A Novel Hybrid Algorithm Based on Firefly Algorithm and Differential Evolution for Job Scheduling in Computational Grid

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ABSTRACT

Scheduling jobs in computational Grids is considered as NP-complete problem owing to the heterogeneity of shared resources. The resources belong to many distributed administrative domains that enforce various management policies. Therefore, the use of meta-heuristics are more appropriate option in obtaining optimal results. In this article, a novel hybrid population-based global optimization algorithm, called the Hybrid Firefly Algorithm and the Differential Evolution (HFA-DE), is proposed by combining the merits of both the Firefly Algorithm and Differential Evolution. The Firefly Algorithm and the Differential Evolution are executed in parallel to support information sharing amongst the population and thus enhance searching efficiency. The proposed HFA-DE algorithm reduces the schedule makespan, processing cost, and improves resource utilization. The HFA-DE is compared with the standard Firefly Algorithm, the Differential Evolution and the Particle Swarm Optimization algorithms on all these parameters. The comparison results exhibit that the proposed algorithm outperforms the other three algorithms.

KEYWORDS

Computational Grid, Differential Evolution, Firefly Algorithm, Job Scheduling, Makespan, Particle Swarm Optimization, Resource Utilization

1. INTRODUCTION

Computational Grid has been considered as an emerging distributed computing system. It is a collection of heterogeneous computing resources connected by a network across dynamic and geographically distributed organizations, to provide a distributed high-performance computing infrastructure (Foster & Kesselman, 2004). The goal of this infrastructure is to share resources among the participating users, which enable them to access high computing power that cannot be provided ordinarily by an individual. The primary issue of Grid efficiency is its job scheduling, i.e. efficiently assigning jobs to resources. Grid environment is dynamic as resources join and leave the system abruptly, and the resources are heterogeneous as they are from different computing domains and subject to diverse controlling policies. These dynamism and heterogeneity issues compel additional challenges to scheduling and hence the conventional mechanisms cannot be directly employed.

The primary objective of job scheduling in computational Grid is to maximize the resource utilization and to minimize processing time of the jobs. This problem has been proven to be NP-complete which means the execution of the algorithms requires exponential time. Exhaustive researches in job scheduling have been going on and many results have been widely accepted.

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In this paper, we have proposed a hybrid algorithm, called HFA-DE, which combines the merits of Firefly Algorithm (FA) and Differential Evolution (DE) concurrently to minimize two key performance parameters, viz. makespan and processing cost, and to maximize resource utilization. The HFA-DE combines the attraction ability of FA with the mixing ability of DE so as to increase the speed of convergence and the diversity of the population. The HFA-DE is compared with the standard FA, standard DE and Particle Swarm Optimization (PSO) algorithms for the above mentioned three parameters.

This paper is organized as follows. Section 2 highlights the relevant past works done on job scheduling in computational Grid environment. Section 3 defines the framework of Grid job scheduling problem. Sections 4, 5 and 6 outline the FA, DE and PSO algorithms respectively. Section 7 describes the HFA-DE algorithm for scheduling jobs in computational Grid systems. Section 8 exhibits the results obtained in this study. Finally, Section 9 concludes the paper.

2. RELATED WORKS

The job scheduling problem in Grid computing is a NP-complete problem (Ma et al., 2011). Task of the scheduler is to manage the jobs and resources. The scheduler performs two main functions: first scheduler selects the appropriate computational resource for the job and then assigns the resource to the jobs (Sharma & Mittal, 2013). New techniques, particularly those based in meta-heuristic algorithms, have been proposed to solve the Grid scheduling problem. These sorts of techniques make realistic assumptions based on a priori knowledge of the concerning environment and of the system load characteristics. The most frequently used meta-heuristic algorithms are Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Firefly Algorithm (FA), Differential Evolution (DE), Ant Colony Optimization (ACO) and Cuckoo Search Algorithm (CSA).

The GA is a meta-heuristic algorithm that imitates the principle of genetic process in living organisms. The GA is a very popular algorithm to solve various types of combinatorial optimization problems. Job scheduling in computational Grid using GA has been addressed by Buyya et al. (2000); Braun et al. (2001); Zomaya and Teh (2001); Martino and Mililotti (2004); Page and Naughton (2005); Gao et al. (2005); Xhafa et al. (2008) and Aggarwal and Kent (2005). Prakash and Vidyarthi (2015) have proposed a new mechanism to maximize the availability of resources for job scheduling in computational Grid using GA. Enhanced Genetic-based scheduling for Grid computing is proposed in (Kolodziej & Xhafa, 2011).

Job scheduling in computational Grid using PSO has been studied by Izakian et al. (2009); Zhang et al. (2008) and Salman et al. (2002). Abraham et al. (2010) proposed an approach for scheduling jobs on computational Grids using fuzzy PSO algorithm. Ghosh and Das (2016) proposed a modified binary version of PSO algorithm for the job scheduling problem in computational Grid.

The FA is a meta-heuristic algorithm, inspired by the flashing behavior of fireflies. Yousif et al. (2011) proposed method based on the FA to dynamically create an optimal schedule to complete the jobs within minimum makespan. The DE is another population based evolutionary algorithm which searches for the global optima by utilizing differences between contemporary population members, which allows the search behavior of each individual to self-tune. Selvi et al. (2011) proposed an approach based on the DE algorithm for scheduling jobs on computational Grid. The proposed approach generates an optimal schedule so as to complete the jobs within a minimum period of time and utilizing the resources efficiently.

An ACO implementation of the problem has been given by Ritchie (2003). Lorpunmanee et al. (2007) have also implemented an ACO algorithm for dynamic job scheduling in Grid environment. Tiwari and Vidyarthi (2014) have examined the effect of inter process communication in auto controlled ACO based scheduling on computational Grid. Job scheduling in computational Grid using CSA has been investigated by Prakash et al. (2012), Rabiee and Sajedi (2013), and Ghosh et al. (2017). A
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