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On complex tasks scheduling scheme in cloud market based on coalition formation☆

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ABSTRACT

With the increasing workload and complexity of tasks submitted by cloud consumers, how to complete these tasks effectively and rapidly with limited cloud resources is becoming more challenging. However, most of existing mechanisms focus on auction-based allocation of cloud resources rather than on the approaches to performing tasks by the allocated cloud resources. In order to solve this problem, this paper first divides the complicated task into multiple sub-tasks, and then presents the problem of sub-tasks scheduling in a formalized manner. Next, a practical task scheduling scheme that includes task scheduling mechanism, winner coalition formation mechanism and payment sharing mechanism is proposed. In addition, this paper gives some useful theorems which can suggest that the proposed scheme possesses task execution efficiency and computational traceability with the time complexity of $|N||T|^2 log|T| + |N|^2$.

1. Introduction

Nowadays, as technology evolves and the computing tasks become more complicated and bothersome, both individuals and enterprises prefer outsourcing their computing tasks to the cloud providers in order to pay for lower cost [1]. Generally, the cloud providers offer Infrastructure as a Service (IaaS) in the form of virtual machines (VM) instances, which can be characterized by a number of computing resources (such as CPU, memory, storage, and networks). As a practical example, Amazon EC2 [2] and Microsoft Azure [3] offer various types of VM instances. In cloud market, each instance type has its pre-defined price which does not change dynamically, and cloud computing uses a pay-as-you-use scheme in which resources are provided on-demand by cloud providers. However, with the increasing workload of tasks submitted by cloud consumers, a problem occurs: the resources in cloud market may be not enough to perform the whole task at once, and one of the most direct methods is dividing the task into multiple sub-tasks, then finish the whole task by executing each sub-tasks one by one. As stated above, scheduling of tasks [4–6] is considered as essential works in cloud computing. In general, task scheduling is the process of mapping the tasks to available resources in cloud market, based on their respective characteristics. To the best of our knowledge, most of existing mechanisms focus on auction-based allocation of cloud resources rather than the subsequent performing the tasks by the allocated cloud resources. Although there are several

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works [7–11] on task scheduling in existing literatures, few of them can be directly employed in the practical cloud market with lots of cloud provider. In this paper, we are motivated to design an applicable task scheduling scheme to schedule the divided sub-tasks wisely and allocate the payment among the winning cloud providers scientifically and efficiently.

Nevertheless, there are many obstacles in designing a practical scheme for the issue of task scheduling. Four major obstacles are listed as follows.

(1) Mechanism for scheduling sub-tasks: Since task is divided into multiple sub-tasks, it is obvious that there are different effects on completion time and execution cost of task if these sub-tasks are performed in different order. Therefore, the mechanism for scheduling sub-tasks wisely is in urgent need.
(2) Mechanism for determining winning cloud providers: There are lots of cloud providers who offer different types of cloud resources, and each of them has the corresponding valuation for their offered cloud resources. Considering the efficiency, it is impossible for cloud market to execute the sub-tasks by using the resources provided by all cloud providers in cloud market. Therefore, designing a mechanism for determining the set of winning cloud providers is essential.
(3) Mechanism for sharing the received Payment: The winning cloud providers form a coalition to complete all the sub-tasks and the cloud market will get the payment paid by the cloud consumers. For cloud market, allocating the received payment effectively becomes an urgent problem. Hence, a payment sharing mechanism is preferred.
(4) Scheme with low execution time: Cloud computing is a very dynamic environment with large amount of cloud providers and sub-tasks. Therefore, in order to be feasible in real cloud market, the task scheduling must have a low computation complexity for deciding the winning cloud providers and the revenue allocated for them.

Our contributions: Based on the problem of sub-tasks scheduling and payment sharing, we firstly present a novel model of computation task scheduling in clouds, in which cloud providers can submits their valuation for their offered cloud resources. Subsequently, we propose an efficient task scheduling scheme which consists of Task Scheduling Mechanism, Winner Coalition Formation Mechanism and Payment Sharing Mechanism to solve the obstacles proposed above. Finally, aiming at the proposed task scheduling scheme with three mechanisms, we give some useful theorems to verify the efficiency of the proposed scheme.

The remainder of the paper is organized as follows. Section 2 introduces the related research works about the task scheduling and coalition formation in cloud market. In Section 3, we introduce the task scheduling model and its corresponding task scheduling scheme. Section 4 describes the proposed mechanisms and characterizes their theoretical properties. In Section 5, we give a simple example to illustrate the effectiveness of the proposed scheme. We conclude this paper and present our future works in Section 6.

2. Related work

In recent years, market-based approach in IaaS is attracting more and more attention in research community. In this section, we present the most closely related works in this domain.

Task scheduling in various fields: Topcuoglu H et.al. [7] presented two novel scheduling algorithms for a bounded number of heterogeneous processors with an objective to simultaneously meet high performance and fast scheduling time, and the comparison study showed that the proposed algorithms can significantly surpass previous approaches. Sprunt B et.al. [8] proposed a general sporadic server algorithm for scheduling soft and hard deadline aperiodic tasks in real-time systems, which greatly improved response times for soft deadline aperiodic tasks and can guarantee hard deadlines for both periodic and aperiodic tasks. Lakshmanan K et.al. [10] characterized various scheduling penalties arising from multiprocessor task synchronization, and then proposed a synchronization-aware task allocation algorithm for explicitly accommodating these global task synchronization penalties, which showed that significant benefits can be achieved in terms of task scheduling, allocation and synchronization. Delavar A G et.al. [11] presented a synthetic method based on genetic algorithm, for independent task scheduling in cloud computing systems, which runs the tasks by a special ordering considering resource load balancing and quality of service, achieved the optimize makespan and achieving good performance is achieved.

Agent coalition formation: Shehory O et.al. [12] suggested that the agents form coalitions in order to perform tasks or improve the efficiency of their performance, and then presented algorithms for task allocation among computational agents via coalition formation in a non-super-additive environment. Saad W et.al. [13] presented a cooperation model for roadside units which is formulated as a coalition formation game with transferable utility, and then proposed a coalition formation algorithm, which achieved the goal that all roadside units can take individual decisions to join or leave a coalition while maximizing their payoffs. Modeling the game where agents form the coalition, Junwu Zhu et.al. [14] aimed to the property that equilibrium allocation must be the socially optimal assignment, and then presented two algorithm to confirm a stable equilibrium utility vector.

Utility sharing in game theory: Due to the particularity of utility sharing problem, it is always studied as a separate section in game theory [15]. Housman D [16] introduced the core concept as a tool to study stable coalitions, which is a sharing scheme that any sharing in Core don't cause the participants out of their coalition because forming a new coalition can't make participants obtain higher utility. Shapley [17] proposed the concept of shapley value, which solved the defect of the core concept, and its main particularity is to share utility according to the marginal contribution and the utility which the agent could get is equal to the excepted value of the marginal contributions made by the agent to the joined coalition.