# A study on various job scheduling algorithms in Multi-Cloud Environment

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**Abstract:** Job scheduling problem in cloud computing environment is considered to be NP complete problem. Since cloud computing differs from the traditional computing in various aspects, the existing job scheduling algorithms cannot be used in cloud environment. The problem becomes even harder when there is a multi-cloud environment. This paper studies the existing job scheduling algorithms in cloud computing environment and identifies their features and challenges. A detailed analysis of the existing job scheduling algorithms is presented in the paper. To overcome the challenges of the existing algorithms, a new job scheduling algorithm; Self-Adaptive Brainstorming is proposed for multi-cloud environment which is based on the existing Brain Storming Optimization algorithm. The methodology and expected outcome for the same is discussed in the paper.

**Keywords:** Job scheduling, multi-cloud, cloud computing

## 1. Introduction

Cloud computing is used to provide the calculation platform for Internet users as a large-scale distributed dynamic group. The cloud computing is usually in ultra large scale and high scalability. To be more specific, cloud computing can be linked with a large number of idle resources and constitute a large scale resource pool [9]. And then this size can be dynamically adjusted according to the application and demand, which can maximize the utilization of various resources present in the cloud computing system to provide services for users and applications [10] [11]. Cloud computing can be considered as a large-scale distributed computing paradigm. Cloud Computing has evolved from the traditional distributed computing and grid computing [1,2]. The nature of computational resources available in cloud can be highly dynamic and probably heterogeneous. Cloud computing differs from traditional distributed computing in terms of scalability, elasticity and on-demand resource allocation [13]. The various computing resources provided by cloud may be geographically distributed and can be shared among various jobs in cloud.

One of the many important activities performed in grid and cloud computing environments is job scheduling. The objective of job scheduling is to provide available computational resources in cloud as a service over the network [17]. Job scheduling in cloud computing environment is known to be NP-complete problem [18]. The complexity and practical importance of job scheduling is seeking researcher's attention worldwide [14] [19]. Task scheduling problem is a difficult problem in the research field on cloud computing [20, 21]. According to the characteristics of cloud computing the task should be assigned to different resource nodes corresponding to perform appropriate strategies, in order to achieve a better result[20, 22, 23].The process of task scheduling is equivalent to the traditional computer operating system scheduling [28] [29] [30]. According to a certain order, it executes distributed processors for execution and processing to minimize the consumption of data communication. The process of scheduling is to make the operating system sharing the resources and avoiding the competition. Therefore, a good scheduling algorithm will be effective and reasonable in process, effectively improve the utilization rate of resources.

A lot of work has been done in various aspects of job scheduling problem [12] and on different platforms [13] [14] [15] [16]. Some motivating research results have been obtained for efficiently scheduling jobs in cloud, but such problems are still considered as NP-complete [18]. Many of the job scheduling algorithms used in cloud computing are rule based [20] as they are quite easy to understand and simple to implement. Rule based algorithms have shown poor performance when used for scheduling complex tasks [21]. Some of the commonly used meta-heuristic techniques applied for scheduling jobs in grid and cloud environment are Particle Swarm Optimization (PSO) [23] [24], Genetic Algorithm (GA) [22], and Ant Colony Optimization (ACO) [25] [27]. Due to the exploratory capability of PSO for finding optimal solutions, it has a faster convergence rate and obtains better solutions than GA and ACO [26]. Considering enhanced performance of PSO over ACO and GA, many variants and hybrid versions of PSO have been used for benchmarking the proposed algorithm. Unfortunately, scheduling algorithms that were used in traditional distributed computing could not do well in cloud computing environment because of its dynamic nature and large-scale infrastructure.

## 2. Related Work

In 2014, Sung et al. [1] have tried to optimize job scheduling by making use of biogeography-based optimization (BBO). BBO migration technique was used for changing the existing solutions and for adapting new better solutions. BBO has offered the advantage of adaptive process, which has been developed for binary integer job scheduling problem in cloud computing environment. It was observed with the help of experimentation that the performance of the methods proposed were better than the other methods that are considered in job scheduling problems.

In 2014, Xiaoli et al. [2] have proposed a new multi-objective bi-level programming model that is based on MapReduce to enhance the energy efficiency of servers. Firstly, the energy consumption variation with respect to the performance of servers was taken into consideration; secondly, dynamic adjustment of data locality could be done as per the current network state; and lastly, the direct dependency of task-scheduling strategies on data placement policies has been taken into consideration. They have formulated the problem as an integer bi-level programming model. Specific-design encoding and decoding methods were introduced for solving the methods efficiently. Based on these, a new effective multi-objective genetic algorithm based on MOEA/D is proposed. As there are usually thousands of jobs that need to be scheduled on the cloud, this was considered as a large-scale resource optimization problem and a local search operator was designed to enhance the convergence rate of the proposed algorithm. The numerical experiments have indicated the effectiveness of the proposed model and algorithm.



In 2016, Fredy et al. [3] have developed a real-time dynamic scheduling system to execute efficiently task-based applications on distributed computing platforms in order to minimize the energy consumption. They have presented a polynomial-time algorithm that combines a set of heuristic rules and a resource allocation technique in order to get good solutions on an affordable time scale. The proposed algorithm has minimized a multi-objective function which combines the energy-consumption and execution time according to the energy-performance importance factor provided by the resource provider or user, also taking into account sequence-dependent setup times between tasks, setup times and down times for virtual machines (VM) and energy profiles for different architectures. A prototype implementation of the scheduler has been tested with different kinds of DAG generated at random as well as on real task-based COMPSs applications.

In 2016, Yongsheng et al. [4] have developed an adaptive algorithm for scheduling modular non-linear parallel jobs in meteorological Cloud, having a unique parallelism which can be configured only at the time of beginning the execution. Unlike some existing works, this algorithm has taken into account four characteristics of the jobs simultaneously, which includes job deadlines, average execution time, number of resources assigned, and the overall system load. They have demonstrated the efficiency and effectiveness of the scheduling algorithm with the help of simulations using WRF (Weather Research and Forecasting model) which has been popularly used in scientific computing. Further, the evaluation results have proved the effectiveness of the proposed algorithm.

In 2015, Toktam et al. [5] have suggested to perform scheduling of scientific and data intensive workflows on the hybrid models of volunteer computing system and Cloud resources in order to improve the utilization of the above mentioned environments and improve the percentage of workflow meeting deadlines. The proposed system for scheduling workflows divides a workflow into smaller sub-workflows so as to reduce data dependency among sub-workflows. These smaller sub-workflows are then scheduled to be distributed on the volunteer resources in accordance with the proximity of resources and load balancing policy of the system. In this phase the execution time of all the sub-workflows is estimated on selected volunteer resources. If the sub-deadline of any sub-workflow is missed because of the large waiting time, then that sub-workflow is re-scheduled on the public Cloud resources. The above mentioned re-scheduling improves the performance of the system by enhancing the number of workflows meeting the deadline.

In 2017, Jiachen et al. [6] have introduced a a simplified model for task scheduling system in cloud computing. Different from the previous research of cloud computing task scheduling algorithm, the simplified model in this paper was based on game theory as a mathematical tool. Based on game theory, the task scheduling algorithm considering the reliability of the balanced task was proposed. Based on the balanced scheduling algorithm, the task scheduling model for computing nodes was proposed. In the cooperative game model, game strategy was used for the task in the calculation of rate allocation strategy on the node. Through analysis of experimental results, it was shown that the proposed algorithm has better optimization effect.

In 2017, Hend et al. [7] have developed grouped tasks scheduling (GTS) algorithm that can be used for scheduling tasks in cloud computing network by applying quality of service (QoS) to satisfy user requirements. The proposed algorithm has distributed tasks into five categories; each category has tasks with similar attributes (user type, task type, task size, and task latency). After adding tasks into right category, they have started scheduling these tasks into available services. Scheduling was done in two steps: first step was deciding which category will be scheduled first. This was depended on the attributes of the tasks that belong to each category so the category that has tasks with high value of attributes will be scheduled first. Second step was deciding which task inside the chosen category will be scheduled first. This was depended on the execution time of task so the task that has minimum execution time will be scheduled first.

In 2016, Mohammed and Shafi [8] have implemented the Discrete Symbiotic Organism Search (DSOS) algorithm which is used for optimally scheduling tasks over cloud resources. The Symbiotic Organism Search (SOS) was a newly developed meta-heuristic optimization technique which can be used for solving numerical optimization problems. The SOS imitates the symbiotic relationships such as commensalism, mutualism, and parasitism; exhibited by organisms in an ecosystem. The experimentation and simulation results have shown that DSOS performs better than the Particle Swarm Optimization (PSO) which was one of the most popular heuristic optimization techniques used for task scheduling problems. DSOS is also suitable for large-scale scheduling problems because it has shown faster convergence when the search space gets bigger. An analysis of the proposed technique was conducted using t-test and showed that the performance of DSOS was significantly better than that of the PSO particularly in case of large search space.



## 3. Problem in Existing Work

The detailed review on job scheduling algorithms in cloud computing with the appropriate advantages and disadvantages is shown in Table 1. The recent job scheduling algorithms are BBO [1], GA [2], Graph theory [3], Scheduling with job parallelism [4], Partition based scheduling [5], Game theory [6], Grouped tasks scheduling [7] and Symbiotic organism search optimization [8]. The BBO algorithm [1] is an adaptive process that can produce new good solutions, yet it is not as good in exploiting some complex solutions and there is no appropriate condition for selection of the best members from each solution that may lead to cause uncertainty. Moreover, GA [2] exhibits less energy consumption and can solve the model efficiently with less convergence speed, whereas it cannot assure constant optimization response time and fails to find the global optimum. Better solution and optimum energy savings can be provided by the graph theory [3], but its approximation ratio is worst and it consumes huge amount of memory. Furthermore, Scheduling with job parallelism [4] takes less execution time, can tolerate the mistakenness in system's load condition, attains higher completion ration and it can do all types of parallel jobs, yet it is non-adaptive to user-defined resource preference. The Partition based scheduling [5] enhances the percentage of successful workflows and attains high improvement factor and use poor resource utilization for hard timing constraints. Even more, Game theory [6] can easily possible to compute the stability of nodes and exhibits high response time, yet the technique is complicated and it cannot solve the competitive problems. Moreover, minimum execution time is used by Grouped tasks scheduling [7], provides better load balancing and average latency whereas it fails under the condition of having more number of attributes and it is not applicable in real-time applications. The Symbiotic organism search optimization [8] is easier to implement, but it is unable to deal with discrete optimization problems, complexity in solving the real problems and takes a long computation time. Therefore, job scheduling algorithms in cloud computing still requires additional improvements to overcome the aforementioned challenges.

Table 1: Review on Job scheduling algorithms in Cloud computing

| **Author [Citation]** | **Adopted Methodology** | **Features** | **Challenges** |
|---|---|---|---|
| Sung et al. [1] | Biogeography-based optimization | ❖ It is an adaptive process<br>❖ Can produce new good solutions | ❖ It is not good in exploiting solutions<br>❖ There is no provision for selection of the best member from each generation |
| Xiaoli et al. [2] | Genetic algorithm | ❖ Less energy consumption<br>❖ Can solve the model efficiently with less convergence speed | ❖ Cannot assure constant optimization response time<br>❖ Fails to find the global optimum |
| Fredy et al. [3] | Graph theory | ❖ Provides better solution and energy savings<br>❖ Applicable for run-time scheduling | ❖ Worst approximation ratio<br>❖ Consumes huge amount of memory |
| Yongsheng et al. [4] | Scheduling with job parallelism | ❖ Less execution time<br>❖ Can tolerate the mistakenness in | ❖ Not adaptive to user-defined resource preference |

| | | | |
|---|---|---|---|
| | | system's load condition<br>❖ Higher completion ratio<br>❖ Can do parallel jobs | |
| Toktam et al. [5] | Partition based scheduling | ❖ Enhances the percentage of successful workflows<br>❖ Attainment of high improvement factor | ❖ The result may not be optimal<br>❖ Poor resource utilization for hard timing constraints |
| Jiachen et al. [6] | Game theory | ❖ Easily possible to compute the stability of nodes'<br>❖ high response time | ❖ The technique is complicated<br>❖ It cannot solve the competitive problems |
| Hend et al. [7] | Grouped tasks scheduling | ❖ Minimum execution time<br>❖ Better load balancing<br>❖ Average latency | ❖ Failed if increasing the number of attributes<br>❖ Not applicable in real-time |
| Mohammed and Shafi [8] | Symbiotic organism search optimization | ❖ Easier to implement<br>❖ Benefit factor and parasite vector mechanism | ❖ Not possible to deal with discrete optimization problems<br>❖ Difficult for solving complex real problems<br>❖ Takes a long computation time |



## 4. Proposed Solution and Methodology

This proposal intends to exploit human inspired optimization algorithm for solving the job scheduling problem in the cloud environment. Since the job scheduling is challenging under multi-cloud environment, this proposal intends to improve the renowned human inspired optimization algorithm called as brain storm optimization with self-adaptive characteristics. While the traditional brain storm optimization clusters the individuals, which are time consuming and low-level characterization, the proposed self-adaptive brain storm optimization algorithm will rank the individuals adaptively based on the improvement in the solutions. As a result, the recommendation of solutions gets improved and so the desired updating can be done. With this context, the scheduling process will be performed. Here, the allocation of jobs for resources of heterogeneous cloud will be encoded as brain storming process. The steps involved in the simplified Brain Storm Optimization are shown below in figure 1 and the flowchart for the same is shown in figure 2. The resultant scheduling scheme will be evaluated for different performance constraints such as resource utilization rate, job completion and make span. A combined objective model will be derived and subjected to solve job scheduling problem using the proposed optimization algorithm.

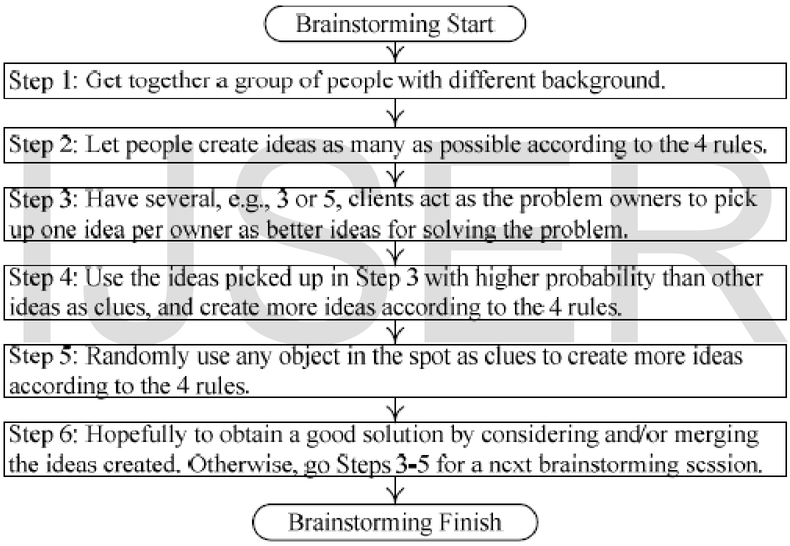


Figure 1: Steps in a typical Brainstorming Process

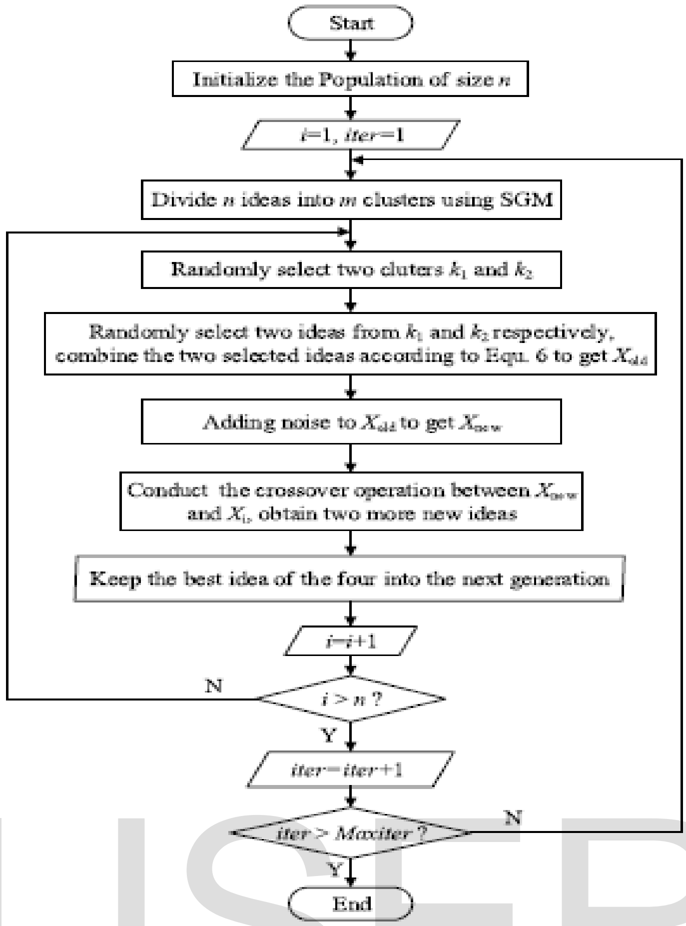


Figure 2: Flowchart of Simplified Brain Storm Optimization

The steps involved in the proposed jobshop scheduling algorithm are given below.

**Step 1:** Acquire the availability of cloud resources and job details

**Step 2:** Derive the multi-objective optimization model to consider the performance constraints of job scheduling

**Step 3:** Initialize with different allocation recommendations, perform self-adaptive brainstorming.

**Step 4:** Repeat the process with updating model so that the scheduling schemes are improved

**Step 5:** Terminate the process once the target of scheduling is accomplished.

## 5. Conclusion

The proposed jobshop scheduling in multi-cloud environment will be developed in JAVA and experimentations will be carried out. The performance of the proposed algorithm will be compared against the conventional meta-heuristic search algorithms in terms of resource utilization, throughput and makespan.

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