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ORIGINAL ARTICLE

Multiobjective Variable Neighborhood Search algorithm for scheduling independent jobs on computational grid

S. Selvi [a,*], **D. Manimegalai** [b,1]

[a] *Department of Electronics and Communication Engineering, Dr. Sivanthi Aditanar College of Engineering, Tiruchendur 628215, Tamil Nadu, India*
[b] *Department of Information Technology, National Engineering College, Kovilpatti 628503, Tamil Nadu, India*

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Abstract Grid computing solves high performance and high-throughput computing problems through sharing resources ranging from personal computers to super computers distributed around the world. As the grid environments facilitate distributed computation, the scheduling of grid jobs has become an important issue. In this paper, an investigation on implementing Multiobjective Variable Neighborhood Search (MVNS) algorithm for scheduling independent jobs on computational grid is carried out. The performance of the proposed algorithm has been evaluated with Min–Min algorithm, Simulated Annealing (SA) and Greedy Randomized Adaptive Search Procedure (GRASP) algorithm. Simulation results show that MVNS algorithm generally performs better than other metaheuristics methods.

1. Introduction

Grid computing is a form of distributed computing that involves coordinating and sharing computing, application, data and storage or network resources across dynamic and geographically dispersed organization [1]. Users can share grid resources by submitting computing tasks to grid system. Resources can be computers, storage space, instruments, software applications, and data, all connected through the Internet and a middleware layer that provides basic services for security, monitoring, resource management and so forth.

One of the main motivations of the grid computing paradigm has been the computational need for solving many complex problems from science, engineering, and business such as

* Corresponding author. Tel.: +91 8903484336; fax: +91 4639 243188.
E-mail addresses: mathini31@yahoo.co.in (S. Selvi), megalai_nec@yahoo.co.in (D. Manimegalai).
[1] Tel.: +91 9442636698; fax: +91 4632 232749.

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hard combinatorial optimization problems, protein folding and financial modelling [2–4]. As a cooperative environment of solving problem, it is necessary for the grids to develop efficient job scheduling schemes and resource management policies in regard to their objectives, scope, and structure. However, there exists different and somewhat conflicting QOS objectives for management and security policies among the hierarchy based grid entities such as grid users (applications), grid resource administrative and virtual organization administrative. To increase the level of satisfaction of various grid entities, grid resource management system must use the scheduling strategy, which provides a compromise solution by considering several conflicting objectives.

Minimization of makespan is the most popular and extensively studied system-related optimization criterion. Makespan is an indicator of the general productivity of the grid system: Small values of makespan mean that the scheduler is providing good and efficient planning of tasks to resources. Considering makespan as a standalone criterion not necessarily implies the optimization of other objectives. Hence, it is necessary to devise the task scheduling algorithms in order to optimize both system-related and user-related objectives. One of the user-related objectives is the flowtime, which refers to the response time to the user submissions of task executions. Minimizing the value of flowtime means that the average response time of the grid system is being reduced. However, as discussed in [5], minimizing the makespan requires the most demanding jobs to be assigned to the fastest resource, at the expense of increasing the finish time of other jobs, and hence increasing flowtime. On the other hand, optimizing flowtime requires all jobs to finish quickly on the average, at the expense of having the most demanding jobs taking a longer completion time, thus increasing makespan. This justifies the search for algorithms that minimize both makespan and flowtime. Scheduling n jobs to m resources had been shown to be NP-complete [6]. Meta-heuristic approaches have shown their effectiveness for a wide variety of hard combinatorial problems and also for multi-objective optimization problems.

The main contribution of this work is the thorough experimental exploration of multiobjective VNS, with the problem specific neighborhood structures to solve the grid job scheduling problem, by minimizing the makespan and flowtime objectives. Efficient numerical results are reported in the experimental analysis performed on a set of 72 well known and large heterogeneous computing scheduling problem instances. The comparative study shows that the proposed MVNS is able to achieve high problem efficiency and outperforming the results of Min–Min algorithm, SA and GRASP algorithms.

Variable Neighborhood Search is a simple and effective meta-heuristic method developed to efficiently deal with the hard optimization problem. VNS is a framework for building heuristics, based upon systematic changes of neighborhoods both in descent phase, to find a local minimum, and in perturbation phase to emerge from the corresponding valley. VNS has also demonstrated good performance on industrial applications such as the design of an offshore pipeline network [7] and the pooling problem [8]. It has also been applied to real-world optimization problems, including optimization of a power plant cable layout [9], optical routing [10] and online resources allocation problem for ATM networks [11]. Applications of VNS are diverse which include the areas such as location problems, data mining, graph problems, mixed integer problems, scheduling problems, vehicle routing problems and problems in biosciences and chemistry [12].

2. Related works

Due to the popularization of distributed computing and the growing use of heterogeneous clusters in the 1990s [13,14], the heterogeneous computing scheduling problem (HCSP) became especially important. Hence many researchers paid attention in solving the HCSP. But the multiobjective HCSP variants that propose the simultaneous optimization of several efficiency metrics have been scarcely studied. Krauter et al. [15] provided a useful survey on grid resource management systems, in which most of the grid schedulers such as AppLes, Condor, Globus, Legion, Netsolve, Ninf and Nimrod use simple batch scheduling heuristics. Braun et al. [16] studied the comparison of the performance of batch queuing heuristics, Tabu Search (TS), GA and Simulated Annealing (SA) to minimize the *Makespan*. The results revealed that GA achieved the best results compared with the batch queuing heuristics. Some of the job scheduling algorithms are nature-inspired, e.g., SA [17], Ant Colony Optimization [18], Particle Swarm Optimization [19], Differential Evolution (DE) [20], parallel Cross generational elitist selection, Heterogeneous recombination, and Cataclysmic mutation (pCHC) [21]. There are also non-nature-inspired metaheuristics, such as TS [22], Threshold Accepting (TA) [23], and VNS algorithm [24]. Xhafa [25] studied the performance of Memetic algorithm (MA) with different local search algorithms including TS and VNS. The experimental results revealed that MA + TS hybridization outperforms the combinations of MA with other local search algorithms. Abraham et al. [26] proposed the variable neighborhood particle swarm optimization algorithm. They empirically showed the performance of the proposed algorithm and its feasibility and effectiveness for scheduling work flow applications. Lusa and Potts [27] proposed the VNS algorithm for the constrained task allocation problem and compared the performance of the proposed algorithm with the other local search procedures. Moghaddam et al. [28] presented a hybrid GA and VNS to reduce the overall cost of task executions in grid environment.

Few works have considered the optimization of makespan and flowtime objectives for the scheduling problem [25,29]. Jacob et al. [30] studied the optimization of four objectives, namely makespan, resource utilization, time and cost of application for solving the HCSP. Xu et al. [31] experimented the Chemical Reaction Optimization (CRO) algorithm based grid job scheduling problem by considering makespan, flowtime and tardiness of the solution.

The VNS algorithm has received relatively little attention in solving the grid job scheduling problem. From the literature, it is known that VNS has been used in hybridization with other algorithms for such problems. To our knowledge, there are no other antecedents on applying explicit VNS to solve the heterogeneous computing scheduling problem tackled in this work, so the approach presented here is a novel approach in