Artificial Bee Colony (ABC) algorithm is enhanced with modification in the ABC fitness function. This allows the resources to be distributed evenly among the existing hosts. The proposed Enhanced ABC (E-ABC) exhibited wise allocation of VMs which reduced the number of VM migrations from the overloaded hosts to the underloaded hosts. In the process, Support Vector Machine (SVM) was integration for migrating VM migration. The effectiveness of the proposed E-ABC was evaluated against existing Enhanced-Cuckoo Search (E-CS) and Ant Colony Optimization (ACO) leading to the following observation.

- E-ABC exhibits reduced energy consumption of nearly, 15.45% was observed against E-CS and 17.03% was observed against ACO.
- Reduced SLA violations of about 23.86%, and 22.86 % was observed using E-ABC against existing E-CS and ACO, respectively.
- These observations are supported by decrease in the number of false or wrong VM migrations that were reduced by 10.91%, and 10.67%, achieved against E-CS and ACO, respectively.

In the next optimized VM allocation and migration work, researchers proposed an Energy Aware ABC (EA-ABC) to validate the performance of VMs. The optimal VM information is reported to SVM that trains the system for good and bad migrations. The designed EA-ABC is then evaluated against two existing works based on CS and Firefly Algorithm (FFA) and lead to the following conclusions.

- EA-ABC with SVM exhibited 10% to 30% reduced VM migrations when analysed against CS (Naik et al.) and FFA (Kansal and Chana) which is due to improved ability to allocate best VMs.
- An average reduced energy consumption of 10% to 25% was attained by EA-ABC over CS and FFA based optimization work of Naik et al. and Kansal and Chana.
- Further, minimal SLA violations are also observed even with large number of VMs are included in the simulation analysis resulting in an average reduction of 20% in the number of SLA violations.

Overall, it was observed that the integration of SI and ML approaches significantly reduced the existing challenges of cloud data centers. The modification in the fitness function of ABC, significantly reduced the overall issues of the cloud computing environment in terms of VM migrations, number of hosts, energy consumption, and SLA violations.

8.2 FUTURE SCOPE

The present work had focused on the implementing various strategies to improve the fitness function used in the nature inspired ABC algorithm. Moreover, SVM also proved to be a good candidate to distinguish good and bad migrations. In future, other set of similar optimization algorithms will be investigated to further improve the existing work while multi-class Ml approaches could be integrated for performance analysis against other state of art techniques.

REFERENCES

1. F. F. Moghaddam, M. B. Rohani, M. Ahmadi, T. Khodadadi, en K. Madadipouya, “Cloud computing: Vision, architecture and Characteristics”, in 2015 IEEE 6th Control and System Graduate Research Colloquium (ICSGRC), IEEE, 2015, bll 1–6.

2. M. V. Fard, A. Sahafi, A. M. Rahmani, en P. S. Mashhadi, “Resource allocation mechanisms in cloud computing: a systematic literature review”, IET Softw., vol 14, no 6, bll 638–653, Des 2020.

3. N. Khan, N. Ahmad, T. Herawan, en Z. Inayat, “Cloud Computing: Locally Sub-Clouds instead of Globally One Cloud”, International Journal of Cloud Applications and Computing (IJCAC), vol 2, no 3, bll 68–85, 2012.

4. P. Mell en T. Grance, “The NIST Definition of Cloud Computing”, National Institute of Standards and Technology Special Publication, vol 53, bll 1–7, 2011.

5. A. A. Patel en J. N. Rathod, “Reducing Power Consumption & Delay Aware Resource Allocation in Cloud Data Centers”, Journal of Information, Knowledge and Research in Computer Engineering, vol 2, no 2, bll 337–339, 2013.

6. X. Tan en Y. Kim, “Cloud computing for education: A case of using Google docs in MBA group projects”, in 2011 International Conference on Business Computing and Global Informatization, Shanghai, China, 2011.

7. C. Newcombe, T. Rath, F. Zhang, B. Munteanu, M. Brooker, en M. Deardeuff, “How Amazon web services uses formal methods”, Commun. ACM, vol 58, no 4, bll 66–73, Mrt 2015.

8. W. Y. C. Wang, A. Rashid, en H. M. Chuang, “Toward the trend of cloud computing”, Journal of Electronic Commerce Research, vol 12, no 4, 2011.

9. D. C. Wyld, Moving to the cloud: An introduction to cloud computing in government. 2009.

10. S. Al-Haj, E. Al-Shaer, en H. V. Ramasamy, “Security-aware resource allocation in clouds”, in 2013 IEEE International Conference on Services Computing, Santa Clara, CA, USA, 2013.

11. P. Guo en L.-L. Bu, “The hierarchical resource management model based on cloud computing”, in 2012 IEEE Symposium on Electrical & Electronics Engineering (EEESYM), Kuala Lumpur, Malaysia, 2012.

12. R. V. Deshmukh en K. K. Devadkar, “Understanding DDoS attack & its effect in cloud environment”, Procedia Comput. Sci., vol 49, bll 202–210, 2015.

13. H. Shukur, S. Zeebaree, R. Zebari, D. Zeebaree, O. Ahmed, en A. Salih, “Cloud computing virtualization of resources allocation for distributed systems”, Journal of Applied Science and Technology Trends, vol 1, no 3, bll 98–105, Jun 2020.

14. B. Wang, Y. Zheng, W. Lou, en Y. T. Hou, “DDoS attack protection in the era of cloud computing and Software-Defined Networking”, Comput. netw., vol 81, bll 308–319, Apr 2015.

15. J. Li et al., “CyberGuarder: A virtualization security assurance architecture for green cloud computing”, Future Gener. Comput. Syst., vol 28, no 2, bll 379–390, Feb 2012.

16. J. Spring, “Monitoring cloud computing by layer, part 1”, IEEE Secur. Priv., vol 9, no 2, bll 66–68, Mrt 2011.

17. L. M. Vaquero, L. Rodero-Merino, J. Caceres, en M. Lindner, “A break in the clouds: towards a cloud definition”, 2008.

18. K. Stanoevska-Slabeva en T. Wozniak, “Cloud basics-an introduction to cloud computing”, in grid and cloud computing, berlin, heidelberg: springer, 2010, bll 47–61.

19. R. K. Das, M. R. Patra, en A. K. Misro, “Cloud immunization and security for e-governance applications”, Int. J. Cloud Comput. Serv. Sci. (IJ-CLOSER), vol 2, no 3, Mei 2013.

20. Q. Zhang, L. Cheng, en R. Boutaba, “Cloud computing: state-of-the-art and research challenges”, J. Internet Serv. Appl., vol 1, no 1, bll 7–18, Mei 2010.

21. V. V. Rao en M. V. Rao, “A survey on performance metrics in server virtualization with cloudenvironment”, journal of cloud computing, 2015.

22. M. D. Kasi Viswanath, S. Kusuma, en S. K. Gupta, “Cloud computing issues and benefits modern education”, Global Journal of Computer Science and Technology, 2012.

23. S. S. Manvi en G. Krishna Shyam, “Resource management for Infrastructure as a Service (IaaS) in cloud computing: A survey”, J. Netw. Comput. Appl., vol 41, bll 424–440, Mei 2014.

24. Y. Jadeja en K. Modi, “Cloud computing-concepts, architecture and challenges”, in 2012 International Conference on Computing, Electronics and Electrical Technologies (ICCEET), IEEE, 2012, bll 877–880.

25. V. K. Reddy en L. S. S. Reddy, “Security architecture of cloud computing”, International Journal of Engineering Science and Technology (IJEST), vol 3, no 9, bll 7149–7155, 2011.

26. R. Moreno-Vozmediano, R. S. Montero, en I. M. Llorente, “Key challenges in cloud computing: Enabling the future internet of services”, IEEE Internet Comput., vol 17, no 4, bll 18–25, Jul 2013.

27. K. R. Jackson et al., Performance analysis of high performance computing applications on the amazon web services cloud. in 2010 ieee second international conference on cloud computing technology and science. IEEE, 2010, bll 159–168.

28. M. G. Avram, “Advantages and challenges of adopting cloud computing from an enterprise perspective”, Procedia technol., vol 12, bll 529–534, 2014.

29. Q. Z. Sheng, X. Qiao, A. V. Vasilakos, C. Szabo, S. Bourne, en X. Xu, "Web services composition: A decade's overview", Inf. Sci. (Ny), vol 280, bll 218–238, Okt 2014.

30. J. Sen, "Security and privacy issues in cloud computing", in Cloud Technology, IGI Global, 2015, bll 1585–1630.

31. C. Stergiou, K. E. Psannis, B. B. Gupta, en Y. Ishibashi, "Security, privacy & efficiency of sustainable Cloud Computing for Big Data & IoT", Sustain. Comput. Inform. Syst., vol 19, bll 174–184, Sep 2018.

32. M. Alkhalaileh, R. N. Calheiros, Q. V. Nguyen, en B. Javadi, "Data-intensive application scheduling on Mobile Edge Cloud Computing", J. Netw. Comput. Appl., vol 167, no 102735, bl 102735, Okt 2020.

33. R. Amin, S. Vadlamudi, en M. M. Rahaman, "Opportunities and challenges of data migration in cloud", opportunities and challenges of data migration in cloud. engineering international, vol 9, no 1, bll 41–50, 2021.

34. S. Basu et al., "Cloud computing security challenges & solutions-A survey", in 2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, 2018.

35. H. Tabrizchi en M. Kuchaki Rafsanjani, "A survey on security challenges in cloud computing: issues, threats, and solutions", J. Supercomput., vol 76, no 12, bll 9493–9532, Des 2020.

36. J. Zhang, N. Xie, X. Zhang, K. Yue, W. Li, en D. Kumar, "Machine learning based resource allocation of cloud computing in auction", machine learning based resource allocation of cloud computing in auction. comput. mater.continua, vol 56, no 1, bll 123–135, 2018.

37. K. Chitharanjan en R. SenthilKumar, "A study of resource allocation techniques in cloud computing", Int. J. Bus. Inf. Syst., vol 36, no 2, bl 254, 2021.

38. Y. S. Patel, N. Mehrotra, en S. Soner, “Green cloud computing: A review on Green IT areas for cloud computing environment”, in 2015 International Conference on Futuristic Trends on Computational Analysis and Knowledge Management (ABLAZE), Greater Noida, India, 2015.

39. L. Schuler, S. Jamil, en N. Kuhl, “AI-based resource allocation: Reinforcement learning for adaptive auto-scaling in serverless environments”, in 2021 IEEE/ACM 21st International Symposium on Cluster, PP. 804-811.

40. X. Qie, S. Jin, en W. Yue, “An energy-efficient strategy for virtual machine allocation over cloud data centers”, J. Netw. Syst. Manag., vol 27, no 4, bll 860–882, Okt 2019.

41. L. Qi, Y. Chen, Y. Yuan, S. Fu, X. Zhang, en X. Xu, “A QoS-aware virtual machine scheduling method for energy conservation in cloud-based cyber-physical systems”, World Wide Web, vol 23, no 2, bll 1275–1297, Mrt 2020.

42. A. E. Ezugwu, S. M. Buhari, en S. B. Junaidu, “Virtual machine allocation in cloud computing environment”, Int. j. cloud appl. comput., vol 3, no 2, bll 47–60, Apr 2013.

43. Y. Xing en Y. Zhan, “Virtualization and Cloud Computing”, in Lecture Notes in Electrical Engineering, Berlin, Heidelberg: Springer Berlin Heidelberg,2012, bll 305–312.

44. Zhang, H. Huang, X. Wang, “Resource provision algorithms in cloud computing: A survey,” Journal of Network and Computer Applications, 2016, Vol.64, pp. 23-42.

45. T. Guarda, M. F. Augusto, I. Costa, P. Oliveira, D. Villao, en M. Leon, The impact of cloud computing and virtualization on business. in international conference on advanced research in Technologies, Information, Innovation and Sustainability. Cham: Springer,2021, bll 399–412.

46. G. Singh en M. Mahajan, “A green computing supportive allocation scheme utilizing genetic algorithm and support vector machine”, computing, vol 23, 2019.

47. S.-Y. Jing, S. Ali, K. She, en Y. Zhong, “State-of-the-art research study for green cloud computing”, J. Supercomput., vol 65, no 1, bll 445–468, Jul 2013.

48. S. K. Garg en R. Buyya, “Green cloud computing and environmental sustainability”, bll 315–340, 2012.

49. A. Jain, M. Mishra, S. K. Peddoju, en N. Jain, “Energy efficient computing-green cloud computing”, in 2013 International Conference on Energy Efficient Technologies for Sustainability, IEEE, 2013, bll 978–982.

50. Mavridis en H. Karatza, “Combining containers and virtual machines to enhance isolation and extend functionality on cloud computing”, Future Gener. Comput. Syst., vol 94, bll 674–696, Mei 2019.

51. R. Gowriprakash, “A combined traffic and workload-aware optimized virtual machine migration in cloud computing”, turkish journal of computer and mathematics education (turcomat), vol 12, no 10, bll 3354–3365, 2021.

52. M. Dhaini, M. Jaber, A. Fakhereldine, S. Hamdan, en R. A. Haraty, “Green computing approaches-a survey”, informatica, no 1, 2021.

53. Dharshika en N. G. Cholli, “Green Cloud Computing: Redefining the future of Cloud Computing”, International Research Journal on Advanced Science Hub, vol 3, no Special7S, bll 12–19, Jul 2021.

54. J. A. Mehta, P. K.Nanavati, en V. K. Mehta, “A survey on green cloud computing”, International Journal of Engineering Applied Sciences and Technology, vol 6, no 1, Mei 2021.

55. X. D. Zhang, “Machine Learning”, A matrix algebra approach to artificial intelligence, pp. 223-440. Springer. Singapore, 2020.

56. H. S. Yahia et al., “Comprehensive survey for cloud computing based nature-inspired algorithms optimization scheduling”, Asian Journal of Research in Computer Science, bll 1–16, 2021.

57. E. H. Houssein, A. G. Gad, Y. M. Wazery, en P. N. Suganthan, Task scheduling in cloud computing based on meta-heuristics: review, taxonomy, open challenges, and future trends. Swarm and Evolutionary Computation. 2021.

58. D. Karaboga en B. Basturk, “A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm”, J. Glob. Optim., vol 39, no 3, bll 459–471, Okt 2007.

59. A. Salahudeen, S. B. Junaidu, en A. K. Ayeni, “An improved ant colony optimization algorithm for scheduling in cloud computing environment. recent trends in cloud computing and web engineering”, vol 3, 2021.

60. A. Pradhan, S. K. Bisoy, en A. Das, “A survey on PSO based meta-heuristic scheduling mechanism in cloud computing environment”, J. King Saud Univ. - Comput. Inf. Sci., Jan 2021.

61. F. Marini en B. Walczak, “Particle swarm optimization (PSO). A tutorial”, Chemometr. Intell. Lab. Syst., vol 149, bll 153–165, Des 2015.

62. X. S. Yang en S. Deb, “Engineering optimisation by cuckoo search”, Int. j. math. model. numer. optim., vol 1, no 4, bl 330, 2010.

63. I. Fister, X. S. Yang, en J. Brest, Memetic self-adaptive firefly algorithm. in swarm intelligence and bio-inspired computation. elsevier, 2013, bll 73–102.

64. F. Farahnakian, T. Pahikkala, P. Liljeberg, J. Plosila, N. T. Hieu, en H. Tenhunen, “Energy-aware VM consolidation in cloud data centers using utilization prediction model”, IEEE trans. cloud comput., vol 7, no 2, bll 524–536, Apr 2019.

65. S. B. Shaw en A. K. Singh, “Use of proactive and reactive hotspot detection technique to reduce the number of virtual machine migration and energy consumption in cloud data center”, Comput. Electr. Eng., vol 47, bll 241–254, Okt 2015.

66. L.-D. Chou, H.-F. Chen, F.-H. Tseng, H.-C. Chao, en Y.-J. Chang, "DPRA: Dynamic power-saving resource allocation for cloud data center using particle swarm optimization", IEEE Syst. J., vol 12, no 2, bll 1554–1565, Jun 2018.

67. N. J. Kansal en I. Chana, "Energy-aware virtual machine migration for cloud computing-a firefly optimization approach", Journal of Grid Computing, vol 14, no 2, bll 327–345, 2016.

68. C. Jo, Y. Cho, en B. Egger, "A Machine Learning Approach to Live Migration Modeling"", in Proceedings of SoCC '17, vol 14, Santa Clara, CA, USA, 2017.

69. K. Karthikeyan et al., "Energy consumption analysis of Virtual Machine migration in cloud using hybrid swarm optimization (ABC–BA)", J. Supercomput., vol 76, no 5, bll 3374–3390, Mei 2020.

70. K. Haghshenas, A. Pahlevan, M. Zapater, S. Mohammadi, en D. Atienza, "MAGNETIC: Multi-agent machine learning-based approach for energy efficient dynamic consolidation in data centers", IEEE trans. serv. comput., bll 1–1, 2019.

71. M. Hassan, A. Babikar, S. Zobli, B. M. Magdi, en M. E. Amien, "Machine Learning based approach for VM migration"", Technology horizons journal, vol 2, no 3, bll 83–88, 2018.

72. M. Masdari en H. Khezri, "Efficient VM migrations using forecasting techniques in cloud computing: a comprehensive review", Cluster Comput., vol 23, no 4, bll 2629–2658, Des 2020.

73. T. Le, "A survey of live Virtual Machine migration techniques", Comput. Sci. Rev., vol 38, no 100304, bl 100304, Nov 2020.

74. J. Li, M. Qiu, Z. Ming, G. Quan, X. Qin, en Z. Gu, "Online Optimization For Scheduling Preemptable Tasks On IaaS Cloud Systems"", Journal Of Parallel And Distributed Computing, vol 72, no 5, bll 666–677, 2012.

75. A. Hameed et al., "A survey and taxonomy on energy efficient resource allocation techniques for cloud computing systems", Computing, vol 98, no 7, bll 751–774, Jul 2016.

76. J. N. Khasnabish, M. F. Mithani, en S. Rao, “Tier-Centric Resource Allocation in Multi-Tier Cloud Systems”, IEEE trans. cloud comput., vol 5, no 3, bll 576–589, Jul 2017.

77. W. Zhu, Y. Zhuang, en L. Zhang, “A three-dimensional virtual resource scheduling method for energy saving in cloud computing”, Future Gener. Comput. Syst., vol 69, bll 66–74, Apr 2017.

78. H. A. Kurdi, S. M. Alismail, en M. M. Hassan, “LACE: A Locust-Inspired Scheduling Algorithm to Reduce Energy Consumption in Cloud Datacentres”, IEEE Access, vol 6, bll 35435–35448, 2018.

79. V. Chaudhrani, P. Acharya, en V. Chudasama, “Energy aware computing resource allocation using PSO in cloud”, in Information and Communication Technology for Intelligent Systems, Singapore: Springer Singapore, 2019, bll 511–519.

80. Das, Jaydeep, et al. "A Learning Technique for VM Allocation to Resolve Geospatial Queries." Recent Findings in Intelligent Computing Techniques. Springer, Singapore, 2019, 577-584.

81. H. Jia et al., “Security strategy for virtual machine allocation in cloud computing”, Procedia Comput. Sci., vol 147, bll 140–144, 2019.

82. S. K. Mishra, B. Sahoo, en S. K. Jena, “A secure VM consolidation in cloud using learning automata”, in Advances in Intelligent Systems and Computing, Singapore: Springer Singapore, 2019, bll 617–623.

83. X. Ruan, H. Chen, Y. Tian, en S. Yin, “Virtual machine allocation and migration based on performance-to-power ratio in energy-efficient clouds”, Future Gener. Comput. Syst., vol 100, bll 380–394, Nov 2019.

84. V. Barthwal, M. Rauthan, en R. Verma, “Virtual Machines Placement Using Predicted Utilization of Physical Machine in Cloud Datacenter”, in International Conference on Advances in Engineering Science Management & Technology (ICAESMT)-2019, Dehradun, India, 2019.

85. K. Dubey en S. C. Sharma, “An extended intelligent water drop approach for efficient VM allocation in secure cloud computing framework”, J. King Saud Univ. - Comput. Inf. Sci., Nov 2020.

86. A. S. Joshi en S. D. Munisamy, “Dynamic degree balanced with CPU based VM allocation policy for load balancing”, J. Inf. Optimiz. Sci., vol 41, no 2, bll 543–553, Feb 2020.

87. C. Harold, S. Lim, J. S. Babu, en S. S. Chase, “Automated Control in Cloud Computing: Challenges and Opportunities””, ACM Proceedings of the First Workshop on Automated Control for Data Centers and Clouds, 2009.

88. A. Beloglazov, J. Abawajy, and R. Buyya, “Energy-aware Resource Allocation Heuristics for Efficient Management of Data Centers for Cloud Computing,” Future Generation Computer Systems, Elsevier, vol. 28, issue 5, pp. 755-68, 2012.

89. Li, J., Qiu, M., Ming, Z., Quan, G., Qin, X., & Gu, Z, “Online optimization for scheduling preemptable tasks on IaaS cloud systems. Journal of Parallel and Distributed Computing, vol.72, pp. 666-677, 2012.

90. S. Esfandiarpoor, A. Pahlavan, and M. Goudarzi, “Virtual Machine Consolidation for Data center Energy Improvement”, Cornell University Library, Ithaca, New York, 2013.

91. Z. Xiao, W. Song, and Qi Chen, “Dynamic Resource Allocation Using Virtual Machines for Cloud Computing Environment”, IEEE Transactions on Parallel and Distributed system, vol. 24, issue 6, pp. 1107-1117, 2013.

92. Y.-J. Chiang, Y.-C. Ouyang, and C.-H.R. Hsu, "An efficient green control algorithm in cloud computing for cost optimization," IEEE Transactions in Cloud Computing, vol. 3, no. 2, pp. 145–155, Aug. 2015.

93. T. Kaur en I. Chana, “Energy efficiency techniques in cloud computing: A survey and taxonomy”, ACM computing surveys (CSUR), vol 48, bll 1–46, 2015.

94. S.M. AlIsmail and H.A. Kurdi, "Review of energy reduction techniques for green cloud computing," International Journal of Advanced Computer Science Application, Vol. 1, No. 7, pp. 189–195, 2016.

95. G. Han, W. Que, G. Jia, en L. Shu, “An efficient virtual machine consolidation scheme for multimedia cloud computing”, Sensors (Basel), vol 16, no 2, bl 246, Feb 2016.

96. M. Masdari, S. S. Nabavi, en V. Ahmadi, “An overview of virtual machine placement schemes in cloud computing”, J. Netw. Comput. Appl., vol 66, bll 106–127, Mei 2016.

97. M. Tang, X. Dai, J. Liu, en J. Chen, “Towards a trust evaluation middleware for cloud service selection”, Future Gener. Comput. Syst., vol 74, bll 302–312, Sep 2017.

98. G. Han, W. Que, G. Jia, en W. Zhang, “Resource-utilization-aware energy efficient server consolidation algorithm for green computing in IIOT”, J. Netw. Comput. Appl., vol 103, bll 205–214, Feb 2018.

99. T. Wang et al., “A comprehensive trustworthy data collection approach in sensor-cloud system”, IEEE Trans. Big Data, bll 1–1, 2019.

100. J. John en J. Norman, “Major vulnerabilities and their prevention methods in cloud computing”, in Advances in Intelligent Systems and Computing, Singapore: Springer Singapore, 2019, bll 11–26.

101. X. Sui, D. Liu, L. Li, H. Wang, en H. Yang, “Virtual machine scheduling strategy based on machine learning algorithms for load balancing”, EURASIP J. Wirel. Commun. Netw., vol 2019, no 1, Des 2019.

102. X. Zhang et al., “Energy-aware virtual machine allocation for cloud with resource reservation”, J. Syst. Softw., vol 147, bll 147–161, Jan 2019.

103. N. K. Chien, V. S. G. Dong, N. H. Son, en H. D. Loc, “An efficient virtual machine migration algorithm based on minimization of migration in cloud

computing", in Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Cham: Springer International Publishing, 2016, bll 62–71.

104. R. W. Ahmad, A. Gani, S. H. A. Hamid, M. Shiraz, A. Yousafzai, en F. Xia, "A survey on virtual machine migration and server consolidation frameworks for cloud data centers", J. Netw. Comput. Appl., vol 52, bll 11–25, Jun 2015.

105. H. Xiao, Z. Hu, en K. Li, "Multi-objective VM consolidation based on thresholds and ant colony system in cloud computing", IEEE Access, vol 7, bll 53441–53453, 2019.

106. A. Singh en S. Kinger, "Virtual machine migration policies inclouds", International Journal of Science and Research, vol 2, no 5, bll 364– 367, 2013.

107. Shalu en D. Singh, "Artificial neural network-based virtual machine allocation in cloud computing", J. Discrete Math. Sci. Cryptogr., vol 24, no 6, bll 1739–1750, Aug 2021.

108. D. Karaboga en B. Akay, "A survey: algorithms simulating bee swarm intelligence", Artif. Intell. Rev., vol 31, no 1–4, bll 61–85, Jun 2009.

109. N. Gholipour, E. Arianyan, en R. Buyya, "A novel energy-aware resource management technique using joint VM and container consolidation approach for green computing in cloud data centers", Simul. Model. Pract. Theory, vol 104, no 102127, bl 102127, Nov 2020.

110. A. Mehta, Efficient Resources Allocation and Energy Reduction with Virtual Machines for Cloud computing. 2018.

111. United States Data Center Energy Usage Report (US DC EUR), 2014, accessed online in Dec, 2021 at https://www.osti.gov/servlets/purl/1372902

112. P. Ranganathan, "Technical perspective: ASIC clouds: specializing the datacenter", Commun. ACM, vol 63, no 7, bll 102–102, Jun 2020.

113. R. K. Karda en M. Kalra, “Bio-inspired threshold based VM migration for green cloud”, in Advances in Data and Information Sciences, Singapore: Springer Singapore, 2019, bll 15–30.

114. B. B. Naik, D. Singh, en A. B. Samaddar, “FHCS: Hybridised optimisation for virtual machine migration and task scheduling in cloud data center”, IET Communications, vol 14, no 12, bll 1942–1948, 2020.

115. Sharma, Neeraj Kumar, and Ram Mohana Reddy Guddeti. "On demand virtual machine allocation and migration at cloud data center using hybrid of cat swarm optimization and genetic algorithm." In 2016 Fifth International Conference on Eco- friendly Computing and Communication Systems (ICECCS), pp. 27-32. IEEE, 2016.

116. Li, H., Zhu, G., Cui, C., Tang, H., Dou, Y., & He, C."Energy-efficient migration and consolidation algorithm of virtual machines in data centers for cloud computing." Computing 98.3 (2016): 303-317.

117. M. Lin, and R. Weiwei, "Multi-resource scheduling and power simulation for cloud computing." Information Sciences 397 (2017): 168-186.

118. Shabeera, T. P., SD Madhu Kumar, Sameera M. Salam, and K. Murali Krishnan. "Optimizing VM allocation and data placement for data-intensive applications in cloud using ACO metaheuristic algorithm." Engineering Science and Technology, an International Journal 20, no. 2 (2017): 616-628.

119. Sharma, Yogesh, Weisheng Si, Daniel Sun, and Bahman Javadi. "Failure-aware energy-efficient VM consolidation in cloud computing systems." Future Generation Computer Systems 94 (2019): 620-633.

120. Li, Lianpeng, Jian Dong, Decheng Zuo, and Jin Wu. "SLA-aware and energy-efficient VM consolidation in cloud data centers using robust linear regression prediction model." IEEE Access 7 (2019): 9490-9500.

121. Raksha et al. “Bio-inspired Threshold Based VM Migration for Green Cloud” Advances in Data and Information Sciences :15-30.

122. Boonhatai Kruekaew, Warangkhana Kimpan," Enhancing of Artificial Bee Colony Algorithm for Virtual Machine Scheduling and Load Balancing Problem in Cloud Computing" International Journal of Computational Intelligence Systems, Vol. 13(1), 2020, pp. 496–510.

123. Kaaouache, Mohamed Amine, and Sadok Bouamama. "An energy-efficient VM placement method for cloud data centers using a hybrid genetic algorithm." Journal of Systems and Information Technology (2018).

124. Wang, Tian, et al. &quot , A comprehensive trustworthy data collection approach in sensor-cloud system, IEEE Transactions on Big Data (2018).

125. Xialin Liu, Junsheng Wu, Gang Sha and Shuqin Liu," Virtual Machine Consolidation with Minimization of Migration Thrashing for Cloud Data Centers", Hindawi Mathematical Problems in Engineering ,Volume 2020, Article ID 7848232, 13 pages

126. Tarahomi, M., Izadi, M. and Ghobaei-Arani, M., 2020. An efficient power-aware VM allocation mechanism in cloud data centers: a micro genetic-based approach. Cluster Computing, pp.1-16.

127. Karthikeyan, K., R. Sunder, K. Shankar, S. K. Lakshmanaprabu, V. Vijayakumar, Mohamed Elhoseny, and Gunasekaran Manogaran. "Energy consumption analysis of Virtual Machine migration in cloud using hybrid swarm optimization (ABC–BA)." The Journal of Supercomputing 76, no. 5 (2020): 3374-3390.

128. Songara, Neha, and Manoj Kumar Jain. "Design of QoS and Energy Efficient VM Consolidation Framework for Cloud Data Centers." In Advances in Cybernetics, Cognition, and Machine Learning for Communication Technologies, pp. 171-179. Springer, Singapore, 2020.

129. Li, H., Zhu, G., Cui, C., Tang, H., Dou, Y., & He, C."Energy-efficient migration and consolidation algorithm of virtual machines in data centers for cloud computing." Computing 98.3 (2018): 303-317.

130. Tabrizchi H, Kuchaki Rafsanjani M, Balas VE. 2021. Multi-task scheduling algorithm based on self-adaptive hybrid ICA_PSO algorithm in cloud environment. Advances in Intelligent Systems and Computing 1222:422_431DOI 10.1007/978-3-030-52190-5_30.

131. Li X, Gao R, Yu L, Li N, Liu J, Wang Y, Feng E. 2021. Memetic strategy of particle swarm optimization for one-dimensional magnetotelluric inversions. Mathematics 9(519)1_22.

132. Balakrishna, S.K., Shetty, S.M., Martis, J.E., Ramasamy, B. (2022). "Genetic Algorithm-Based Pseudo-Random Number Generation for Cloud Security.," In Misra, S., Kumar Tyagi, A., Piuri, V., Garg, L. (eds) Artificial Intelligence for Cloud and Edge Computing. Internet of Things. Springer, Cham. https://doi.org/10.1007/978-3-030-80821-1_10.

133. Kruekaew B, Kimpan W. 2020. Enhancing of artificial bee colony algorithm for virtual machine scheduling and load balancing problem in cloud computing. International Journal of Computational Intelligence Systems 13(1):496_510 DOI 10.2991/ijcis.d.200410.002.

134. Tamura Y, Sakiyama T, Arizono I. 2021. Ant colony optimization using common social information and self-memory. Complexity 2021: DOI 10.1155/2021/6610670.

135. Zhang G, Wang H, Zhao W, Guan Z, Li P. 2021. Application of improved multiobjective ant colony optimization algorithm in ship weather routing. Journal of Ocean University of China 20:45_55 DOI 10.1007/s11802-021-4436-6.

136. Lu, Jiawei, et al. "Optimal machine placement based on improved genetic algorithm in cloud computing," The Journal of Supercomputing 78.3 (2022): 3448-3476.

DISSEMINATION OF WORK

Published Work in Journals

1) Suruchi Talwani, Dr.Jimmy Singla, "A Systematic Review of Cloud Resource Allocation Techniques for achieving Quality of Service", Journal of Advanced Research in Dynamical and Control Systems, Vol. 11,2019(Scopus-Indexed).

2) Suruchi Talwani et al., "Allocation and Migration of Virtual Machines using Machine learning*",*Computers,Materials & Continua(CMC), Volume 70,2021(Scopus and WOS).

3) Suruchi Talwani,Jimmy Singla, "A Comprehensive Review on Energy Efficient Virtual Machine (VM) Allocation and Migration Techniques", Turkish Online Journal of Qualitative Inquiry (TOJQI),Volume 12,Issue 4,*2021*(Scopus Indexed).

Published Work in Conferences

1) Suruchi Talwani, Jimmy Singla, "Enhanced Bee Colony Approach for reducing the energy consumption during VM migration in cloud computing environment", in 1st International Conference On Computational Research And Data Analytics(ICCRDA), 2021(ScopusIndexed).
2) Suruchi Talwani,Jimmy Singla, "A Comprehensive Review of Virtual Machine Migration Techniques in Cloud Computing", in 1st International Conference On Intelligent Communication And Computational Research (ICICCR),2020.