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Refining Service Delay Using Temporal Task Scheduling for Profit Maximization in Hybrid Cloud

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Abstract: As cloud computing is becoming growingly popular, consumers' tasks around the world arrive in cloud data centers. A private cloud provider aims to achieve profit maximization by intelligently scheduling tasks while guaranteeing the service delay bound of delay-tolerant tasks. However, the aperiodicity of arrival tasks brings a challenging problem of how to dynamically schedule all arrival tasks given the fact that the capacity of a private cloud provider is limited. Previous works usually provide an admission control to intelligently refuse some of arrival tasks. Nevertheless, this will decrease the throughput of a private cloud, and cause revenue loss. This paper studies the problem of how to maximize the profit of a private cloud in hybrid clouds while guaranteeing the service delay bound of delay-tolerant tasks. We propose a profit maximization algorithm (PMA) to discover the temporal variation of prices in hybrid clouds. The temporal task scheduling provided by PMA can dynamically schedule all arrival tasks to execute in private and public clouds. The sub problem in each iteration of PMA is solved by the proposed hybrid heuristic optimization algorithm, simulated annealing particles warm optimization (SAPSO). Besides, SAPSO is compared with existing baseline algorithms. Extensive simulation experiments demonstrate that the proposed method can greatly increase the throughput and the profit of a private cloud while guaranteeing the service delay bound.

***Note to Practitioners*:** This paper aims to solve the problem of task scheduling for a private cloud in hybrid clouds. The aperiodicity of arrival tasks brings a challenge of maximizing the profit of a private cloud provider while guaranteeing the service delay bound of delay-tolerant tasks. Existing methods usually provide an admission control to refuse some of arrival tasks that exceed the capacity of a private cloud. This paper first proposes an architecture of temporal task scheduling in hybrid clouds. Based on the architecture, a PMA algorithm is proposed to provide temporal task scheduling which can maximize the profit of a private cloud by intelligently dispatching arrival tasks to execute in private and public clouds within the service delay bound. Preliminary simulation experiments show that the proposed temporal task scheduling is feasible but it has not yet been implemented in real hybrid clouds. In future research, we will extend this work to incorporate multiple different tasks that require heterogeneous resources including bandwidth.

Index Terms: Heuristic Algorithm, Hybrid Clouds, Profit Maximization, Service Delay, Task Scheduling.

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INTRODUCTION

CLOUD computing can efficiently provide on-demand computing resources over the network to consumers worldwide. Typically, computing resources in cloud datacenters are dynamically delivered to consumers using a pay-as-you-go pricing model. In addition, the economy of scale brought by cloud computing attracts an increasing number of companies to deploy their applications in cloud datacenters. As a typical part of cloud, Infrastructure as a Service (IaaS) provides the foundation for applications [3]. Typical IaaS providers such as Rackspace and Amazon EC2 [4] provide services to consumers based on a pay-per-use model. An IaaS provider manages its own limited resources. Therefore, similar to the definition in [5], from the perspective of an IaaS provider, private cloud in this paper denotes a resource-constrained IaaS provider that may outsource some of its tasks to execute in external public clouds when it cannot deliver promised quality-of-service (QoS) with its resources. A private cloud provider aims to provide services to consumers' tasks in the most cost-effective way while guaranteeing the specified QoS. Therefore, profit maximization is a critically important goal for a private cloud provider [6].

The uncertainty and aperiodicity of arrival tasks makes it difficult to predict the future arrival tasks, and brings major challenge to operators of a private cloud. Therefore, it is possible that a private cloud provider cannot satisfy all arrival tasks with its limited resources if the arrival tasks are massive. The existing works usually provide an admission control mechanism to refuse some of arrival tasks that exceed the capacity of a private cloud [7]. Nevertheless, this will decrease the through put of a private cloud, and inevitably cause revenue loss to the private cloud provider. However, the mechanism of hybrid clouds enables a private cloud provider to make use of public clouds where resources are delivered in the form of virtual machines (VMs) when resources of a private cloud is fully occupied [8]. Delay-tolerant tasks usually have a strict service delay bound to meet. Moreover, cloud providers such as Amazon EC2 provide resources in the form of VMs to paying consumers. In the real life, the execution prices of each VM type offered by public cloud providers vary with time [9].Besides, the power prices in a private cloud also express temporal diversity [7]. Therefore, this presents an opportunity to maximize the profit of a private cloud by a temporal task scheduling while guaranteeing the strict service delay bound of all tasks. The temporal task scheduling can intelligently dispatch arrival tasks to execute in private and public clouds within the service delay bound. There are several differences between the proposed temporal task scheduling in hybrid clouds and conventional areas including manufacturing, transportation, etc. Therefore, we clearly summarize the differences as follows.

1. The virtualization of cloud enables resources to be encapsulated as VMs that can be delivered on demand. Besides, services in a cloud can be dynamically configured and delivered. Therefore, a private cloud can keep scalable and schedule tasks using VMs provided by other public clouds even if resources in a private cloud is fully occupied. However, the available resources in conventional scheduling are usually limited and fixed.
2. The economy of scale enabled by the cloud makes a private cloud provider focus on maximizing its profit by providing a pay-as-you-go pricing model. However, scheduling in conventional areas usually difficult to deliver essential resources (e.g., manufacturing tools) on demand.
3. The prices in hybrid clouds vary during the service delay bound. The temporal diversity in prices presents an opportunity to propose a temporal task scheduling that maximizes the profit of a private cloud provider in hybrid clouds. However, compared to applications in a cloud, the scheduling period in conventional areas is much longer. Therefore, the service delay bound of arrival tasks for cloud applications cannot be guaranteed with conventional scheduling. In this paper, we study the profit maximization problem for a private cloud provider in hybrid clouds.

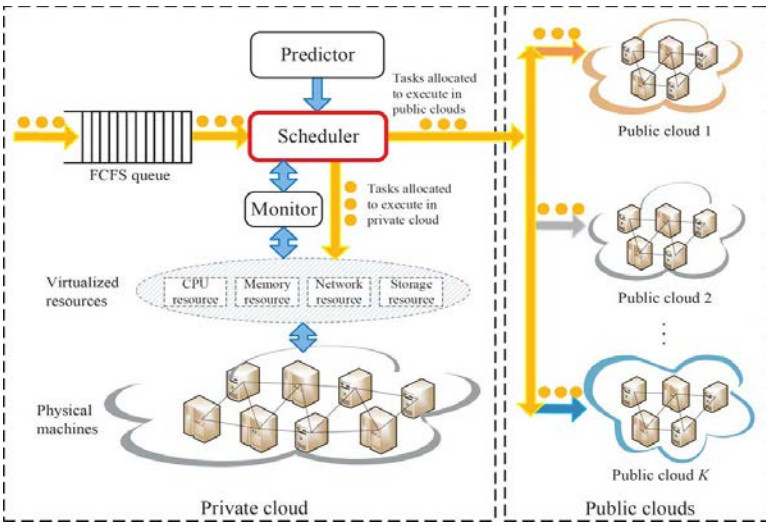
The execution prices of VMs in public clouds, and the power prices in the private cloud exhibit temporal diversity. We formulate the profit maximization problem for a private cloud provider and propose PMA to solve it. Then, we adopt public real-life workload to evaluate the proposed method. Extensive simulations have shown that the proposed method outperforms existing task scheduling methods in terms of throughput and profit.

The main contribution of this paper is described as follows. First, this work focuses on delay-tolerant tasks and strictly guarantees the service delay bound of all tasks. Second, we propose an architecture of temporal task scheduling in hybrid clouds where a private cloud can outsource some of its arrival tasks that exceed the capacity of a private cloud to public clouds provided that the service delay bound of all task is strictly guaranteed. Third, this work proposes a PMA algorithm to maximize the profit of a private cloud provider by intelligently scheduling arrival tasks to execute in private and public clouds. The rest of this paper is organized as follows. Section II discusses the related work in the literature. Section III presents the architecture of temporal task scheduling in hybrid clouds. Section IV presents the system model and problem formulation. The details of the proposed solution algorithms are given Section V. Extensive simulation experiments are conducted to evaluate the effectiveness of the proposed method in Section VI. Extensive simulation experiments are conducted to evaluate the effectiveness of the proposed method in Section VI .Finally, Section VII concludes this paper.

RELATED WORK

This section presents an overview of papers related to this research topic and compares the proposed temporal task scheduling with existing works. Resource allocation is a basic problem in cloud data centers[10]–[12]. The objective of resource allocation is to reasonably provision limited resources in cloud data centers to process consumers' arrival tasks with the constraint that the performance requirement of arrival tasks must be ensured. So far, there have been a growing number of recent studies to investigate the problem of resource allocation in cloud data centers [13]–[15]. Authors in [13] proposed a lightweight simulation system to model real-time resource allocation in cloud data centers. Authors in [14] presented a method to optimize data center resource and to support green computing according to application demands. Authors in [15] studied the effect of future workload information on dynamic provisioning of resources, and presented a decentralized algorithm to dynamically provision resources. However, all above works focus on resource allocation without the consideration of profit maximization of a private cloud.

Task scheduling in data centers has attracted much attention as the demand for cloud applications increases [5], [7], [16]–[18]. Authors in [16] presented an approach that can dynamically allocate machines in cloud data centers to minimize the total energy consumption by considering the heterogeneity of both workloads and machines. Authors in [17] proposed an algorithm to utilize idle time of allocated resources to replicate tasks. Therefore, the performance variation of resources on work flows with soft deadlines can be mitigated. Authors in [18] proposed three different algorithms to provide energy-aware scheduling of tasks. The algorithms were tested and compared with other existing scheduling algorithms. However, all above works focus on task scheduling without consideration of the temporal variation of prices within the service delay bound in private and public clouds. Authors in [5] proposed an approach to schedule tasks to maximize the profit of a private cloud while guaranteeing the corresponding delay bound. This scheduling problem was formulated and solved by a heuristic algorithm. However, this work in [5] does not consider the price variation in private and public clouds during the delay bound. Authors in [7] proposed a two-stage design to minimize energy cost of data centers and dynamically schedule tasks to execute in datacenters. However, this work in [7] chooses to refuse excessive tasks that exceed the capacity of a private cloud. In contrast, the temporal task scheduling in our work aims to maximize the profit of a private cloud provider by considering the temporal diversity in prices, and intelligently scheduling all arrival tasks to execute in private and public clouds. A few existing works investigated the profit maximization problem by adopting queueing models to evaluate the service delay performance [19]–[21]. Authors in [19] studied the configuration of a multiserver system for profit maximization fora cloud. An M/M/m queueing model is adopted to analytically formulate a multiserver system in their method. The expected profit of a cloud in each time slot is calculated. Authors in [20] proposed a hybrid queueing model to specify the number of virtual machines for a multitier application in a cloud. Then, this paper formulates a nonlinear constrained problem and develops a heuristic algorithm to maximize the profit of a cloud provider.



These works usually select the metric of the expected service delay. Then, based on the expected service delay, a utility function is proposed to model the expected profit. Authors in [21]derived a mathematical model to calculate the profit in large data centers. Based on this model, a profit maximization method with and without behind-the-meter renewable generators is developed and assessed.

However, these works can only guarantee the expect delay bound of consumers' tasks. The long tail in service delay of tasks means that some of tasks may experience longer service delay [22]. Different from above works, the proposed temporal task scheduling can guarantee the service delay bound of all arrival tasks.

ARCHITECTURE OF TEMPORAL TASK SCHEDULINGIN HYBRID CLOUDS

The architecture of the temporal task scheduling in hybrid clouds is shown in Fig. 1. The architecture consists of two major parts which are private and public clouds, respectively. In the private cloud, a huge number of computers are pooled to provide virtualized resources including CPU, memory, network and storage. *Monitor* component monitors the virtualized resource pool, and reports the latest information to the *Scheduler* component.

The arrival tasks from consumers are enqueued into a FCFS queue. All the information about the FCFS queue (e.g., the number of arrival tasks) is sent to the *Scheduler* component. In addition, the *Predictor* component can execute typical prediction algorithms to predict future information about private and public clouds based on the corresponding historical data.

In this paper, we mainly consider the *Scheduler* component that executes the proposed temporal task scheduling to maximize the profit of a private cloud while guaranteeing the service delay bound of all tasks. Based on the information collected from the *Monitor* component, the *Predictor* component and the

FCFS queue, the *Scheduler* component executes the temporal task scheduling and determines the number of scheduled tasks that execute in private and public clouds at each time slot, respectively.

MODELING AND FORMULATION

In this section, we present the formulation of temporal task scheduling that maximizes the profit of a private cloud provider in hybrid cloud. In this paper, similar to the work in [21], the private cloud system is modeled as a discrete-time system that evolves in a sequence of equal-length time slots. Our work focuses on the delay-tolerant tasks.

Each task maybe massive-scale data analysis, scientific computing, large-scale image processing, etc. With the massive-scale deployment of commodity computers in cloud data centers, more and more cloud data centers support many-core computing and incline to parallelize the applications.

Thus, each task can be decomposed to functionally equivalent small tasks that can be mapped into multiple computers and completed in a shorter time [23]. Besides, there are many existing works that can predict the future information according to past data [24]. Therefore, to make the formulation clear, we explicitly make several assumptions organized as follows.

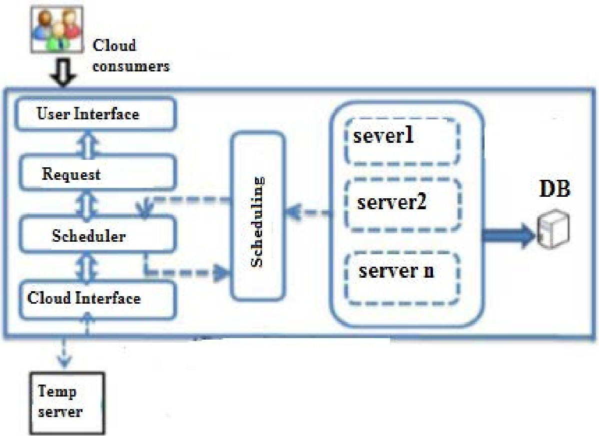
1. It is assumed that the number of arrival tasks in time slot, is known.
2. We assume that the *Predictor* component can report the information including the future charging prices and the future power prices of a private cloud, the future execution prices of VMs in public clouds, and the future running time of tasks to the *Scheduler* component.
3. Similar to the work [7], we assume that each task can be replaced by a number of parallelized subtasks which are small enough to execute. Therefore, each task can finish its execution within one time slot.
4. It is assumed that the capacities of public clouds are unlimited to process tasks. Therefore, each task scheduled to execute in public clouds can finish its execution in one time slot.
5. We assume that time and cost related to data and network is negligible.

EXISTING METHOD

The number of servers is comparatively small which makes them unsuitable for performance analysis of cloud computing data centers.

Approximations are very sensitive to the probability distribution of task service times.

User may submit many tasks at a time because of this bags-of-task will appear.

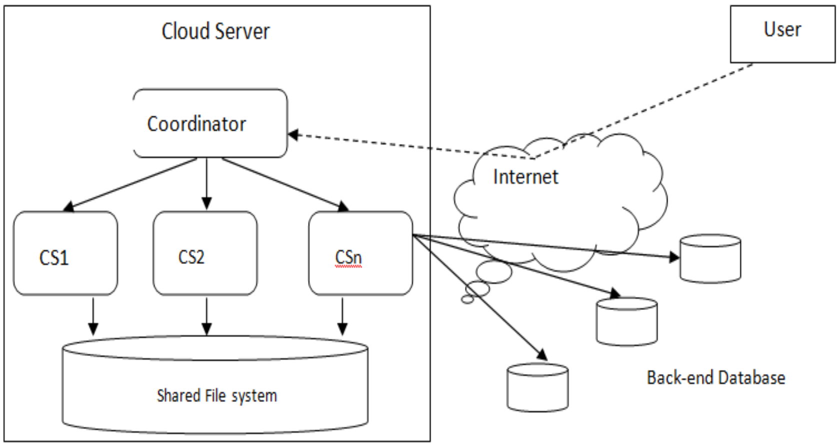


PROPOSED METHOD

In Proposed system, the task is sent to the cloud center is serviced within a suitable facility node; upon finishing the service, the task leaves the center.

A service level agreement, SLA, outlines all aspects of cloud service usage and the obligations of both service providers and clients, including various descriptors collectively referred to as Quality of Service (QoS).

QoS includes availability, throughput, reliability, security, and many other parameters, but also performance indicators such as response time, task blocking probability, probability of immediate service, and mean number of tasks in the system, all of which may be determined using the tools of queuing theory.



SYSTEM ANALYSIS

Requirements & Specification

Software Requirement Specification (SRS) is the starting point of the software developing activity. As system grows more complex it became evident that the goal of the entire system cannot be easily comprehended. Hence the needs for the requirement phase Specification. The software project is initiated by the client needs. The SRS is the means of translating the ideas of the minds of clients (the input) into a formal document (the output of the requirement phase.) The SRS phase consists of two basic activities:

Problem/Requirement Analysis:

The process is order and more nebulous of the two, deals with understand the problem, the goal and constraints

Requirement Specification

Here, the focus is on specifying what has been found giving analysis such as representation, specification languages and tools, and checking the specifications are addressed during this activity.

The Requirement phase terminates with the production of the validate SRS document. Producing the SRS document is the basic goal of this phase.

ROLE OF SRS

The purpose of the Software Requirement Specification is to reduce the communication gap between the clients and the developers. Software Requirement Specification is the medium though which the client and user needs are accurately specified. It forms the basis of software development. A good SRS should satisfy all the parties involved in the system.

Modules Details

- Server Formation
- Analysis of Performance
- Task Scheduling
- Predicting Result
- Clustered classification
- Auto scaling

Server Formation

In our project, the server calculates which cloud doing which job. That is monitoring cloud access, cost calculation and equal sharing of jobs in cloud.

Analysis of Performance

We analyze and compare the performance offered by different configurations of the computing cluster, focused in the execution of loosely coupled applications.

In particular, we have choose different cluster configurations with different number of worker nodes from the three cloud providers and different number of Jobs, we use the following acronyms infrastructure; Amazon EC2 Europe cloud Azure EC2 US cloud.

Task Scheduling

Each and every user assigns the task to cloud, so that task will assign to the cloud in priority scheduling basis or if anyone cloud is free mean, user job assign to that cloud.

Predicting Result

If we assign the job in priority scheduling way to a anyone cloud, we got an output correctly and shortly. The amount or cost will reduced and transferred to cloud owner of the using of cloud.

Clustered Classification

Here multiple servers formed into cluster formation. Group applications into service Performance of classes which are then mapped onto server clusters which parses application level information in Web requests and forwards them to the servers with the corresponding applications running.

After the servers may be clustered then allocate the task which can be assigned to each server and calculate the performance and priority.

Each server machine can host multiple applications. The applications store their state information in the backend storage servers. It is important that the applications themselves are stateless so that they can be replicated safely.

Auto Scaling

The space timing calculates by the reference of cloud usage. That is, the cost also calculates based on cloud space utilization and cloud usage.

The server calculates which cloud doing which job. That is monitoring cloud access, cost calculation and equal sharing of jobs in cloud. We analyze and compare the performance offered by different configurations of the computing cluster, focused in the execution of loosely coupled applications.

CONCLUSION

The economy of scale offered by cloud computing has attracted an increasing number of corporations to deploy their applications in cloud data centers. The uncertainty of the arrival tasks brings a big challenge for a private cloud to schedule all the arrival tasks while guaranteeing the service delay bound.

In this paper, we study the profit maximization problem of a private cloud provider by utilizing the temporal variation of prices in hybrid cloud. To solve the problem, this paper proposes a profit maximization algorithm (PMA) to provide the temporal task scheduling which can dynamically schedule all the arrival tasks to execute in private and public clouds. Each iteration in the PMA algorithm is tackled by the proposed hybrid heuristic optimization algorithm, simulated annealing particle swarm optimization (SAPSO). Experimental results demonstrate that the proposed approach can greatly increase the profit and throughput of a private cloud while meeting the service delay bound. In the future, we would like to investigate the optimality gap between our current close-to-optimal solution and the theoretically optimal solution. In addition, we would like to implement a realistic cloud and evaluate our proposed scheduling method. Besides, we also would like to extend our work to consider scheduling of cloud storage tasks.

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