

A Closer Look at Ant Colony Optimization Algorithm to Migrate of Virtual Machines in Cloud Data Centers

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Abstract

Today, the variety of cloud data centers that provide large-scale Internet services is enlarging rapidly. While the operating cost of these centers also increases due to energy consumption. The key challenge of energy efficiency in the cloud is to reduce service level agreement violations and resource usage. In the meantime, the idea of virtualization uses the migration technology of virtual machines to consolidate the server workload and improve the energy consumption of cloud data centers. Virtual machine integration prevents the low efficiency of storage equipment and servers and their large space occupation. Virtual machine selection is one of the sub-problems in the technique of dynamic merging of virtual machines, which selects the best candidate virtual machine from among the virtual machines that are loaded on the host for migration. This research looks at the methods of solving the problem of choosing virtual machines for migration, which has improved energy consumption. Remarkably, the investigation of ant colony optimization algorithms for choosing a virtual machine help to choose a virtual machine in cloud environments, reduce the energy consumption costs and more than a few migrations of virtual machines and raise the level of customer satisfaction.

Keywords: Cloud Computing, Virtual Machine, Ant Colony Algorithm, Energy Consumption, Distributed System

I. INTRODUCTION

The cloud's primary focus is on delivering reliable, secure, fault-tolerant, and scalable infrastructure for hosting Internet applications. These programs have

different combinations, configurations and implementation requirements [22]. Hosting cloud application data centers consumes a huge amount of energy, which manages high operating costs and increasing the amount of carbon to the environment [21]. Resources in cloud computing are provided in an integrated and dynamic manner based on service level agreements (SLA) amid the service provider and the customer. By combining servers, the number of active physical hosts can be minimized and in this way the energy consumption can be reduced, but this action should not violate SLA contracts or lower the quality of service.

This article aims to investigate the development process of ant colony optimization algorithm in the problem of selecting virtual machines for allocation to physical hosts in cloud computing and also tries to minimize energy consumption and the number of physical hosts on in a data center by an optimal allocation. This method can bring more profit for cloud service providers and reduce harmful environmental effects, but at the same time, it is important that the quality of the service provided by the cloud service provider does not decrease, or in other words, the SLA contracts are not violated.

The rest of this paper is organized in this way. The importance of cloud data centers and description of its system design is present in Section 2, which includes the cloud computing and virtualization. Section 3 describes the ant colony optimization algorithm. Section 4 provides an overview of previous studies in regard to the application of the ant colony optimization algorithm in the virtual machine placement problems. Finally, Section 5 concludes the whole article.

II. THE IMPORTANCE OF CLOUD DATA CENTERS

A. Cloud Computing

Cloud computing is a distributed computing model that provides scalable and reliable services to subscribers. Figure 1 demonstrates the types of computer systems and the location of cloud computing.

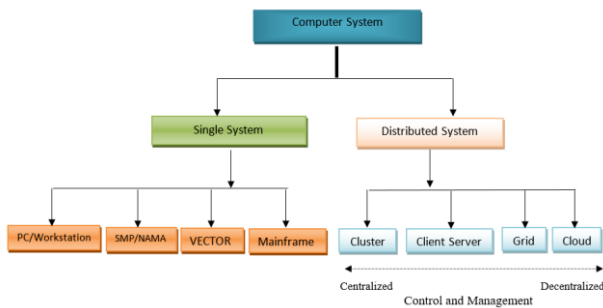


Figure 1. Types of computer systems

Cloud and Grid computing both use the platform in the virtual environment, but they have two major differences. First, we have virtualization in the cloud, but not in the grid, and secondly, we have to pay for doing our work in the cloud, which is not the case in the grid. The work that must be done in the cloud has a series of limitations, including that it must be done in a specified time and also has a cost limit.

Emerging technologies, including online games, VANET AdHoC networks, mobile computing applications and wireless sensor networks, etc. in order to improve and develop the capabilities use the cloud hosting services including Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) [21]. For example, Space Cloud Computing (VCC) uses a combination of VANET and CloudCom to help car drivers to reduce accidents, traffic and travel time. Similarly, to improve remote health care, a wireless sensor network (WSN) are combined with cloud and exploitation of its services. Virtualization technology is the backbone of cloud computing, which actively provides scalable services to customers. Due to the growing and complexity of the computing world, cloud computing, like cluster or grid computing, has been created with the aim of processing a huge amount of data.

B. Virtualization

Today, servers in cloud data centers host a large number of applications. These centers use virtualization to efficiently manage resources and optimize energy consumption. Virtualization uses machine migration to reallocate virtual machines within cloud data centers to achieve various goals, including server maintenance, energy reduction, load balancing [6], and fault tolerance

for scalability. Virtualization uses a hypervisor to capably manage various virtual machines running on a single physical server for the best use of resources. Also, it provides the basis of cloud computing and is very important in terms of economic growth [23]. However, the shared hosting of several virtual machines leads to a decrease in the applications performance due to high resource competition. Figure 2 shows a virtualization architecture versus traditional architecture.

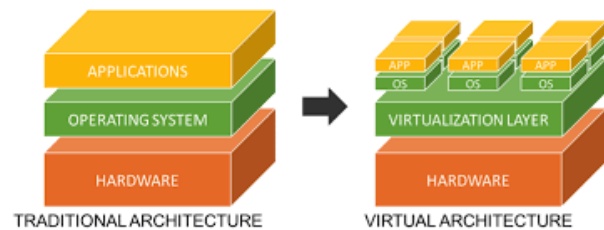


Figure 2. Traditional Architecture Vs Virtual Architecture

Virtualization provides an opportunity to consolidate multiple running virtual machines and causes some physical nodes to be turned off, thus helping to save energy. Commercial products such as VMware spheres and Microsoft System Center Virtual Machine, which provide a virtualization platform, support the consolidation of servers. Virtual machine migration technology handles the server consolidation framework to shut down unnecessary servers. Considering that the growing speed of energy demand from information and communication technology tool is a main reason of global warming as a result of the exponential increase of CO₂ and the production of greenhouse gases, virtualization reduces the energy demand of cloud data centers through efficient utilization of resources. It runs multiple virtual machines on a hardware resource with respect for privacy and a strict confidentiality policy. Resources including CPU, bandwidth, memory, network, etc. are dynamically provided to a VM based on the required presentation of the host workload. Virtualization uses VM migration technology to stabilize server workload and enhance energy consumption of cloud data centers.

Migration of virtual machines is the practice of using patterns of moving them throughout the data center to achieve the load balance [2], energy efficiency [3], quality of services [4], revenue improvement [19], and etc. In resource management, migration is done with 2

main goals: load balancing and server consolidation (Figure 3). In load balancing, the target is to allocate the processing load equivalently on all the physical servers of a data center and to avoid large differences in the level of resource utilization in physical servers.

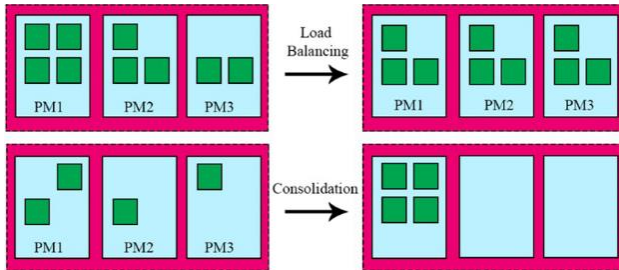


Figure 3. Migration aimed at load balancing and consolidation of servers [5]

In the integration of servers, in the process of deploying virtual machines, they usually use optimization algorithms to decide on which physical host, a virtual machine should be placed. In this regard, several effective heuristic methods have been invented. These heuristics take an estimate of the required resources of the virtual machines and the available capacities of the host's physical machines as the input and then decides on which physical host should be deployed with the virtual machines. It should be mentioned that the goal is to minimize the total number of physical hosts and subsequently save the energy consumption. During the past decades, inspired by the behaviors of natural phenomena, a growing interest in algorithms has been grown [1, 30, 8, 34, 35, 16]. It has been presented by many researchers that these algorithms are suitable for solving complex computational problems something like optimization of objective functions [28, 42], pattern detection [37, 40], control objectives [25, 33, 10], image processing [27, 38] filter modeling [32, 36] and so on.

A variety of heuristic methods have been implemented by previous studies so far, including genetic algorithm [16], simulated annealing algorithm [35], ant colony optimization algorithm [1], swarm optimization [8], etc. These algorithms are gradually analyzed or strengthened by scientists in many various fields to solve various optimization problems [24, 26, 29, 31, 12, 41]. Although, there is no certain algorithm to attain the appropriate solution for all optimization problems. Some algorithms provide better solutions to certain problems than the others. Consequently, the

search for new heuristic optimization algorithms is an open problem [18]. Otherwise, the optimization problems develop in many fields, both in basic sciences and in used fields such as economics and engineering. One of the most well-known optimization methods is the Ant Colony Optimization (ACO). Its parallel character makes it particularly attractive for operation and execution in high performance computing environments [7].

III. ANT COLONY OPTIMIZATION ALGORITHM

Ants communicate with each other by a substance called pheromone that they leave on the ground as they move. If an ant travels a path, it can identify its return path by smelling the pheromone it has placed on the ground. Moreover, other ants can sense the pheromones of others to know that another ant has traveled this way. In fact, the message exchange is done by placing pheromone on the ground. However, these pheromones don't always stay on the ground and slowly evaporate after a while. Indeed, two main actions, i.e. pheromone spraying and pheromone evaporation, are the actions that make the main idea of the ant colony optimization algorithm. Figure 4 presents the main steps of the ant colony optimization algorithm [20].

Algorithm 1 Main steps of ACO Algorithm

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Initialization
repeat
    The ants are placed on the starting nodes
    Each ant achieves a state transition procedure to gradually
    build a solution
    Each ant updates the local pheromone until all the ants
    have built a solution
    Update of the overall pheromone under rule preset until
    the achievement of the ending condition
until End condition
Stop further iterations
    
```

Figure 4. Ant Colony Algorithm

Ants are able to find the optimal path from their colony to food in a collective movement. Without having vision, they can find their path by using the power of their community [9]. By studying and investigating how ants work, scientists were able to identify an algorithm that can find something close to the global optimum in an optimization problem with a very good approximation. Furthermore, ACO has been successfully used in a choice of optimization problems such as the traveling salesman problem, network routing problem, network coding resource minimization, and also the virtual machine placement (VMP) problem due

to its valuable distributed positive feedback process and firm parallel computing capability [9, 34].

IV. RELATED WORKS

This section reviews the ACO algorithms that have been successfully developed to VMP problems in different studies. Alharbi *et al.* expressed the VMP problem with minimum energy consumption as a constrained combinatorial optimization problem and an ant colony system (ACS) was developed with problem-specific heuristics to achieve an energy-efficient solution [11]. The findings are depending on physical machine (PM) utilization and capacity while active PMs are preferred rather than turning on new PMs. Zhao *et al.* tackled the high energy consumption and reduced VM performance in VMP. A performance-guaranteed

and power-aware multi-objective ACO was proposed to enhance the latter two objectives at once [12]. Liu and *et. al* recommended an ACO for the VMP problem to minimize the number of active physical servers [13]. Pheromone is placed between both VMs, and heuristics between VM and PM show how resource utilization is developed. In another research, ACS algorithm is proposed that includes local search techniques and order trade that decrease the number of active servers in heterogeneous and homogeneous environments [14]. Ants were guided by a previously deposited pheromone to study optimistic solutions through VM grouping. Wei and *et. al* improved an adaptive multi-objective ACO to decrease communication cost and power consumption in traffic-aware data center networks [15].

Table 1. Comparison of Developed ACO Algorithms in Different Studies

Refs.	Technique	Objective(s)	Advantages	Weaknesses
[11]	ACS	<ul style="list-style-type: none"> • PC of PMs 	<ul style="list-style-type: none"> • Good scalability 	<ul style="list-style-type: none"> • High complexity
[12]	ACO	<ul style="list-style-type: none"> • PC of PMs • VM performance 	<ul style="list-style-type: none"> • Good tradeoff between VM performance and power consumption 	<ul style="list-style-type: none"> • Low feasibility for large-scale scenarios • Network resource is ignored
[13]	ACO	<ul style="list-style-type: none"> • Number of active PMs 	<ul style="list-style-type: none"> • Low complexity 	<ul style="list-style-type: none"> • Network resource is ignored
[14]	ACO	<ul style="list-style-type: none"> • Number of active PMs 	<ul style="list-style-type: none"> • Strong global exploration • High stability 	<ul style="list-style-type: none"> • High complexity • Network resource is ignored
[15]	ACO	<ul style="list-style-type: none"> • PC of PMs and switches • Communication cost 	<ul style="list-style-type: none"> • Fast convergence • Robust search capability 	<ul style="list-style-type: none"> • High complexity
[16]	ACO	<ul style="list-style-type: none"> • PC of PMs and switches 	<ul style="list-style-type: none"> • Good scalability 	<ul style="list-style-type: none"> • PC of communication is ignored
[17]	AP-ACO	<ul style="list-style-type: none"> • PC of PMs • Communication cost 	<ul style="list-style-type: none"> • Fast convergence and robust search capability 	<ul style="list-style-type: none"> • Focus on CPU power consumption
[19]	ACS-BVMP	<ul style="list-style-type: none"> • PC of PMs • Maximize communication revenue 	<ul style="list-style-type: none"> • Good scalability 	<ul style="list-style-type: none"> • Constraints of the complete accurate network topology ignored
[39]	ETA-ACO	<ul style="list-style-type: none"> • PC of PMs • Total bandwidth resource consumption 	<ul style="list-style-type: none"> • Time complexity is lower 	<ul style="list-style-type: none"> • Poor scalability

The above ACO algorithms have demonstrated tremendous optimization performance while addressing various VMP problems. ACO algorithms in [11, 13, 14] are for single-objective VMP, while [12, 15] are for dual-objective VMP. To work out multi-objective optimization problems, multiple objectives must be considered concurrently. Although, the best solution for one objective may be the worst solution for another objective due to the conflicts and incomparability between those objectives. Moreover, practically there is no single best solution to the problem, rather, there is a set of solutions that are exclusive considering all the goals [17]. Table 1 indicates the comparison of a number of VMP algorithms reviewed in this section, with regard to the applied objective(s), advantages, disadvantages and technique.

An energy-efficient virtual machine placement plan that sought to decrease power consumption and communication cost in traffic-aware data center networks was proposed by Huazhi *et al.* An ant colony optimization was presented with adaptive parameter setting to balance its robust search capability and fast convergence in the optimization problems [17]. Using the ETA-ACO algorithm, Xing *et al.* formulate a virtual machine placement problem (VMP), where the switches and the total power consumption of physical machines (PMs) and network bandwidth resources among virtual machines is jointly minimized [39]. The proposed ETA-ACO has the same complexities as in [12, 13, 15], but its time complexity is lower than [11, 14, 39]. Qin *et al.* introduced a multi-objective Ant Colony System (ACS) algorithm termed ACS-BVMP. The purpose is to find the Pareto optimal solution set that can concurrently enlarge the communication revenue and reduce the power consumption of PMs [19].

Ragmani *et al.* proposed a fuzzy hybrid ant colony optimization (FACO) algorithm for virtual machine programming to ensure high performance in a cloud environment. The suggested fuzzy module assesses the previous information to estimate the amount of pheromone and choose a suitable server while maintaining optimal computing time [10]. By multi-

objective hybrid optimization, Gao *et al.* achieved the minimization of total resource loss and energy consumption based on ACO algorithm, which efficiently obtained a set of non-dominated solutions [21]. Focusing on VM migration in the cloud environment using the ACO algorithm, Arviselvi *et al.* improved CPU and memory usage by reducing traffic congestion in cloud data centers. Their proposed

approach led to better memory management and reduces traffic and maximizes CPU usage while the current status of virtual machines and PMs is not interrupted [23].

All the methods mentioned above can contribute to the better performance of data center network (DCN) by optimally using resources and reducing energy consumption. Thanks to these advantages, we will propose a multi-objective algorithm to improve the design in future studies.

V. CONCLUSION AND FUTURE WORK

In general, the problem of optimal integration of virtual machines with physical hosts can be divided into three sub-problems.

1. The first problem is when should a virtual machine migrate?
2. For the second problem, which virtual machine should be migrated?
3. The third problem should answer that where the selected virtual machines migrate?

In most of the methods presented so far, processor efficiency has been used as the main parameter in order to reduce the level of service level agreement violations and reduce energy consumption. But the noteworthy point is that in real data centers, it is not possible to manage virtual machines and how they are placed on hosts alone without considering other features. This issue has caused the latest methods presented are not very desirable and efficient in actual implementation and use.

In this study, a closer look at the methods provided to solve the problem of choosing virtual machines for migration has been taken. In particular, the investigation of ant colony optimization algorithms for choosing a virtual machine is in dynamic integration, which will include the following features:

- Helping to choose a virtual machine in cloud environments according to various available factors
- Reducing energy consumption costs
- Increasing the level of customer satisfaction based on the reduction of SLA violations
- Reducing the number of migrations of virtual machines

Consequently, in future studies, an algorithm based on the ant colony algorithm will be tried to achieve a better result by combining different factors. The factor of bandwidth and RAM, which have an effect on the

migration time, is combined with the processor efficiency factor and its impact on service level agreement violations. Undoubtedly, it will reduce the violation of service level agreements in addition to saving more energy. The results will obtain in reference to energy consumption and the optimal use of physical hosts in a way that can provide services to many virtual machines, without violating the SLA agreement, which will be effective compared to the presented methods.

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