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Research Article

Meta-heuristic Algorithms for Task and Workflow Scheduling in Cloud Computing Environment: An Overview

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Abstract

The meta-heuristic based algorithms are used to address the NP hard problems and they prove their efficiency in solving nearly all of these problems. They produced optimal solutions for large number problems in different domains. One of these domains is the task scheduling and load balancing in Cloud computing environment. Cloud Computing offers good mechanisms to distribute tasks among several virtual resources. Suitable task and workflow scheduling solutions are required to deliver a high performance and accomplish some objectives such as: reliability, security, and load balancing in the cloud environment. In this research, different meta-heuristic algorithms are discussed and a comparison between them is made by illuminated their properties.

Keywords: Meta-heuristic Algorithms; Task Scheduling; Cloud Computing

Introduction

Meta-heuristic algorithms also called approximate algorithms are used in solving many different problems in the computer science field. They are used to deliver an optimal solution or near optimal solution in sensible computational time. Moreover, they produced better results compared with deterministic algorithms in terms of quality and computational time [1].

Many meta-heuristic based algorithms have been developed to deal with the two types of scheduling in the cloud environment: task scheduling and workflow scheduling. There is some quality of services that controls the Cloud resources and services available to users which are based on Pay-as-per-use manner. The high performance computing is needed especially for large and complex application due to big amount of data and computation which are executed by Cloud resources. Scheduling between tasks must be done to optimize resources utilization and reach a high quality of services.

The big solution space obtained by task and workflow scheduling made them classified as NP-hard problems. There- fore, it takes a large period of time to get the optimal solution, several scheduling methods have been proposed to solve them by many researchers, technically, task scheduling is much easier compared to workflow scheduling as it only contracts with a group of tasks without any interdependency and perform them in a random order. On the other hand, work- flow scheduling is much complex since a workflow usually comprises of a group of dependent tasks collaborating together and the scheduler would assign the workflow tasks among virtual machines VMs with respect to their dependencies and execution order.

Some performance metrics are considered when developing any scheduling Meta-heuristic algorithm. These metrics are used to as-

sess the performance of a given method. Although, it can be seen that is not probable to consider all these metrics for an algorithm since it rely on many other factors such the working environment. The following are performance objective parameters of scheduling algorithm appeared in the literature review are:

- **Makespan:** The total time needed by the resources to finish the executing of all tasks. It denotes the duration from the resources assigned a task to the time it completes that task. An efficient scheduling method should have minimum makespan.
- **Resource utilization:** It refers to the utilization of VM, CPU, and storage in such that these resources are well used. Researchers should try to maximize the resource utilization in order to have a good scheduling technique.
- **Energy savings:** Tasks should be mapped to VM in such that the energy consumption should be decreased. If the tasks are poorly assigned it will waste an enormous power due to the large numbers of servers that formulate the datacenters.
- **Cost:** Cost plays a key role for any system. For schedul- ing algorithms, the overall cost of activities should be minimized as possible.

Generally, scheduling problem includes tasks that have to be scheduled on resources depending on some several restrictions such as the agreements between users and cloud providers to improve objective function such as the good quality of services delivered to users. Many complex and computation applications can be organized as workflows. The workflow applications are usually defined as the arrangement of tasks to be treated in well-known order to achieve a certain goal. Scheduling in cloud environment for either tasks or overflow is classified as NP-hard problems. Hence, there is no ideal (optimal) solution available until now within a polynomial time for these type of problems [2]. However, meta-heuristic based algorithms treat these problems by giving close optimal solution in an acceptable time.

Despite the use of a several number of meta-heuristic algorithms, there is no ideal solution for the scheduling problem in the Cloud environment is produced. Hence, there is a need to explore and develop more scheduling algorithms that gives feasible and better solutions.

In this paper, we present a comprehensive study of various scheduling algorithms based on some meta-heuristic methods such as: Particle Swarm Optimization (PSO), Intelligent Water Drops (IWD), Ant Colony Optimization (ACO), Genetic Algorithm (GA), and other methods. A review on different meta- heuristic scheduling algorithms is done then a comparison between them is made.

Meta-heuristic algorithms

In this paper, we concentrate on the most popular and recent used algorithms in solving the scheduling problem on cloud computing environment. Here is a brief description of some of them:

- **Particle Swarm (PSO) algorithm:** Particle Swarm Optimization (PSO) is an optimization algorithm, based on population, global search and meta-heuristic, proposed in [3]. It is a robust optimization method addressed many optimization problems. In this method, the particles swarm is generated arbitrarily at the beginning, and each particle location denotes a probable solution. Every particle is located in the search space and has a fitness parameter and speed to determine the velocity and track of its movement. Particles transfer in the search space depends on the updated location and velocity to find an enhanced solution. At the end of each iteration, particle swarm systematically close to the optimal location. At that point, the optimal solution will be reached.
- **Intelligent Water Drops (IWD) algorithm:** Intelligent Water Drops (IWD) is an optimization technique that is stimulated from detecting normal water drops flowing in rivers using a cluster of water drops to cooperatively seeking for optimal solutions for a particular problem and it solved different problems. It was presented in [4]. It detected that a river repeatedly selects a best path concerning the circumstances of its surrounds to reach its final goal that is a sea. The Intelligent Water Drops (IWD) algorithm is used to assign a number of IWDs to reach the optimal solution. It uses a completely connected graph to formulate an optimization problem, the IWDs moves in the edges of the graph and each IWD starts making its solution regularly by the movements between the vertices of the graph with the direction of heuristic to get optimal solutions.
- **Genetic Algorithm (GA):** Genetic Algorithm is considered as the best evolutionary algorithms that are used to make an optimization on any complex problems. It was introduced in

[5]. The first process in the Genetic Algorithm is to select an initial solution randomly and this solution will be optimized in each time of generate a new solution. After that, we will use the crossover and mutation operation in order to construct new population at each time and that will happen in the earlier generation. The Genetic Algorithm that is based on population and meta-heuristics has different operators that will applied on the initial random population to get the optimized individuals. Sometimes, the selection operators to select a solution from the population to be a parent is used and the crossover operator may be used in order to create offspring and change the offspring by using mutation operator with respect the mutation rule.

- **Ant Colony Algorithm (ACA):** Ant colony optimization algorithm (ACA) is an example of a dynamic task scheduling calculation which was proposed in [6]. ACO is appropriate to use in the clouds; Changing condition and kind of the tasks should adjust to the scheduling technique in order to achieve a good task scheduler. This algorithm concentrate on the several stages the first of all is utilized a positive appreciation system and mimics in order to carry out a real ant colony in nature when they search for food and crossing point each other by secretion pheromone in their route.

Literature Review

In this section, the works are explored and organized according to the used Meta-heuristic algorithm.

Task scheduling based on (PSO) algorithm

A task-scheduling algorithm based on dynamic adaptive PSO (DAPSO) algorithm was presented in [7] to enhance the performance of the original PSO in such that minimize the make span and the maximize the resource utilization, therefore the task run time is optimized. This algorithm combined the (DAPSO) with Cuckoo search called (MDAPSO); the (DAPSO) algorithm is good for global searches. On the other hand, it cannot avoid local optima so in order to enhance the inertia weight and improve the trapping in a local search the Cuckoo search is used. A task-scheduling algorithm based on multi-objective optimization and PSO algorithm called (MOPSO) was presented in [8] that depend on an objectives ranking strategy and includes assessing a three objectives individually to discover the best solution of PSO algorithm and find the optimal VM for each task. These objectives are to reduce the task execution cost, reduce the expected completed time and the CPU speed of VM.

A task-scheduling algorithm based on PSO was presented in [9] which capable to balance the load among VMs by selecting the VM with the maximum compatibility for holding a request. This algorithm used the load balance stage after each initialization step in PSO. Hence, the construction of the initial population rather than a random population in order to improve the particle positions. A task-scheduling algorithm based on modified PSO algorithm was presented in [**?**] that combined the PSO algorithm with the Simulated Annealing algorithm (ASA) where it used to produce a high rate of convergence by avoiding the trapping in a local search. This algorithm focused on the average scheduling length and the successful execution ratio in cloud computing.

Workflow scheduling based on (IWD) algorithm

Processing of an application in cloud computing is made by splitting it into number of workflows and developing them to get the estimated result. The workflows are arranged depend on Quality of Services (QoS) that are differs based on different users. In this section, some workflow scheduling techniques based on IWD algorithm presented. A workflow- scheduling algorithm based on IWD algorithm was presented in [10] that used to decrease the cost of execution by made a tradeoff of the communication cost between resources and the cost of total resources. Moreover, it creates a kind of load balancing by allocating tasks to available resources. A virtual machine scheduling algorithm based on modified IWD algorithm was presented in [11] for dynamic allocation of virtual machines on hosts in homogeneous and heterogeneous environments in order to minimized the total cloud data center energy consumption. The algorithm selects the solution that is taking minimum power as the optimal solution. A workflow- scheduling algorithm based on IWD algorithm was presented in [12] in such that it maps the tasks of the workflow applications among resources according to the fitness function of IWD algorithm, which increased the solution quality and improve the speed of convergence. Therefore, The solution which giving minimum make span is selected. A workflow-scheduling algorithm based on a modified IWD algorithm was presented in [13] that aimed to fulfil the following objectives in cloud: reducing makespan and the executing workflows cost. The modified IWD algorithms works by allocating the workflow tasks to the cloud VMs depend on the best IWD paths obtained.

Task scheduling based on GA algorithm

There are several approaches have been planned to solve any issue related to Genetic Algorithm in order to apply them in task scheduling. The work proposed in [14] present a genetic approach for the grid task scheduling to find better solutions within a minimum amount of time. They reduce the Make- span and flow-time. In addition, they get the employment of available resources. An enhanced genetic technique for static task scheduling was presented in [15] that supposed to improve the solutions of task scheduling. The benefit of evolutionary genetic algorithm and heuristic techniques can use in this research. The results approved that the proposed method supports reachability, deadlock free and fairness is- sues. A genetic Algorithm based scheduling was presented in [16], in this research there are three basic objectives that the GA has to achieve. Firstly, reduce the makespan, increase the utilization, and enhance the speedup ratio. The results of the experiment approve that the presented algorithm has big improvements over the HGAAP, GAHD-CS, and PGA in terms of the investigated objectives.

The researchers in [17] used a hybrid heuristic genetic algorithm with adaptive parameter (HGAP) that depends on genetic algorithm and heuristic earliest finish time (HEFT). The crossover's parameters possibility is adaptive according to the status of the current evolution and then finds improved solution. They have addressed just one objective, which is makespan minimization. A genetic algorithm for task scheduling on heterogeneous systems is presented in [18]. The (HEFT) approach is used to assign each task to the appropriate processor. In such that the calculation of priority of a task is extremely time consuming. This approach addressed one objective that is minimization of makespan.

Aimed at large scale and multi objective resources allocation there is an efficient non-dominated sorting genetic algorithm II (NSGA-II) addressed in [19]. In this research, at the earlier stages we have to know the entire information about the tasks. The main benefit of this algorithm is that overall task execution time and power consumption will be different. The authors improved the makespan and energy consumption simultaneously. Another proposed approach is a "template- based genetic algorithm" (TBGA) which considered the users quality of service constraints in order to schedule the tasks [20]. the proposed approach firstly computes the size of the templates for each processor independently. Templates mean the maximum size of all the tasks that the processes can allocate. Then, the algorithm uses the size of the template to make the combination process between the processors and the tasks using GA. It measured one purpose; reduce the makespan.

Task scheduling based on AC algorithm

A lot of researchers used ACO in order to solve the NP problems, which are hard to solve in an ordinary ways. Such as, graph coloring problem, vehicle and scheduling problem. Recently, many researchers used this algorithm to deal with any scheduling method. Vinh., *et al*. [21] used an improved ant colony algorithm to deal with different task scheduling in cloud. This research prove that ACO algorithm accelerate the clouds task comparing with Round Robin and other optimization algorithm.

A Task Scheduling algorithm based on ACO algorithm was presented in [22] to improve the system efficiency; the researcher used the modified ACO algorithm for achieving task scheduling with reduced makespan in a standard environment for cloud. In the same way, Delavar., *et al*. [23] addressed the concept of task scheduling in the grid-computing environment using the ant colony optimization technique to minimize the cost and the time. Kumar and Venkatesan [?], [24] introduced task-scheduling method by using the effective multi-objective Genetic Algorithm HGA-ACO can find the best task allocation method. (GA) initializes the best pheromone for ACO algorithm and the ACO use the crossover operation to enhance the GA solution.

Other approaches for scheduling

Many researches are introduced in this domain which used a combination of multi-heuristic algorithms. Sundararaj [25] combined the Bee and Ant colony approaches to assign tasks to process in the cloud computing for the mobile. The proposed approach deals with two-way mobile cloud computing with offloading technique. This technique uses the ACO algorithm to minimize the overhead problems and the delay in the response time.

Mansouri., *et al*. [26] proposed a hybrid task scheduling approach by combining the modified particle swarm optimization and fuzzy theory. This algorithm used important issues for example length of tasks, speed of CPU, and total execution time in the fuzzy system for the calculation of the fitness. Sreenu and Malempati [27] proposed a fractional gray walf optimization technique with modification on the position of each task. This technique uses a multi-objective

task scheduling. The algorithm addressed multiple objectives such as the execution of time, cost, consumption of the energy, and resource utilization.

Su., *et al*. [28] proposed cost efficient task scheduling that executed large number of programs on the cloud. The researchers applied this algorithm through two heuristic approaches. This method dynamically combined between tasks and the virtual machine. In addition, service providers of cloud will rent vendors cloud resources by the concept of pay per use service model.

Comparison between different meta-heuristics scheduling methods

There are several task scheduling and workflow-scheduling methods proposed by several researchers in cloud environment, in the following table a comprehensive comparison between them is discussed.

As demonstrated in the literature review and the assessment table above, we can figure out the following characteristics of using meta-heuristic optimization techniques in scheduling algorithms in cloud and finally some future directions were mentioned:

- Optimization algorithms has advantages to minimize or maximize an objective function that is why they are used in cloud computing. The objective in task scheduling is to minimize or maximize the performance metrics.
- Minimization of makespan is the most desirable parameter the researchers focused on because the users want to execute their application as fast as possible.
- There is a trade-off among execution time besides cost. If a user requests to execute his job faster, he has to pay more that is why faster resources are regularly expensive.
- PSO algorithm is the most frequently used in scheduling in cloud computing and there is more than one survey presented an analysis of different PSO algorithms in scheduling in cloud differed in how they calculated the objectives in the fitness function.
- Combining meta-heuristic algorithm with some other meta-heuristic algorithm or local searching lead to enhancing solution quality.
- Most researchers have proposed and discussed a few number of objectives when addressing scheduling algorithms. Thus, there is a need to address and develop scheduling algorithms with many objectives.
- There are many parameters such as security, load balancing, and storage cost needs further investigation in scheduling in cloud computing.

Author Name and Year of Publication	Scheduling Al-gorithm	Objective Parameter	Findings
(Al-maamari and Omara, 2015) [7]	MDAPSO	Minimizes makespan and maxImize resource utilization	This research introduced meta-heuristic approach based on PSO algorithm called (MDAPSO), this algorithm has been compared with the original PSO and other PSO versions and it outperforms them in terms of makespan and resource utilization.
(Alkayal., *et al*. 2016) [8]	MOPSO	Minimizes waiting time and execution time, maximizes Throughput.	this research introduced a multi-objective PSO based technique to optimize the task scheduling procedure. MOPSO algorithm has shown improvements in the throughput and reduction in the total execution time.
(Ebadifard and Babamir, 2018) [9]	PSO	Maximizes resource utilization and Minimizes makespan	This research introduced a PSO based algorithm besides the load balancing technique to enhance the allocation of requests without looking for the request compatibility. This algorithm has been compared with the Round Robin, and enhanced PSO task scheduling and it outperforms these algorithms in terms of resource utilization, makespan and it reach the near optimal solution very fast.

(Jana., *et al*. 2019) [29]	MPSO	Average schedule length and ratio of successful execution.	This research introduced a meta-heuristic approach based on PSO algorithm called (MPSO), this algorithm has been compared with Max-Min task schedul- ing and the result has shown that the proposed method average schedule length is decreased and the successful ratio is increased.
(Sivaparthipan., *et al*. 2015) [10]	IWD	Minimize the total execution cost	This research introduced an IWD based scheduling algorithm that decreased the total cost of execution. The result has shown that the IWD algorithm outperforms the Best Resource Selection algorithm in cost savings.
(Verma., *et al*. 2017) [11]	MIWD	Energy savings	This research introduced a modified IWD algorithm to optimize the energy consumption. The result has shown that MIWD algorithm attained superior energy savings with fewer number of VM migrations and growing number of VMs compared to the original IWD algorithm.
(Kalra and Singh, 2017) [12]	IWD	Minimize makespan	This research introduced an IWD based scheduling algorithm that mapping tasks to resources targeting to reduce the makespan. The result has shown that the presented method outperforms PSO and SGA algorithm according to makespan.
(Elsherbiny., *et al.* 2018) [13]	IWDC	Minimize makespan and cost	This research introduced an IWDC based scheduling algorithm that allocated the tasks of the workflow to the VMs in cloud depending on the best IWD paths obtained. This algorithm has been compared with Max-Min, Round robin, FCFS, and MCT and the result has shown that IWDC algorithm has the minimum cost.
(Singh., *et al*. 2019) [14]	GA	Reduce the make-span and the flow-time simultaneously	This research uses a genetic algorithm for grid task scheduling to improve the efficiency .
(Keshanchi., *et al*. 2017) [15]	N- GA	Enhance the execution time	This research used GA besides a heuristic (HEFT) technique for the task assignment process.
(Bose., *et al*. 2019) [16]	GA	Increase the speed up. Minimize the makespan	In this research, they designed a genetic algorithm for multi-core system. This algorithm has big improvements in compare with the GAHDCS, HGAAP, and PGA in.
(Ding., *et al*. 2017) [17]	HGAAP	Minimize the makespan	In this research, a hybrid genetic algorithm with adaptive parameter (HGAAP) is discussed by combined between the heuristic scheduling algorithm and genetic algorithm.
(Yuming., *et al*. 2014) [18]	MPQGA	Minimize the execution time	The key point in this approach is to use a rank to each subtask when using a heuristic-based earliest finish time (EFT) approach.
(Friese, 2016) [19]	NSGA-II	Optimized makespan and en-ergy consumption at the same time	This paper improved a chromosome structure for task scheduling using the genetic algorithm depend on collections of related tasks and machines.
(Sheng and Li, 2016) [20]	TBGA	Minimizing the makespan of a given task set in Clouds	This Research concentrated on modifying ACO to address cloud task scheduling

(Reddy and Kumar, 2019) [22]	MACO	Reducing Makespan and decrease the degree of imbalance	This research deal with cloud task scheduling based on the Modified ACO algorithm
(Kumar and venkatesan, 2019) [24]	HGA-ACO	minimize response time, completion time and throughput	This research improved the well performance in task distributions and the quality of service parameters.
(Mansouri., *et al*. 2019) [26]	FMPSO	Enhance load balance and cloud throughput	This research has better makespan, the ratio of enhancement, the degree of imbalance and the total execution time compared to other methods.
(Sreenu and Malempati, 2019) [27]	MFGMTS	Meet the user requirement and increase the efficiency	This approaches concentrate on reducing the execution time, decrease cost, and communication cost.

Table 1: Comparison between different meta-heuristics scheduling methods in cloud.

Conclusions and Future Work

Meta-heuristic optimization algorithms have become popular because of its effectiveness in a wide-range applications scope including scheduling algorithms in cloud. In this paper, we have discussed several meta-heuristic scheduling algorithms (task scheduling and workflow scheduling) in cloud computing, classified them, studied their characteristics and properties, and compared between them. In addition, we presented some points of view about using optimization algorithms in cloud scheduling and some future directions. The performance metrics in task scheduling such as makespan and resource utilization couldn't be compared because they are applied in different data sets. Therefore, as a future work, we hope to apply most of them and compute the same metrics over the same data sets.

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