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Research Article

A Comprehensive Review on Energy Efficient Virtual Machine (VM) Allocation and Migration Techniques

Suruchi Talwani, Jimmy Singla

School of CSE, Lovely Professional University, Punjab

suruchi.21629@lpu.co.in, jimmy.21733@lpu.co.in

Abstract: Virtual machines (VM) are most frequently utilized by engineers as well as many organizations. Cloud computing is a framework that provides the feature of running another operating system on the same host machine without changing the mode of the system. From the last couple of years, the data centers are evolving enormously in complexity, size and energy consumption. One of the major challenges that are faced by the researchers is the reduction of energy used. Hence, energy management is the key issue that has to be a focus on thoroughly. Also, the energy can be managed by the appropriate allocation of virtual machines (VM). Many researchers have presented their work in order to maintain energy efficiency by using different techniques and methodology, but still, it lacks in its rationale. That's why this study presented a road map of the research gap by which a researcher can analyze that how could energy efficiency be maintained. A number of artificial intelligence techniques used by the researchers for virtual machine allocation and migration and these methodologies also help to reduce the energy consumption are reviewed in this paper. The significant objective of this study is to analyze all the methodologies used by the researcher, and according to that evaluation, the best technique can be figured out. Additionally, this paper also assists in conducting future research work as it illustrated the several directions that can be used for further research work.

Keywords: Artificial Intelligence, Cloud computing, Data Centers, virtual Machine allocation, energy consumption.

1. Introduction

Virtual machine refers to an environment that deals reside within a computer. It is a mechanism that deals with an isolated partition of the actual host machine. Engineers use this partition just to balance the storage of the machine. Generally, this virtual machine works with its own CPU power, operating system, resources, RAM etc. [1]. No doubt, this could breach the overall security of the machine. Moreover, it also consumes a large amount of energy. In order to manage this, several researches and mechanism are analyzed in this study. Cloud computing is a novel and frequently approachable business model as it enables the different devices or virtual machine to have an accurate amount of network access [2]. It is evident that there is a high demand for resource utilization as cloud computing is dealt with a large number of cloud centers that stores the data in a well-organized manner [3], [4]. However, this causes major problems like the emission of greenhouse gases as well as service costs. It is effectively analyzed that the virtual machines are those technologies that consume a high amount of energy [5],[6]. It also has the possibility that virtualization technology could entirely make the whole network lack energy [7]. If the virtual machines are allocated appropriately and adequately, then it definitely leads to the fascination of work in data centers [8]. Hence, in the case of cloud computing, the allocation of the virtual machine becomes a major concern. The virtual machines are allocated in such a manner that does not only fulfil the requirement of the application, but also consumes less energy [9]. Figure 1 shows the allocation of virtual machine (VM).

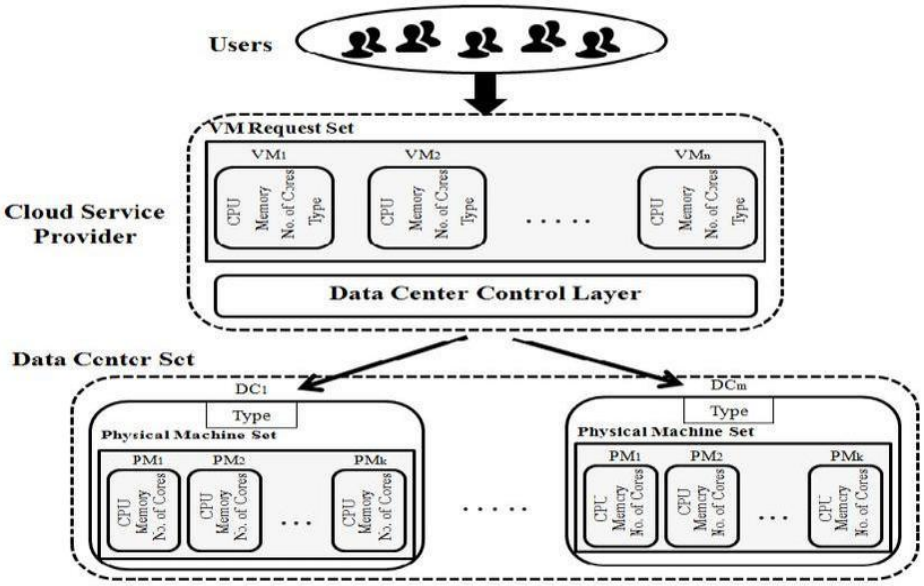

Figure 1: Allocation of Virtual Machine (VM) [10]

Additionally, the migration of the virtual machine is also necessary as it assists in enhancing the use of required resources, tolerates the faults and also helps in balancing the loads of nodes that are under processing [11]. The virtual machine (VM) migration is responsible for the migration of virtual devices' state between the physical host while the process of virtual machine migration occurs [12]. Figure 2 displays the overview of the virtual machine migration process on a distributed cloud data centers.

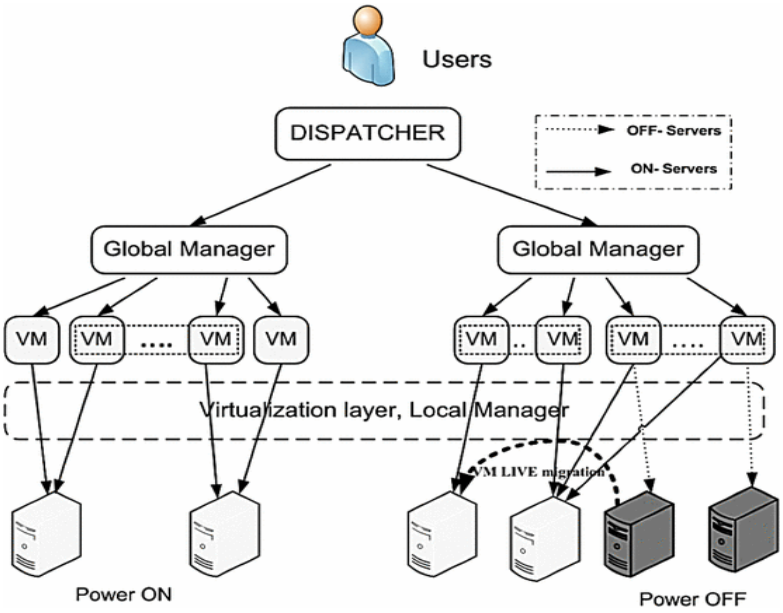

Figure 2: Virtual Machine Migration Process [12]

The researchers have done a considerable amount of research work to reduce the energy consumption during the process of allocation as well as migration of virtual machine. Artificial intelligence is the most used domain by researchers to accomplish their decided objectives. An artificial Intelligence introduced a number of algorithms that can be used for the optimization problems, such as ant colony optimization [13], cuckoo search algorithm [14], bee colony algorithm, bat colony algorithm [5], reinforcement learning [15], etc. These are the emerging techniques or algorithms that assist the researchers to solve the optimization of any parameter, whether it is energy or distance or power.

The entire paper is arranged in an effective manner as given: Section 2 of the paper is a comprehensive review of different algorithms or techniques used by the researchers to reduce the energy during the allocation as well as migration of virtual machine in cloud data centers. Further, the next section, i.e., section 3, is all about discussion as well as analysis of the conducted work and the future directions are also discussed. The last section, i.e. section 4, gives the conclusion of the whole work done in this paper.

2. Artificial Intelligence techniques used for virtual machine allocation and migration

This section enlightens the various research work done by using artificial intelligence techniques for the allocation as well as migration of virtual machine (VM).

2.1. Artificial Neural Network (ANN)

The sophisticated functionality to perform a particular task by the human brain is the idea from which an artificial neural network is being inspired. There is a huge number of neurons in the human brain which are associated with one another and assist in data processing in a parallel manner [16], [17], [18]. This methodology is emerging as it helps to solve computational as well as complex mathematical problems [19], [20]. Figure 3 represents the block diagram of ANN along with its all layers.

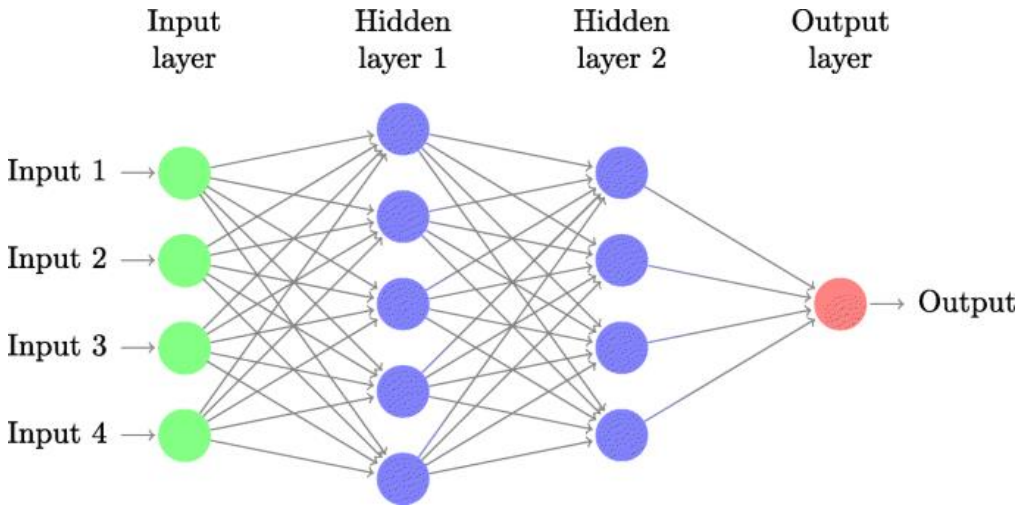

Figure 3: Artificial Neural Network [21].

Rawat et al. (2020) [22] introduced a new model by using an artificial neural network to enhance the real-time applications' performance in the cloud. The genetic algorithm is used by the researcher for the training phase of the proposed system. The performance has been improved by the system by decreasing the waiting time of the task, consumption of power and time of execution of tasks. This model is also compared with existing models and proved as a better system among them. It enhances the time of execution by 36 percent, scheduling time by 77.14 percent as well as the power efficiency is improved by 13 percent.

Kakkar & Young (2018) [23] did the virtual allocation in cloud computing by using the machine learning methodology. The artificial neural network has been used by the researcher to classify the capabilities of host machines such as underloaded, normal loaded and overloaded. Additionally, the artificial neural network is being used for analyzing the modified best fit decreasing technique. The modified best fit decreasing technique is utilized to keep an eye on the power allocation scheme. It also assists in updating the minimum power, which is necessary for virtual machine allocation as well as migration. According to the results, it is observed that the accuracy of allocation is 99.99 percent. Moreover, the average gradient value and the average rate of error for this developed model is 54.08 and 0.001478, respectively.

Singh et al. (2020) [24] accomplished an objective of minimizing the consumption of energy and SLA violation by using the artificial neural network and modified best fit decreasing algorithm with several migrations. It is stated that the energy which is required for migration can be optimized by utilizing these techniques. The proposed methodology is also compared with the existing models which are introduced by other researchers. As the result of the comparative study, it is observed that the proposed model is better than others, and also it overcome the limitations as well as loopholes of the existing models.

Shalu & Singh (2021) [25] presented the allocation of the virtual machine by using the enhanced modified best fit decreasing algorithm. The artificial neural network is also used to cross-validate the virtual machines which are allocated on physical machines by using the E-MBFD technique. This study also helps to figure out those allocations which are false. The false allocation occurs because of inappropriate resource usage. This research work further also assisted to allocate those virtual machines again. The result of this study shows that this method is best to minimize the consumption of power as well as it also has fewer SLA violation as compared to the traditional methodologies used by other researchers.

N & Basu (2015) [26] presented a mathematical model by using an artificial neural network that can be utilized for the allocation of resources with run-time-instrumentation. The proposed system evaluates the algorithm of resource management mathematically. This model has the ability to utilize resource wastage, as well as this proposed system, has a better response time. This system is executed in a simulator known as cloud-sim on the basis of dynamic instrumentation for the allocation of required resources.

Witanto et al. (2018) [27] provided an approach by using an artificial neural network for the selection of virtual machine consolidation algorithm. This approach adaptively selects an adequate technique corresponding to the environment parameters as well as the priority of cloud providers. The entire simulation has been done by using the PlanetLab. The obtained result illustrated that the proposed selector system has better accuracy as the results of this system is quite satisfactory. It also has more performance score as compared to other methods, which are independent.

Radhakrishnan & Kavitha (2016) [28] proposed a technique that is used for the prediction of data center's availability in future by using the artificial neural network. The various activities of the virtual machine are further operated on the basis of resources that are available in the near future. The result obtained from research work stated that this methodology assists in decreasing the time of processing in data centers. It also helps to reduce the customer application response time by optimizing the migration of virtual machines.

2.2. Reinforcement Learning (RL)

In reinforcement learning, the system does not train about what action it has to be performed; instead, the system has to figure it out on its own by acquiring the rewards for each and every action [29]. It is goal-oriented learning [30]. This learning helps the system to develop a sequence of decisions. The prime objective of it is to make the total reward as maximum as possible [31]. In this learning, there is one or a number of agents which interact with the environment by doing some actions a_t jump into another state S_t and the rewards R_t are distributed according to the performed actions [32]. The proper procedure of reinforcement learning is shown in figure 4.

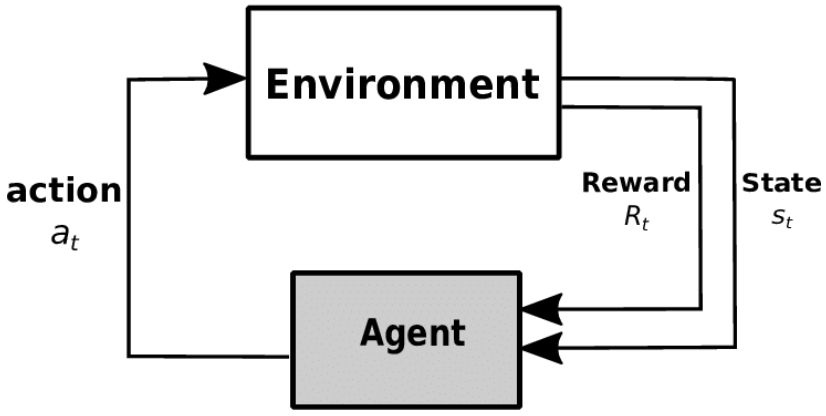

Figure 4: Reinforcement Learning [32]

To reduce the upgrade time, Ying et al. (2020) [33] proposed an approach to schedule the virtual machine migration while doing its up-gradation on any physical machine. The proposed methodology is a kind of scheduler and developed by using deep reinforcement learning. The name of this newly proposed scheduler is RAVEN, and it is an experience-driven methodology. The system has the ability to figure out the minimum migration time even when dealing with a totally unseen environment by doing the interaction with it. The results depict that the simulated approach is more effective in contrast to other scheduling approaches that existed in the literature.

Duggan et al. (2016) [34] created a technique of reinforcement learning along with an identical agent to choose the virtual machine (VM) in the data centers by using efficient energy. This approach has the capability to learn, and according to that, it selects a virtual machine optimally for its migration from a host, which is over-utilized. When the system chooses an adequate virtual machine to migrate it, then the system will be rewarded by its performance feedback. The outcome of the introduced system shows that this system helps in decreasing the consumption of energy as well as it also assists the iterations of migration.

In the case of cloud computing and for the data centers, the main challenge that has to be faced is energy consumption and resource utilization. To overcome this problem, Shaw et al. (2017) [35] proposed an algorithm that has the capacity to optimize the virtual machines as well as can do management of resources effectively. This approach has been developed by using the advanced reinforcement learning consolidation agent. This introduced approach can learn the behaviour of a particular environment without even having considerable knowledge about it. Hence, this system can work under uncertainty. The result of this research work demonstrates that it can enhance energy consumption significantly and decrease service violations as well.

Thein et al. (2020) [36] introduced a framework by using reinforcement learning as well as fuzzy logic to suggest allocation policies optimally. This framework has achieved commendable performance in improving the energy consumption for data centers along with fewer SLA violation. The simulation framework that is being utilized for the development of this proposed approach is CloudSim. The infrastructure efficiency of data centers, power usage effectiveness, as well as CPU utilization, is evaluated at the level of the data center during the allocation process and also effectively demonstrated by using the graphical representation. According to the observed results, the developed framework effectively enhances energy efficiency by considering these mentioned parameters.

2.3. Linear Regression (LR)

The linear regression is utilized to develop the model which can able to predict the association between the considered variables [37]. It is a supervised machine learning algorithm [38] and demonstrates the linear relationship among the independent variable or variables as well as dependent variable [39].

Haghshenas & Mohammadi (2020) [40] developed an approach on the basis of regression that has the capability to forecast the utilization of virtual machine's resources as well as hosts by using the data gathered from previous predictions. The use of historical knowledge for future prediction helps to offer a chance of choosing a host which is considered under higher usage for the virtual machine migration destination. The experimental results are also conducted on this research work which depicts that the proposed methodology helps to decrease the consumption of energy up to 38 percent when compared with other existing methodologies introduced by other researchers in the same domain.

Li et al. (2019) [41] presented a system by utilizing the machine learning approach, i.e. simple linear regression. This system is used to predict the consumption of energy as well as SLA violations of virtual machine (VM) in cloud data centers. The main novelty of this research work is that it does not use native linear regression; instead, to evaluate the error in the proposed model; the researchers utilized the 8 different approaches. The outcome of this research work was that this proposed model decreased the rate of SLA violation up to 99.16 percent as well as the consumption of the energy is also reduced by this approach up to 2.43 percent while working on the real-world workload.

Abdelsamea et al. (2017) [42] proposed an algorithm that assisted in improving virtual machine consolidation. The algorithm has been developed by using multiple regression, which further detected the utilization of CPU, bandwidth as well as memory for the overloaded host. This developed approach is a hybrid factor and also known as Multiple Regression Host Overload Detection (MRHOD). The primary goal of this approach is to decrease the consumption of energy along with all Service Level Agreements. The respective methodology is able to reduce the energy by six times when contrasted with other approaches which were developed by utilizing the single factor. Basically, this methodology overcomes all limitations of single factor algorithms.

Khoshkholghi (2017) [43] introduced an approach by using a weighted linear regression algorithm for the utilization prediction. The presented approach assisted in predicting the future utilization of network bandwidth, RAM as well as CPU by using the heuristic knowledge acquired from previous predictions done on each and every server. This methodology can also be implemented in the live migration process for forecasting host overloading. When the system identifies any host to be overloaded, then the different virtual machine is allocated again to other

hosts in order to decrease the utilization of that specific host. The results observed from this approach are quite satisfying, and also it helps in the reduction of energy that is being consumed along with the fewer SLA violations.

2.4. K - Nearest Neighbor Classifier (KNN)

To classify the unlabelled observation into a correct class, the k- nearest neighbor classifier is used. It classifies those observations in that particular class which has the most similar labelled instances [44]. It is a simple machine learning algorithm used for classification. It is a simple as well as effective technique to solve the problems related to classification [45]. The Euclidean distance is calculated among the unlabeled observation and labelled observation. Further, the unlabeled observations are classified into those class which has minimum distance and a maximum number of neighbors [46].

To schedule the virtual machines, Kavya et al. (2020) [47] presented an algorithm that helped in analyzing the previous scheduling task and by using this past knowledge, it assisted in scheduling the particular virtual machine. The entire algorithm is based on the classification by utilizing the machine learning classifiers such as Naïve Bayes and k- nearest neighbor (KNN) classifier. The various process for cloud management has been used in this research work which helps to keep minimum degradation of performance. The proposed algorithm is also compared with the support vector machine, and according to the computed results, the introduced algorithm has better efficiency than SVM. It also reduces the error rate up to 0.025%.

Ahmed Kanona et al. (2018) [48] proposed a technique on the basis of machine learning which can able to allocate as maximum as possible resources to the host along with assuring all the service level agreement. This research work stated that if the instances of multiple virtual machine are created, then it automatically assists cloud providers for the maintenance as well as utilization of resources more adequately and appropriately in the data centers. The proposed algorithm is also compared with other machine learning prediction models such as support vector machine and regression tree. According to the experimental outcome, the performance of these models is less than the proposed model in this research work.

2.5. Support Vector Machine (SVM)

An algorithm that acquires information or knowledge about the rules of classification, as well as regression from the provided data set, is known as a support vector machine or SVM [49]. This algorithm aids to find out a specific hyperplane from a number of hyperplanes. The distance among the attributes of the parent classes must be maximum in the selected hyperplane [50]. The optimal hyperplane, as well as several hyperplane, are shown in figure 5.

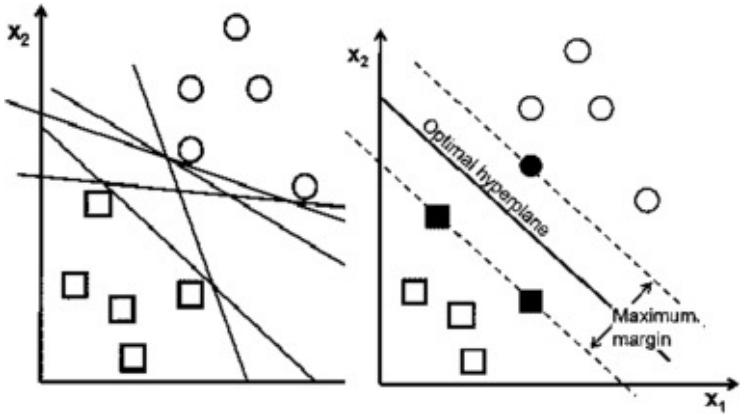

Figure 7: Support Vector Machine [51]

The migration problem of the virtual machine in the cloud data center is being formulated by Tseng et al. (2014) [52]. An algorithm is developed by the researcher to allocate the virtual machine to the PMs. This approach is proposed by using the machine learning technique known as Support Vector Machine (SVM). This Virtual machine allocation technique assisted to accomplish the maximum utilization of necessary resources as well as the number of migrations of the virtual machine is also minimum while the training phase of the system. The developed PMs, as well as VMs, are also used for those data centers which are large in size. The researchers also stated that the proposed algorithm could able to build a network that is balanced, robust as well as stable.

Patel et al. (2016) [53] presented a framework that aids in the prediction on the basis of time series, and the prediction is being made by using historical or past datasets. The researcher proposed the model of time series by using two methodologies of regression, i.e., auto-regression integrated moving average and support vector regression. The support vector machine is also used for classification. The real dataset is utilized to test the developed model in order to evaluate the transferred total number of pages as well as the total time of migration. The SVR model has higher accuracy, i.e. 94.61 percent, whereas the ARIMA has only 91.74% accuracy in forecasting the dirty pages. The researcher also demonstrated that the concept of using a support vector machine along with a support vector machine regression system proved accurate and adequate when in contrast with other systems of machine learning developed by other researchers.

Sotiriadis et al. (2018) [54] introduced a new approach for scheduling of virtual machine in such a manner that it will help to optimize the performance. The entire schedule of VMs is totally on the basis of previous allocations knowledge, i.e., the algorithm used historical or past data to predict the new schedule for virtual machines, which is optimal in nature. The significant intent of conducted research work is to provide an algorithm that is able to minimize the degradation of performance. To accomplish the required goal, the researchers utilized two different schemes of optimizations such as support vector machine and support vector regression. This developed approach aids to minimize the degradation of performance by 19 percent. Additionally, when the real-world workloads have been utilized, the maximization of CPU real-time has been done by 2 percent.

2.6. Swarm Intelligence (SI)

A domain of computer science which deals with different collective intelligence algorithms is known as swarm intelligence [55]. The main inspiration behind the swarm intelligence is the behavior of colonies of insects, flocks, herds or swarms, which work collectively and make decisions to accomplish a required goal or objective. Hence, it is also known as the brain of brains [56]. Swarm intelligence has the ability to solve complex as well as computational optimization problems by taking the idea from biological swarm behavior [57].

To attain a solution that is optimal for energy consumption, Balaji Naik et al. (2020) [58] proposed a hybrid algorithm by using two algorithms of swarm intelligence, known as the Fruit Fly Hybridized Cuckoo Search Algorithm. This proposed approach assisted the researcher to minimize the usage of energy as well as resources in the cloud data centers. The researchers also compare this algorithm with other swarm intelligence algorithm such as particle swarm optimization, ant colony system and also with genetic algorithm. The conclusion of this conducted research work is that the proposed approach is more energy-efficient than ACS, GA as well as PSO. It used 72 percent fewer resources and 68 KwH less energy as compared to other methodologies.

Dinesh Reddy et al. (2017) [59] presented an algorithm to solve the optimization problems such as the utilization of bandwidth as well as memory and the virtual machine's size. The proposed approach is totally based on the modified particle swarm optimization, which is used for VM's initial placement. The experimental results for this conducted research work demonstrated that the developed selection, as well as allocation approach, is minimizing the consumption of energy by 32 percent as well as it also decreases the violations of SLA when compared with other algorithms of swarm intelligence.

Ibrahim et al. (2020) [60] developed an approach of power-aware on the basis of Particle Swarm Optimization for determining the placement, which is either optimal or approximately optimal for those virtual machines which are migrated. The implementation of a fitness function is also being done by researchers in order to achieve the lower consumption of power along with all service level agreement. The proposed algorithm is also compared with a power-aware best fit decreasing algorithm. According to the results, it is observed that the presented algorithm has better performance. The energy consumption is reduced by 8.01 percent. Similarly, the number of migrations of a virtual machine is reduced by 39.65 percent.

Madhumala & Tiwari (2020) [61] provided a survey on the different swarm intelligence algorithms along with their uses in several domains. Additionally, this work also enlightened the several approaches utilized in optimal virtual machine selection as well as placement in cloud system. The whole survey was conducted by researchers by considering some parameters such as optimization of bandwidth as well as memory and computation of cost as well as time and others. This work done stated that there is a huge number of limitation when the swarm intelligence algorithms are applied for placement or selection of virtual machine. Hence, this study recommended to use hybrid algorithms to acquire the solution for optimization of virtual machine placement in the cloud.

Shalu & Singh (2020) [62] reviewed the research work done by various other researchers on the problem of virtual machine migration in cloud computing. This paper illustrated virtualization in an effective manner with

its advantages. Additionally, the approaches, as well as issues of live virtual machine migration, are also discussed in a well-organized way. Further, a comparative study is also conducted by the researchers on the basis of their performance between the algorithms of swarm intelligence such as ant colony optimization, cat swarm optimization, bat algorithm, firefly optimization algorithm, glow worm swarm optimization, monkey search algorithm, artificial bee colony, genetic gray wolf optimization etc., that are used to solve this particular problem.

3. Discussion and Directions for Future Research

A conducted comprehensive review has been done to analyze various techniques used to reduce the consumption of energy for the migration and allocation of the virtual machine in cloud data centers. The various artificial intelligence methodologies are being utilized by the researchers in order to utilize resources, minimizing the energy consumption as well as less violation of service level agreement. The research work done within the year 2014 to 2021 on this particular problem is considered in this review.

Table 1 shows the distinct methodology used by the researchers in the considered time period with their remarks. In some research work, the researcher did really commendable research that helps to attain respective goals. According to the analysis, it is observed that the hybrid algorithms of swarm intelligence are the most effective approach to make an energy-efficient model for this optimization problem. The distribution of the several approaches with respect to years considered in this study is presented in table 2. Likewise, the number of research work done by researchers in a particular year is showed in table 3.

Table 1: Used methodologies along with year and remarks

Sr no.	Author Name	Year	Method	Remarks
1.	Tseng et al. [52]	2014	SVM	Developed an algorithm to allocate the VMs in PMs with effective network
2.	N & Basu [26]	2015	ANN	Minimize the resource wastage and improved response time
3.	Radhakrishnan & Kavitha [28]	2016	ANN	Proposed a prediction technique to predict the availability of data centers
4.	Duggan et al. [34]	2016	RL	Developed a virtual machine selection technique with less energy consumption
5.	Patel et al. [53]	2016	SVM	Prediction Accuracy: 94.61%
6.	Shaw et al. [35]	2017	RL	Minimize the energy consumption along with less violation of SLA
7.	Abdelsamea et al. [42]	2017	LR	Reduced the energy consumption by six times as compared to traditional approaches.
8.	Khoshkholghi [43]	2017	LR	Minimize the energy consumption
9.	Dinesh Reddy et al. [59]	2017	SI	Minimized energy consumption: 32%
10.	Kakkar & Young [23]	2018	ANN	Allocation Accuracy: 99.99% Average Gradient value: 54.08% Average error rate: 0.001478
11.	Witanto et al. [27]	2018	ANN	Assisted in the selection of virtual machine consolidation algorithm with better accuracy

12.	Ahmed Kanona et al. [48]	2018	KNN	Allocate the resources with better performance
13.	Sotiriadis et al. [54]	2018	SVM	Minimize the performance degradation by 19%
14.	Li et al. [41]	2019	LR	Reduced energy consumption by 2.34%
15.	Rawat et al. [22]	2020	ANN	Improved Execution time: 36% Improved Scheduling time: 77.14% Improved Power Efficiency: 13%
16.	Singh et al. [24]	2020	ANN	Minimize the energy consumption
17.	Ying et al. [33]	2020	RL	Successfully proposed an approach for scheduling the VM migration
18.	Thein et al. [36]	2020	RL	Enhanced the energy efficiency
19.	Haghshenas & Mohammadi [40]	2020	LR	Reduced energy consumption by 38%
20.	Kavya et al. [47]	2020	KNN	Reduced error rate: 0.025%
21.	Balaji Naik et al. [58]	2020	SI	Used 72 % fewer resources and 68 KwH less energy
22.	Ibrahim et al. [60]	2020	SI	Reduced energy consumption: 8.01% Reduced number of VM migration: 39.65%
23.	Madhumala & Tiwari [61]	2020	SI	Survey on SI algorithms Recommended hybrid algorithm
24.	Shalu & Singh [62]	2020	SI	Comparative study on SI algorithms
25.	Shalu & Singh [25]	2021	ANN	Minimize the power consumption

Table 2: Distribution of methodologies with respect to years

2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Support Vector Machine	Artificial Neural Network	Artificial Neural Network	Reinforcement Learning	Artificial Neural Network	Linear Regression	Artificial Neural Network	Artificial Neural Network
-	-	Reinforcement Learning	Linear Regression	K – Nearest Neighbor	-	Reinforcement Learning	-
-	-	Support Vector Machine	Swarm Intelligence	Support Vector Machine	-	Linear Regression	-

-	-	-	-	-	-	K – Nearest Neighbor	-
-	-	-	-	-	-	Swarm Intelligence	-
1	1	3	3	3	1	5	1

Table 3: Number of publications in a specific year with respect to considered methodologies

	Support Vector Machine	**Artificial Neural Network**	**Reinforcement Learning**	**Linear Regression**	**Swarm Intelligence**	**K – Nearest Neighbor**
2014	1	-	-	-	-	-
2015	-	1	-	-	-	-
2016	1	1	1	-	-	-
2017	-	-	1	2	1	-
2018	1	2	-	-	-	1
2019	-	-	-	1	-	-
2020	-	2	2	1	4	1
2021	-	1	-	-	-	-
	3	7	4	4	5	2

4. Conclusion

The migration and allocation of virtual machines in the cloud data center with minimum energy used is one of the significant problems in cloud computing. Many researchers put keen efforts to propose new approaches as well as algorithm to solve this optimization problem. This paper effectively reviewed all the techniques that are being used by the different researchers in different period of time. By analyzing all these approaches, this conducted comprehensive review reaches a conclusion that the hybridization of swarm intelligence algorithms will be the best as well as an accurate approach to solve this kind of optimization problem. The limitation of this study is that this paper does not include all the methodologies that are being utilized by the researcher in the considered time span.

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