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Cloud Resource Allocation and Scheduling: A Comprehensive Study

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Abstract: Cloud computing has now become a basic element of IT services delivery, enabling the provision of on demand, scalable computing resources over the Internet, in an efficient manner. The challenge for the efficient management of the resources in cloud computing environments, which are scalable and dynamic by nature, arises from their increasing scale. Traditional methods fail to address the issue of the efficient scheduling of tasks for the load balancing in such environments. In order to overcome this challenge, numerous scheduling methods that are based on metaheuristics have been proposed and effectively applied to various types of cloud computing environments. The aim of this paper is to present a comprehensive survey and comparison of five well known, efficient scheduling methods, which are based on metaheuristics. In the paper, five typical methods, namely, Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Simulated Annealing (SA), and Artificial Bee Colony (ABC), are studied in detail. The principles, advantages, and disadvantages of the five methods are discussed in the paper, and a comparison of the methods is also presented, based on a number of important factors, such as the quality of the solutions found, the execution time, the resource utilization, the scalability of the methods, and the corresponding computational costs.

Keywords: Cloud Computing, Resource Allocation, Task Scheduling, Metaheuristic Algorithms, Optimization.

A. BACKGROUND

The cloud computing environment has many challenges regarding resource allocation and scheduling. Resource scheduling in cloud computing is a critical issue and needs optimization techniques to utilize resources efficiently and economically. Various researchers have contributed to different optimization techniques used in cloud computing. Metaheuristic approaches are commonly used techniques used for optimization and to find the optimal solution in cloud computing resource allocation and scheduling. These strategies are flexible and efficient and overcome the challenges of large-scale cloud systems and workloads. However, there are different types of optimization algorithms. Some of them are Genetic Algorithm, Particle Swarm Optimization, Ant colony optimization, Simulated Annealing, and Artificial Bee Colony. The review paper discusses all these algorithms and compares their performance in cloud allocations and scheduling.

B. OBJECTIVES OF THE STUDY

The objectives of this review paper are as follows:
I. To study cloud resource allocation and scheduling.
II. To analyze and compare various metaheuristic optimization algorithms used for resource allocation and scheduling.
III. To understand the working mechanism of various metaheuristics optimization algorithms and how they contribute to the optimization of cloud resources.
IV. To review the challenges and future scope of resource allocation in cloud computing.
V. To study the advantages and disadvantages of various optimization algorithms used in

CLOUD RESOURCE ALLOCATION AND SCHEDULING.

C. LITERATURE REVIEW

Metaheuristic algorithms are optimization algorithms, and various researchers performed extensive studies and applied them in cloud resource allocation and scheduling to optimize the performance of the system. Buyya et al. emphasized the importance of efficient resource management in cloud computing [1].
Singh and Chana [2] gave the review of cloud resource provisioning approaches and discussed the issues related to balancing and allocating resources. Goldberg [3] introduced Genetic Algorithm (GA), which was implemented in various engineering and optimization problems. Kennedy and Eberhart [4] proposed Particle Swarm Optimization (PSO), and Dorigo and Stützle [5] developed Ant Colony Optimization (ACO).
Kirkpatrick et al. [6] introduced Simulated Annealing (SA), and Karaboga and Basturk [7] proposed Artificial Bee Colony Algorithm.

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VI. RESEARCH METHODOLOGY

This review paper presents a comprehensive study of various metaheuristic algorithms used for cloud resource allocation and scheduling. The main focus of this paper is to review the various optimization algorithms and highlight their advantages and disadvantages in cloud resource allocation and scheduling. The review paper is based on an extensive survey of existing research papers, journals, and conferences related to cloud resource allocation and optimization techniques.
Genetic Algorithm, Particle Swarm Optimization, Ant colony optimization, Simulated Annealing, Artificial Bee Colony algorithms are the commonly used algorithms for cloud resource allocation and scheduling. Hence these algorithms are discussed in detail in the review paper and their pros and cons are analyzed. Besides, a comparison is made between these algorithms and their performance is reviewed.

VII. META HEURISTIC APPROACHES

Metaheuristic approaches are a set of optimization algorithms used to find near-optimal solutions to various optimization problems. The algorithms are capable of solving large-scale optimization problems of cloud allocating and scheduling. These algorithms are efficient in resource utilization and reduce the execution time and balancing of the system. The various types of Meta heuristic approaches used are Genetic Algorithm, Particle Swarm Optimization, Ant colony optimization, Simulated Annealing, Artificial Bee Colony.

A. GENETIC ALGORITHM (GA)

Genetic Algorithm is one of the most commonly used evolutionary optimization algorithms that mimics the law of genetics. This algorithm has been successfully implemented in cloud resource allocation and scheduling. GA follows the process of natural evolution and finds near-optimal solutions to the problems. GA works on biological evolution like the survival of the fittest and selects the best individual from the group with high fitness. The algorithm starts by randomly selecting solutions from the problem set to create an initial population of a solution. The initial population undergoes evolution and selection and better solutions are picked.
Genetic Algorithm is used in cloud computing for efficient allocation of resources and to find optimal schedules for the task. These algorithms improve the resource utilization and reduce the execution time which results in increased performance. Due to the effective global search ability of GA it is considered better in the field of optimization [3].

B. PARTICLE SWARM OPTIMIZATION (PSO)

PSO is an optimization algorithm inspired by the flocking behavior of birds and fish. The working mechanism is based on the movement of individuals in a group towards the best solution. In PSO, particles move through the search space to find optimal solutions to the particular problem. Each particle updates their position according to their own best solution and the best solution found by the neighboring particles. The algorithm is commonly used in various applications like computer science, engineering, and networking. In cloud computing, this algorithm is used for task scheduling to optimize the processes of allocating resources. PSO is implemented to find the optimal schedule of execution which minimizes the execution time and balances the load of the system. The algorithm is widely used due to its simplicity, speed, and accuracy [4].

C. ANT COLONY OPTIMIZATION (ACO)

ACO is a metaheuristic algorithm inspired by the foraging behavior of ants. The algorithm uses artificial ants to find the optimal solution to the given problem. ACO is based on the principle of pheromone trails where ants deposit pheromones to make a path as a guide for other ants to explore the environment. When the ants explore the shorters paths, it intensifies the amount of pheromone which leads to higher chance of finding the shortest path. This algorithm is implemented in cloud computing to improve the utilization of resources, optimize the network, and schedule various tasks. The algorithm helps in finding the optimal path while allocating resources in a way that avoids resource wastage [5].

D. SIMULATED ANNEALING (SA)

SA is an optimization algorithm inspired by the annealing process of metals. The algorithm is used to find the optimal solution to the problems and avoid getting stuck in local optima by allowing the worse solutions in some cases. The algorithm goes through various iterations while searching for the solution to identify the optimal solution. This algorithm has been efficiently used in optimization problems. In cloud allocation and scheduling, SA has been used to optimize the resources by balancing the load and minimizing the cost of execution. This algorithm provides flexibility and robustness to the system [6].

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E. ARTIFICIAL BEE COLONY (ABC)

It is a type of metaheuristic algorithm that follows the foraging behavior of honey bees. This algorithm consist three types of bees i.e. employed bee, onlooker bee and scout bee. Each type of bee plays a distinct role in finding an optimal solution to the given problem. The ABC algorithm has been efficiently implemented in various cloud applications like task scheduling, resource allocation, and load balancing. It helps improves performance of the system by shortening the execution time, utilizing the resources efficiently and achieving a balance in the system. ABC Algorithm has flexibility and simplicity and can be used in optimization problems [7].

VIII. ADVANTAGES AND DISADVANTAGES OF META HEURISTIC APPROACHES

Meta heuristic approaches have a number of advantages and disadvantages in cloud resource allocation and scheduling. Some of the advantages and disadvantages are discussed below.

Advantages of Meta heuristic approaches:

- Improved resource utilization
- Better load balancing
- Reduced execution time
- Flexible
- Efficient in solving complex problems

Disadvantages of Meta heuristic approaches:

- High computational cost
- Complex implementation
- Need for parameter tuning
- May get trapped in local minima/maxima
- Increased processing time

Comparative Analysis of Metaheuristic Approaches

CONCLUSION

The aim of the current review is to provide description and evaluation of the application of five of the available metaheuristics: Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Simulated Annealing (SA), and Artificial Bee Colony (ABC). In the context of the current paper, it is necessary to outline the characteristics of the five metaheuristics, and also to carry out a comparative analysis of the five approaches so as to demonstrate their strengths and weaknesses. The described metaheuristics can be effectively used in the context of the allocation of resources and scheduling of tasks in the cloud computing environment. The majority of the traditional methods of task scheduling have several limitations. The first limitation is that most of the traditional methods for task scheduling have been designed in order to be implemented in a static environment where all of the resources and the tasks are previously known. The second limitation is that most of the methods for the task scheduling do not have an efficient implementation in order to be used in the large-scale and dynamic systems of the cloud computing. In this review, the search space of the system can be explored efficiently in order to implement the task scheduling and efficiently to use all of the resources in the system, by the implementation of the metaheuristics-based methods. GA has global search capability, PSO has fast convergence and simple implementation, ACO is efficient for search path and workflow optimization, SA has ability for avoiding local optima, while ABC has ability for efficiently performing search using multi-role search process and for efficiently exploring search space.

Each of the search techniques mentioned for Resource Allocation and Task Scheduling like GA, PSO, ACO, SA and ABC have their strengths and weaknesses. Most of them have high computational cost and are sensitive to the parameters of the technique. Furthermore, they are prone to get stuck into local optima especially for large problems. Thus, a comparative study has been presented to compare the different techniques for solving scheduling problems and it has been shown that no single technique is able to perform better than the others in all possible cases. This means that the best choice of a metaheuristic technique for a scheduling problem is related to the characteristics of the problem to be solved and to the used computing infrastructure. The choice of a scheduling technique is highly dependent on the used metrics to evaluate the achieved results. Therefore, there is a strong need for new approaches that are able to combine the advantages of different existing techniques in order to enhance their search capabilities. This means that future approaches should aim to develop more robust solutions that are able to avoid local optima.

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FUTURE WORK

It is also necessary to conduct further research to utilize the features of the metaheuristics mentioned above to handle and solve the complex problems arising in scheduling in cloud computing environments. As one possible approach, for instance, new scheduling strategies may be created based on hybrid algorithms which will try to combine the advantages of various algorithms for complex scheduling problems. As another example, powerful global search feature of GA can be easily combined with fast convergence capability of PSO. Similarly, ability to avoid being trapped in the local optimum of SA can be easily integrated with cooperative search of ACO for optimization of complex paths or workflows in the schedules. Furthermore, it is also possible to develop other novel approaches for scheduling in cloud computing that would employ learning or deep learning for tuning the search space on-line in order to automatically solve on-line scheduling problems. It is also expected that a comparative study of the above approaches in terms of using large test beds of real world scheduling problems or even on large test beds of virtualized resources and also using heterogeneous resources will be designed in order to investigate issues of large scale scheduling in detail, especially for the purpose of evaluating the issues of scalability and also the computational costs of using the approaches for large and complex scheduling problems. In addition, multi-objective optimization approaches for scheduling also required for tackling many complex scheduling problems in cloud computing in which many conflicting scheduling objectives are expected to be simultaneously optimized in order to improve overall QoS. For example, time, energy, cost and also QoS are the major scheduling objectives that are expected to be simultaneously optimized in many real world cloud computing environments. The investigation for designing energy-aware scheduling approaches and also carbon-aware scheduling approaches is also required in which a set of novel approaches are expected to be designed for scheduling in the cloud for the purpose of improving and providing sustainability to the cloud computing resources.

COMPARATIVE ANALYSIS OF METAHEURISTIC APPROACHES

TABLE I

Algorithm	Advantages	Limitations
GA	Good globalsearch capability	High computation
PSO	Fastconvergence	May gettrapped
ACO	Effectivepath optimization	Slow convergence
SA	Escapeslocaloptima	Longerexecution
ABC	Simpleand flexible	Requires

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