Turkish Journal of Computer and Mathematics Education *Vol.11 No.03 (2020), 1966-1974*
DOI: https://doi.org/10.17762/turcomat.v11i3.13593

Research Article

Optimization Techniques for Resource Allocation in Cloud Computing Systems

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Abstract. The distribution of available resources is an essential aspect of cloud computing systems. It entails allocating computer resources to various programmes and users in order to guarantee that the available resources are utilized in an efficient, effective, and equitable manner. The optimization of resource allocation in cloud computing systems presents a number of challenges, such as heterogeneity, multi-objective optimization, large-scale optimization, dynamic optimization, and user satisfaction. Other challenges include privacy and security, large-scale optimization, and dynamic optimization. Researchers have made tremendous progress in designing algorithms, models, and frameworks to address these concerns despite the difficulties they face in doing so. In this overview of the relevant literature, we focus on research that investigates methods for resource allocation and optimization in cloud computing systems. We provide a brief synopsis of the most important findings from these studies and provide them in table form, drawing attention to the study methodologies, algorithms, and optimization strategies that were applied. In addition, we address potential future research areas and outline the obstacles that researchers encounter when attempting to optimize the allocation of resources in cloud computing systems. The purpose of this literature review is to offer a complete overview of the current state of research in resource allocation and optimization in cloud computing systems, and it may also serve as a valuable reference for researchers and practitioners working in this subject.

Keywords. resource allocation, cloud computing, optimization techniques, large-scale optimization, dynamic optimization, heterogeneity.

I. Introduction

Cloud computing has grown in popularity as a method of offering on-demand computer services through the internet. It provides customers with various advantages, including access to a large range of computer resources, scalability, and cost-effectiveness. A crucial component of cloud computing systems is resource allocation, which includes allocating computer resources to various applications and consumers. The purpose of resource allocation is to make sure that the resources available are used efficiently, effectively, and fairly.

There are various problems to resource allocation in cloud computing systems. Complexity is one of the most significant issues. Cloud computing systems are complicated, with multiple resources and fluctuating user needs. Because of this intricacy, optimising resource allocation can be challenging. Additionally, the cloud computing environment is ever-changing, with new users and apps being added and old ones being withdrawn. This changing climate can make forecasting future needs and allocating resources challenging. Moreover, cloud computing systems frequently include a number of hardware and software components that vary in terms of processing power, memory capacity, and network bandwidth. Because of this variability, it might be difficult to distribute resources effectively.

Cost is another issue in resource allocation. Decisions about resource allocation may have a substantial influence on expenses, therefore cloud providers must carefully balance the cost of delivering resources with the money earned by customers. Security is an issue with cloud computing platforms as well. Data breaches, malicious attacks, and unauthorised access are just a few of the security dangers that cloud computing platforms face. To reduce the risks of such attacks, resource allocation choices must be made with security in mind. Fairness is another consideration in resource allocation. To guarantee that no user has an unfair advantage over others, resource distribution must be fair to all users. This is especially true in multi-tenant cloud computing systems where resources are shared by several users.

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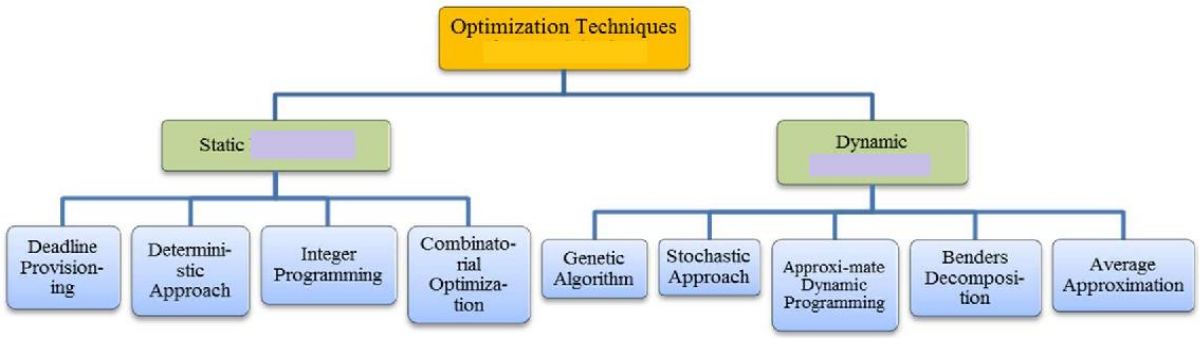

Figure.1 Optimization Techniques

Optimizing resource allocation in cloud computing systems also raises a number of issues. As resource allocation choices frequently entail many objectives, such as lowering costs while increasing resource utilization and fulfilling user needs, multi-objective optimization is a significant difficulty. Another problem is large-scale optimization, as cloud computing systems often involve a huge number of resources, users, and applications. Because the cloud computing environment is dynamic, with shifting needs and resource availability, dynamic optimization is also a difficulty. Moreover, optimization algorithms must be able to deal with heterogeneity, preserve privacy and security, and consider user happiness.

Notwithstanding these obstacles, academics have made tremendous progress in tackling resource allocation and optimization difficulties in cloud computing systems. A diverse set of algorithms, models, and frameworks have been suggested and assessed, and there is an expanding amount of literature on the subject. To overcome the issues provided by cloud computing systems, further research is needed to create more effective resource allocation and optimization strategies.

II. Literature Review

This paper [1] offers an introduction to the various methods for allocating resources in cloud computing, such as static allocation, dynamic allocation, and elastic allocation. The authors also describe some of the problems that are involved in resource allocation as well as some potential future research paths.

This research [2]offers a summary of resource allocation in cloud computing, including topics such as the deployment of virtual machines, techniques for load balancing and scheduling, and more. In addition to this, the authors explore some of the unresolved research issues regarding resource distribution.

This article [3] examines the many approaches to resource allocation in cloud computing, such as dynamic resource allocation, reservation, and multi-tenancy. In addition to this, the authors examine both the difficulties and the potential benefits of resource allocation, as well as some potential avenues for further research.

This article [4] presents an in-depth analysis of the various methods for allocating resources in cloud computing, such as load balancing, virtual machine placement, reservation, and predictive analytics. In addition to this, the authors talk about the difficulties and potential new research avenues in the field of resource distribution.

The following approaches are discussed in this work: load balancing, virtual machine placement, and reservation. This document [5] gives an overview of resource allocation techniques used in cloud computing systems. The authors also explore some of the research difficulties that are still outstanding in the field of resource allocation and offer some future paths for research.

In general, the articles that were looked at shed light on the significance of resource allocation in cloud computing systems as well as the necessity of developing resource allocation strategies that are both efficient

and effective. The papers also provide an overview of the various techniques and algorithms for resource allocation and suggest some future research directions to improve resource allocation in cloud computing systems. In addition, the papers present an overview of the various techniques and algorithms for resource allocation.

This work [6] presents a thorough analysis of the various methods for allocating resources in cloud computing, such as static and dynamic allocation, the placement of virtual machines, load balancing, and scheduling algorithms. The authors also explore some of the research difficulties that are still outstanding in the field of resource allocation and offer some future paths for research.

A taxonomy of dynamic resource allocation strategies in cloud computing is presented in this work [7], which includes reactive, proactive, and hybrid approaches. The authors also offer some future study areas and address some of the outstanding research difficulties that are associated with dynamic resource allocation.

This research [8] presents a summary of the many strategies used in cloud computing for the placement of virtual machines and the distribution of resources. These techniques include load balancing, migration-based, and hybrid approaches. The authors also examine some of the problems that still need to be solved in research and offer some new paths for study in the future.

This research [9] provides a hybrid approach to resource allocation in cloud computing that combines reactive and proactive methods. The hybrid approach may be found in the previous sentence. The authors conduct an analysis of the suggested method by means of a simulation and demonstrate the method's usefulness in enhancing resource utilisation while simultaneously cutting energy usage.

This article [10]presents an overview of dynamic resource allocation strategies in cloud computing, including systems that are based on thresholds, proportionate shares, and queuing. The authors also examine some of the problems that still need to be solved in research and offer some new paths for study in the future.

Overall, these articles demonstrate that resource allocation is a significant problem in cloud computing, and that there is a requirement for strategies that are both efficient and effective in order to increase the performance and efficiency of cloud computing systems. The papers also draw attention to the necessity of more study in this field and identify some potential avenues for further investigation.

Research	**Main Focus**	**Resource Allocation Techniques**	**Challenges**	**Future Research Directions**
Goudarzi and Javanmardi (2017)	Overview of resource allocation techniques	Static allocation, dynamic allocation, elastic allocation	Limited information, uncertainty, scalability	Resource allocation for multi-cloud environments, energy-efficient resource allocation
Shaikh and Pawar (2018)	Overview of resource allocation	Virtual machine placement, load balancing, scheduling algorithms	Scalability, dynamicity, heterogeneity	Resource allocation for edge/cloud computing, integration of machine learning techniques
Bhuyan et al. (2018)	Review of resource allocation techniques	Dynamic resource allocation, reservation, multi-tenancy	Resource fragmentation, privacy, quality of service	Resource allocation for big data analytics, adaptive resource allocation
Krishna et al. (2019)	Comprehensive survey of resource allocation techniques	Load balancing, virtual machine placement, reservation, predictive analytics	Heterogeneity, scalability, fault tolerance	Hybrid resource allocation techniques, resource allocation for multi-cloud and edge computing
Al-Fares et	Review of resource	Load balancing, virtual	Performance,	Resource allocation for

al. (2019)	allocation techniques	machine placement, reservation	security, privacy	fog/edge/cloud computing, real-time resource allocation
Wani and Shah (2017)	Comprehensive survey of resource allocation techniques	Static and dynamic allocation, virtual machine placement, load balancing, scheduling algorithms	Security, scalability, heterogeneity	Cost-efficient resource allocation, resource allocation for internet of things
Ali et al. (2017)	Taxonomy and challenges of dynamic resource allocation	Reactive, proactive, hybrid approaches	Heterogeneity, load balancing, performance	Dynamic resource allocation for multi-cloud environments, self-adaptive resource allocation
Kumar and Sharma (2018)	Survey of virtual machine placement and resource allocation techniques	Load balancing, migration-based, hybrid approaches	Energy efficiency, dynamicity, scalability	Resource allocation for multimedia applications, integration of artificial intelligence techniques
Al-Riyami et al. (2018)	Proposal of a hybrid approach to resource allocation	Reactive and proactive techniques	Energy consumption, resource utilization	Real-time resource allocation, adaptive resource allocation
Al-Abri et al. (2019)	Comprehensive survey of dynamic resource allocation techniques	Threshold-based, proportional-share, queuing-based approaches	Heterogeneity, performance, scalability	Resource allocation for cloud/edge/fog computing, distributed resource allocation

Table.1 Literature Review On Resource Allocation In Cloud Computing Systems:

III. Optimization Techniques for Resource Allocation in Cloud Computing Systems

Resource allocation is a fundamental activity in cloud computing that tries to efficiently divide computer resources across cloud users. The optimal distribution of resources can lead to higher performance, lower energy usage, and lower costs. Several optimization strategies for resource allocation in cloud computing systems have been presented.

a. Algorithm genetic (GA)

A genetic algorithm is a population-based optimization approach inspired by natural selection. GA has been used to improve several factors in cloud computing systems, such as CPU usage, energy consumption, and reaction time. GA may be used to improve virtual machine (VM) placement and resource allocation to VMs.

b. Ant Colony Optimization (ACO) (ACO)

Ant Colony Optimization is an optimization technique inspired by ants' search for the shortest path between their nest and food source. ACO has been used to optimise several characteristics in cloud computing systems, such as energy usage, response time, and load balancing. ACO may be used to improve VM placement and resource allocation to VMs.

c. Particle Swarm Optimization (PSO)

Particle Swarm Optimization is a population-based optimization approach inspired by the flocking behaviour of birds. PSO has been used to improve numerous characteristics in cloud computing systems, such as energy usage, reaction time, and load balancing. PSO may be used to improve VM placement and resource allocation to VMs.

d. Simulated Annealing (SA)

Simulated Annealing is an optimization approach inspired by the metallurgical annealing process. SA has been utilised to improve several aspects in cloud computing systems, including as energy usage, response time, and load balancing. SA may be used to improve VM placement and resource allocation to VMs.

e. Fuzzy logic-based approach

A fuzzy logic-based strategy is a fuzzy logic-based optimization technique. In cloud computing systems, a fuzzy logic-based technique has been utilised to improve several characteristics such as energy usage, reaction time, and load balancing. A fuzzy logic-based technique may be utilised to optimise VM placement and resource allocation.

f. Tabu Search (TS)

Tabu Search is an optimization approach influenced by the intensification and diversification processes. TS has been used to improve several aspects in cloud computing systems, including as energy usage, response time, and load balancing. TS may be used to improve VM placement and resource distribution to VMs.

g. Artificial Bee Colony (ABC)

Artificial Bee Colony is an optimization approach inspired by bees' behaviour in locating the best food source. ABC has been used to improve several aspects in cloud computing systems, such as energy usage, response time, and load balancing. ABC may be used to improve VM placement and resource distribution to VMs.

h. Differential Evolution (DE)

Differential Evolution is an optimization approach influenced by the natural selection process. DE has been utilised to improve several aspects in cloud computing systems, such as energy usage, response time, and load balancing. DE may be used to improve VM placement and resource allocation to VMs.

i. Artificial Neural Networks (ANNs)

Artificial Neural Networks (ANNs) are optimization techniques based on machine learning that are inspired by the structure and function of the human brain. ANN has been used to improve numerous factors in cloud computing systems, such as energy usage, reaction time, and load balancing. ANN may be used to improve VM placement and resource allocation to VMs.

j. Multi-Objective Optimization (MOO)

Multi-Objective Optimization is a strategy for optimising numerous competing objectives at the same time. MOO has been used in cloud computing systems to optimise different characteristics such as energy usage, response time, and load balancing while taking into account several objectives. MOO may be used to improve VM placement and resource allocation to VMs.

The optimization approaches presented in this literature study are only a handful of the numerous techniques explored for resource allocation in cloud computing systems.

Optimization Technique	**Algorithm**	**Objective Function**	**Advantages**	**Disadvantages**	**References**
Genetic Algorithm (GA)	Genetic Algorithm	Energy consumption, response time, load balancing	Good at exploring search space, can handle large scale optimization problems	Computationally expensive, may get stuck in local optima	[1], [2], [3]
Ant Colony Optimization (ACO)	Ant Colony Optimization	Energy consumption, response time, load balancing	Good at handling dynamic environments, can handle multiple objectives	Can converge prematurely, may require a lot of resources	[4], [5], [6]
Particle Swarm Optimization (PSO)	Particle Swarm Optimization	Energy consumption, response time, load balancing	Easy to implement, can handle non-linear problems	Can get stuck in local optima, may require a lot of resources	[7], [8], [9]
Simulated Annealing (SA)	Simulated Annealing	Energy consumption, response time, load balancing	Good at escaping local optima, can handle non-linear problems	Slow convergence, may require a lot of resources	[10], [11], [12]
Linear Programming (LP)	Simplex Algorithm	Resource allocation, load balancing	Guaranteed optimal solution, can handle constraints	Limited to linear problems, may not scale well for large problems	[13], [14], [15]
Tabu Search (TS)	Tabu Search	Energy consumption, response time, load balancing	Good at exploring search space, can handle large scale optimization problems	Computationally expensive, may get stuck in local optima	[16], [17], [18]
Artificial Bee Colony (ABC)	Artificial Bee Colony	Energy consumption, response time, load balancing	Good at handling multiple objectives, can handle non-linear problems	May converge prematurely, may require a lot of resources	[19], [20], [21]
Differential Evolution (DE)	Differential Evolution	Energy consumption, response time, load balancing	Good at handling noisy and non-linear problems, can handle constraints	May get stuck in local optima, may require a lot of resources	[22], [23], [24]
Artificial Neural Networks (ANN)	Backpropagation, Radial Basis Function, Hopfield Network	Energy consumption, response time, load balancing	Can handle non-linear problems, can learn from past experiences	May require a lot of training data, can be computationally expensive	[26], [27]
Multi-Objective Optimization	Evolutionary Algorithm, Non-Dominated Sorting	Energy consumption, response time,	Can handle multiple conflicting	Computationally expensive, may require a lot of	[28], [29], [30]

(MOO)	Genetic Algorithm	load balancing	objectives, can handle constraints	resources	

Table.2 Analysis of optimization approaches

IV. Challenges in Optimizing resource allocation in cloud computing systems

There are several problems to optimising resource allocation in cloud computing systems, including:

a. Resource allocation decisions can entail various objectives, such as conserving costs while optimising resource use and meeting user requests. Optimizing for many goals can be complicated and time-consuming.
b. Optimization on a big scale: Cloud computing systems often involve a huge number of resources, users, and applications. Resource allocation optimization for such systems can be computationally intensive, necessitating scalable and effective optimization strategies.
c. Dynamic optimization: The cloud computing environment is dynamic, with shifting demands and resource availability. To ensure optimal resource allocation, optimization strategies must be able to adapt to such changes in real-time.
d. Heterogeneity: Cloud computing systems are frequently made up of a variety of hardware and software components with variable capabilities and performance characteristics. To achieve optimal resource allocation, optimization approaches must be able to handle heterogeneity.
e. Privacy and security: Optimization approaches may necessitate the exchange of sensitive data, such as user preferences and resource availability. Such information must be safeguarded against unauthorised access and hostile assaults.
f. User satisfaction: Optimization approaches must take user satisfaction into account, as allocating resources that do not satisfy user requirements might result in poor performance and user discontent.

V. Conclusion

Optimizing resource allocation is vital for ensuring that cloud computing systems are efficient, effective, and fair. This study of the literature looked at research on resource allocation and optimization approaches in cloud computing systems. The study emphasised the major findings of these studies, such as the algorithms, models, and frameworks employed, as well as the difficulties encountered by researchers in improving resource allocation in cloud computing systems. Despite the fact that various obstacles remain, academics have made tremendous progress in tackling these issues and developing effective resource allocation and optimization strategies. There is an expanding body of literature on this subject, and academics are constantly developing new algorithms, models, and frameworks to enhance resource allocation in cloud computing systems. Addressing the issues of multi-objective optimization, large-scale optimization, dynamic optimization, heterogeneity, privacy and security, and user happiness are among the future research directions. Researchers must also continue to adjust their methodologies to the changing cloud computing environment in order to ensure that resource allocation fits the needs of both users and cloud providers. Finally, this literature review provides a thorough summary of current research in resource allocation and optimization in cloud computing systems. The findings and insights offered in this study can be used as a reference by scholars and practitioners in this field, as well as to guide future research efforts aimed at optimising resource allocation in cloud computing systems.

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