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A genetic-based approach to web service composition in geo-distributed cloud environment ☆

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ABSTRACT

Independent fine-grain web services can be integrated to a value-added coarse-grain service through service composition technologies in Service Oriented Architecture. With the advent of cloud computing, more and more web services in cloud may provide the same function but differ in performance. In addition, the development of cloud computing presents a geographically distributed manner, which elevates the impact of the network on the QoS of composited web services. Therefore, a significant research problem in service composition is how to select the best candidate service from a set of functionally equivalent services in terms of a service level agreement (SLA). In this paper, we propose a composition model that takes both QoS of services and cloud network environment into consideration. We also propose a web service composition approach based on genetic algorithm for geo-distributed cloud and service providers who want to minimize the SLA violations.

1. Introduction

Cloud computing as a revolutionary technology is changing the entire IT ecosystem, and all aspects of our lives. It brings not only the technical change, but also profound influence on enterprise business applications and business models. Applications are delivered as services over the Internet in cloud environment [1]. Today, users are increasingly accustomed to using the Internet to gain software resources in the form of web services. Web services are self-describing software applications that provide certain functions independently from underlying implementation technologies [2,3]. Through service composition technologies, loosely-coupled services that are independent from each other can be integrated into complex and value-added composited services as long as each component service's interface specification is subject to standard protocols.

The system architecture for service composition in cloud environment is shown in Fig. 1. The cloud architecture includes three layers: software layer, platform layer and infrastructure layer. A user sends composition requests to brokers for utilizing composited web services. The software layer includes brokers and web services. The brokers, which can be centralized or distributed, manage all services that are offered to users by SaaS providers. Web services are registered to brokers by service providers in order to be discovered. The composition engine in platform layer communicates with the brokers to discover candidate services according to the user's request. Based on the candidate services discovered, composition engine generates an execution plan which satisfies user's QoS requirements. The infrastructure layer controls the actual resource allocation in terms of the execution plan generated in platform layer.

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QoS of web services refers to various nonfunctional characteristics such as response time, throughput, availability, and reliability [4]. Given an abstract representation of a composition request, a number of candidate services that provide the same function but differ in QoS can be obtained. Composition engine need to select the best candidate service from a set of functionally equivalent services according to the QoS. The work in [5,6] uses combinational model to find the optimal selection of component services. The authors use linear programming technique which is best suited for small scale problems. But with the increasing scale of problems, the complexity of this method increases exponentially. The work of Mahammad Alrifai et al. addresses the problem by combining global optimization with local selection methods [7,8]. By decomposing the optimization problem into small sub-problems, their approach is able to solve the problem in a distributed manner. The work in [9] extends the methods above. The authors present a strategy to further reduce the search space by examining only the subsets of candidate services since the number of candidate services for a composition may be too large. The above papers do not solve the composition problem in the cloud context. Thus, the distributed network environment is not considered in these papers.

Cloud computing is an increasingly popular computing paradigm. It has become a reliable foundation for a wide array of enterprise and end-user applications [10]. Tao et al. investigate the composition problem of various cloud resource including software and hardware service with multiple objectives and constraints [11]. With the increasing number of cloud service users worldwide, major cloud service providers have been deploying and operating geographically dispersed datacenters to serve the globally distributed cloud users. At the same time, cloud services continue to grow rapidly. The resource capacity of a datacenter is limited, so distributing the load to global datacenters will be effective in providing stable services [12,13]. More and more web services are deployed on geo-distributed cloud datacenters and are offered all over the world. Cloud datacenters depend on networks to connect with each other and cloud users. Network environment has influence on the performance of composited services cross datacenters. QoS of network is a noticeable parameter of service composition. To avoid SLA violations, the network performance has been attracting more and more attention during service composition. In [14], the authors investigate the composition of QoS-aware network communication path across large scale multi-domain networks. They reduce the problem to k-MCOP (k multi-constrained optimal path) problem via domain graph expansion technique and developed a fast search heuristic. Klein et al. [15] propose a generic model towards network-aware service composition in the cloud. The authors estimate the network latency between arbitrary network locations of services or users and propose a network-aware selection algorithm to find services that will result in low latency. However, their work only focuses on response time. Other QoS criteria are not considered in this paper.

In cloud environment, it is a challenge to search for an optimal and feasible composition path efficiently because the problem of service composition is an NP-complete problem. Cloud applications usually involve a large number of components and there are many candidate services for each component. With the increase of the number of components, the number of composition paths increases exponentially. So it is impractical to traverse all the composition paths in search space when the flow of composition is large. Furthermore, an important issue in cloud computing is the need for providers to guarantee the service level agreements (SLAs) established with users [13]. Cloud providers derive their profits from the margin between the operational cost of infrastructure and the revenue generated from users. Therefore, cloud providers are interested in maximizing profit and ensuring QoS for users to enhance their reputation in the marketplace. They are looking into solutions that can minimize the SLA violation. In this paper, we propose a new approach towards web service composition in geo-distributed cloud environment. Our main contributions can be summarized as follows:

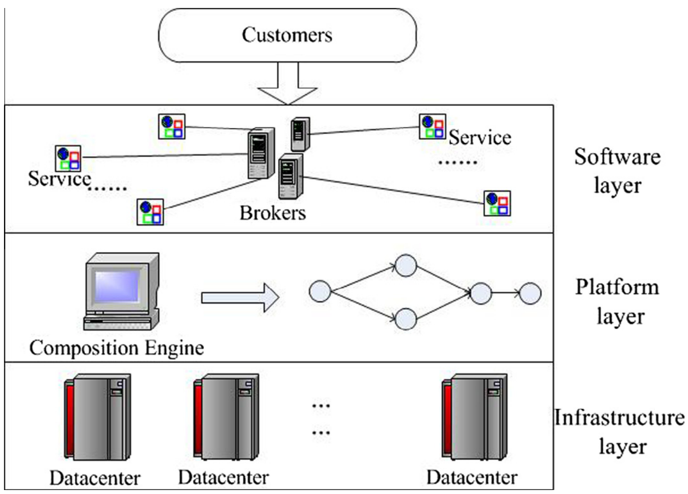

Fig. 1. Composition architecture in cloud environment.