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User-Oriented Many-Objective Cloud Workflow Scheduling Based on an Improved Knee Point Driven Evolutionary Algorithm

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Abstract: Cloud computing is able to deliver large amount of computing resources on demand, and it has become one of the most effective ways to implement large-scale computationally intensive applications. In a cloud computing environment, applications typically involve workflows. Therefore, optimized workflow scheduling can greatly improve the overall performance of cloud computing. However, existing studies on cloud workflow scheduling usually consider at most three objectives only and effective methods to solve scheduling problems with four or more objectives still lack. To address the above issue, a new cloud workflow scheduling model is formulated that simultaneously considers four objectives, namely, minimization of makespan, minimization of the average execution time of all workflow instances, maximization of reliability, and minimization of the cost of workflow execution. To solve this four-objective scheduling problem, an improved knee point driven evolutionary algorithm is proposed. Extensive experimental results demonstrate that the improved algorithm outperforms existing popular many-objective evolutionary algorithms in most experimental scenarios studied in this work, in particular when there is sufficiently large amount of computing resource supply and the time for scheduling is limited.

Keywords: Cloud computing, cloud workflow scheduling, many-objective optimization problems, knee point driven evolutionary algorithm

1. Introduction

With the ubiquitous growth of the Internet, cloud computing has proliferated in a number of fields [1]. Most cloud computing applications are composed of multiple tasks, and there are dependency relationships among tasks. These tasks constitute a workflow, called the cloud workflow [2]. Cloud workflow scheduling aims to allocate cloud workflow tasks to the resource nodes (virtual machines) in the cloud computing environment with specific constraints to obtain the optimal scheduling result. This problem has become a hot topic in the field of cloud computing and has received increasing attention from both academia and industry.

However, most existing studies deal with cloud workflow scheduling as a single-, bi-, or three-objective optimization problems by either making unrealistic assumptions that cannot be met in many application scenarios, or neglecting some important requirements of the service provider or the users [3-5]. For example, existing studies typically minimize execution time or execution costs only, without taking into account other scheduling objectives such as reliability. In addition, time-related objectives usually consider minimizing the makespan, which is insufficient in dealing with many online application systems, in particular when the quantity of cloud workflow instances is large. In this situation, some workflow instances may start to execute at an earlier time, but their follow-up tasks may finish at a later time. This scenario does not necessarily lead to an increment in the total completion time of all workflow instances, but will result in a longer average completion time of instances, which will unfavorably affect user experience. Further, most studies do not explicitly perform scheduling for user quality of service (QoS) or scheduling for provider efficiency. Therefore, it is highly desirable to formulate cloud workflow scheduling as a many-objective optimization problem taking into account the requirements from service provider
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