# Dynamic cloud service selection using an adaptive learning mechanism in multi-cloud computing

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## ARTICLE INFO

## ABSTRACT

Cloud service selection in a multi-cloud computing environment is receiving more and more attentions. There is an abundance of emerging cloud service resources that makes it hard for users to select the better services for their applications in a changing multi-cloud environment, especially for online real time applications. To assist users to efficiently select their preferred cloud services, a cloud service selection model adopting the cloud service brokers is given, and based on this model, a dynamic cloud service selection strategy named DCS is put forward. In the process of selecting services, each cloud service broker manages some clustered cloud services, and performs the DCS strategy whose core is an adaptive learning mechanism that comprises the incentive, forgetting and degenerate functions. The mechanism is devised to dynamically optimize the cloud service selection and to return the best service result to the user. Correspondingly, a set of dynamic cloud service selection algorithms are presented in this paper to implement our mechanism. The results of the simulation experiments show that our strategy has better overall performance and efficiency in acquiring high quality service solutions at a lower computing cost than existing relevant approaches.

## 1. Introduction

Cloud services describe various computing collections that indicate different abilities to run the applications of users across the systems or platforms of multiple enterprises over the Internet. In cloud computing businesses, there are different types of cloud services, e.g., storage services, computing services and application services, which are respectively accommodated by many cloud service providers, e.g., GoGrid's Cloud Platform (2013), Amazon S3 (2013), Google App Engine (2013), Windows Azure (2013) and Salesforce-Cloud (2013) etc. More and more users establish applications by using a pattern of hybrid cloud services which integrate local cloud services with public cloud services, e.g., we constructed our own photo sharing application in which we developed a module of picture inputting, and then selected software on a cloud picture editor for online editing from some cloud application providers. We finally selected a cloud storage service for storing the substantial number of pictures into the cloud disks where we made some different selections of cloud services for integrating the application. With growing demands from users, as this example demonstrates, a lot of services accessed through interface invocation in the Internet can also be extended into common cloud services, i.e., cloud services can be viewed as a kind of Web services in a cloud computing environment. Due to increasingly preferred requirements of users for cloud services and differentiated quality of cloud services from numerous cloud service providers in terms of running performance (e.g., the number of CPUs or the storage capacity) and using price, it is no wonder users become slightly perplexed. Thus, how to select the most appropriate cloud services to satisfy users' various online applications becomes very important.

The general practice of cloud service providers is to advertise or publish various levels of cloud services based on their different performance and the quoted prices on their Web sites. Users are then left to select one or more services for the required tasks. This method has some drawbacks in that selections of users are passive and the running statues of cloud services selected are changing, even though providers promise the quality of their cloud services are the best. However, for users, many online applications need higher stability as well as lower prices in terms of the selected

services. To let the cloud service selection automatically adapt to the diverse cloud service environments, a natural choice would be to adopt brokers to manage the cloud service resources and to help users fulfill the work of the service selection by means of using an adaptive method. The brokers may look like agents, which are the concept in the field of distributed artificial intelligence, but they can solve distributed tasks for different fields, and own some autonomous and pro-active characteristics that cloud services do not have (Huhns, 2003; Huhns et al., 2005).

Many applications (e.g., some daily activities (Isern et al., 2011) and theoretic and engineering problems) use agent technologies to process their contained services. Agents may make optimized selections for continuous service demands according to current statuses and any changes to services managed by them. The existing work of Sim (2009, 2012) used autonomous agents to manage cloud resources and employed an agent-based distributed problem solving approach to support the cloud service selection and composition. The method (Gutierrez-Garcia and Sim, 2013) presented horizontal and vertical selection and composition through using consumer agents, broker agents, service provider agents and resource agents, and the self-organizing approach based SCTs and SR-CNP regulated the selection and composition process at the time of service failures.

However, current technologies of the service selection of multiple tasks still encounter new challenges regarding certain problems: (i) most of the managed cloud service information on some functions and their performance remains static once they are registered into broker agents by respective providers, and there is little possibility of updating their abilities to fulfill the work of selection. Because of the relative independence of cloud service providers and the changeability of services provisioned, successful services performed at current time may not be useful the next time, and new or better services may also emerge. As the centralized processing model for cloud service selections cannot deal with the above situations, we must use a distributed method to solve the dynamic service selections; (ii) the search cost of cloud services is very high due to the shortcomings of some models, and the existing centralized or distributed methods ((Liu et al., 2004; Hwang et al., 2008; Channa et al., 2005; Oh et al., 2007) still need to cost much more to find service selection solutions to complete the required tasks of users; and (iii) current methods lack an efficient mechanism on service selection when changes of service status happen. We should take advantage of a dynamic method to handle this troublesome problem.

In terms of the above motivation, a dynamic cloud service selection model and strategy are proposed, which will help users efficiently realize their cloud service requirements. In contrast to existing work, we take the performance (e.g., the number of CPUs or the storage capacity) and corresponding price of different cloud services into consideration, and let the cloud service brokers dynamically select the cloud services with the best ratio of performance to price. The model proposed in this paper uses a kind of adaptive learning approach to conduct cloud service selections at a smaller cost in the runtime.

The contributions of this paper are as follows:A cloud service selection model that adopts cloud service brokers is provided. It runs the process of dynamic cloud service selection and contains three layers, the user layer, cloud service broker layer and cloud service resource layer. Each of the cloud service brokers manage some cloud service information registered by the cloud service providers.A dynamic cloud service selection strategy deployed in the cloud service brokers is devised. It provides a real time selection of services and an adaptive learning mechanism that supports dynamic service selection. The mechanism involves incentive, forgetting and degenerate functions that can realize the self-adaptive regulation for optimizing next service selection according to the
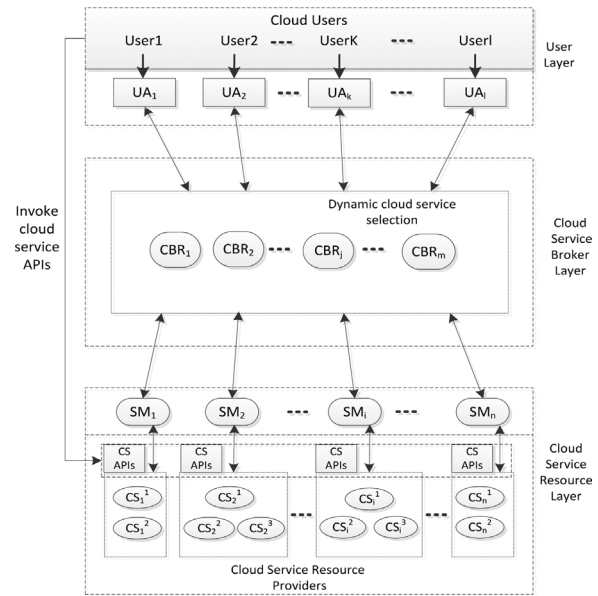


**Fig. 1.** The cloud service selection model.

status of current service selection.Based on the proposed strategy, a set of dynamic cloud service selection algorithms are presented, which provide detailed steps of the cloud service selection.Through elaborate simulation experiments, we evaluated the performance of our method, and the multi-profile results demonstrate its advantages and efficiency.

The remainder of this paper is organized as follows. Section 2 introduces a problem scenario and our cloud service selection model. In Section 3, a dynamic cloud service selection strategy is proposed.Section 4 describes the cloud service selection algorithms based on the cloud service selection model and strategy. Experimental setups and results are shown in Section 5, and Section 6 provides summaries of related work. The conclusion to this paper and future work is presented in Section 7.

## 2. Problem scenario and cloud service selection model

Cloud services can be viewed as special Web services (computing units) under a cloud computing environment, such as computing services, storage services and application services, etc. These cloud services may be selected to satisfy the users' tasks in terms of service integration where it is slightly difficult for semantic service technologies to directly handle the dynamic service selection. Adopting service broker technology is an efficient means to carry out the intermediary service management and self-learning to facilitate the cloud service selection.

Thus, we construct a cloud service broker-based service selection model (CBRSM) whose aim is to conduct cloud service management and selection. Encapsulating one or more piece of cloud service information into a cloud service broker (CBR) makes the cloud service selection flexible and controllable. Subsequently, an adaptive learning mechanism is used to carry out the work of dynamic cloud service selection for the requirement tasks of users. The CBRSM is composed of three parts: user layer, cloud service broker layer, and cloud service resource layer as shown in Fig. 1. Many cloud service resources supply users through opening their invocation APIs on the Internet, and cloud users may efficiently select their desired services by using cloud service brokers. Hence, our focus is how to help users dynamically select the best matching services through adopting the CBR when facing so many cloud providers. Let's illustrate the structure of the CBRSM as follows.