A Novel Self-Organization Approach for Stigmergy Based Cloud Service Composition

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ABSTRACT

This article describes how cloud computing and the convergence toward “Everything as a service” have encouraged the proliferation of services ready for use. These facilities have increased the requests of the companies for the development of the applications. In this context, where the reusability is needed, cloud service composition techniques are widely used. However, traditional centralized service composition techniques are not sufficient to address the needs of applications in highly dynamic and open environments. Early attempts for service composition models in decentralized environments have been proposed, but they are limited by their ability to adapt when deploying in highly dynamic and open environments. In this paper, the authors use Stigmergic-based self-organization mechanisms inspired from nature to model the decentralized service interactions and handle service composition in highly dynamic and open environments.

KEYWORDS

Ant Colony Optimization, Cloud Computing, QoS, Self-Organization, Services Composition, Stigmergy

1. INTRODUCTION

Cloud computing is a collection of accessible resources that can be dynamically composed based on the user’s requirements. Cloud services are defined and provided at three levels: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) (Gutierrez-Garcia & Sim, 2012). This arrangement allows users of cloud services to focus on what the services provide to them rather than how the services are implemented or hosted. The number of cloud providers is increasing (e.g., GoGrid, Amazon, and Google), along with the number of services they offer (e.g., Software-as-a-Service applications and computing resources). The increasing demands for complex cloud services create the need for dynamic, automated, and adaptive composition of cloud services in a decentralized open environment in which cloud services can dynamically arrive and depart (Gutierrez-Garcia & Sim, 2012).

According to Navimipour and Vakili (2017), existing approaches to web/cloud service composition can be divided into three distinct categories, namely, framework-based, agent-based, and heuristic-based approaches. The advantage of framework-based approaches to service composition is that they organize and manage searching, selecting, and composing the cloud services (Navimipour & Vakili,
2017). However, the framework-based approaches presented in this paper (Benfenatki, Da Silva, Benharkat, & Ghodous, 2014; Di Martino, Cretella, & Esposito, 2016; Nguyen, Lelli, Papazoglou, & van den Heuvel, 2012; Qui, 2014; Sasikaladevi, 2016; Tsai, Sun, & Balasooriya, 2010; Zhou, Athukorala, Gilman, Riekk, & Ylianttila, 2012) are defined in a centralized manner, which can lead to system overloads. The agent-based approaches that have been proposed (Bastia, Parhi, Pattanayak, & Patra, 2015; Gutierrez-Garcia & Sim, 2012; Mellah, Hassas, & Drias, 2013; Rodrigues, Leitão, & Oliveira, 2014; Sim, 2012; Singh, Juneja, & Malhotra, 2015; Val, Rebollo, Vasirani, & Fernandez, 2014) are very flexible and autonomous (Kumar, 2012; Talia, 2011). However, they suffer from the problem of communication through messages and do not adapt well to large and open environments, where services can dynamically arrive and depart and the QoS may improve or deteriorate. Mostafa et al. (2014) demonstrated the effectiveness of a stigmergy mechanism that was used to manage the dynamic nature of trust, but this work is based exclusively on the criteria of trust and reputation, which creates a difficulty for selecting new members joining the system for the first time, as they have no historical record. Additionally, the proposed adaptation is only linked to changes in the QoS and not to changes in the environmental structure (Mostafa, Zhang, & Bai, 2014). Finally, the heuristic-based approaches that have been proposed (Gohain & Paul, 2016; Karimi, Izazadeh, & Rahmani, 2016; Li, Jiang, & Ge, 2014; Seghir & Khababa, 2016; Wu, Chen, & Huang, 2016; Yu, Chen, & Li, 2015) incorporate optimization algorithms in order to produce optimized composition plans. However, these approaches suffer from a high level of complexity.

The purpose of cloud service composition is to fulfill functional and/or nonfunctional user requirements. Functional requirements concern the overall result of the application that is to be developed, while nonfunctional requirements (quality of service; QoS) concern the quality of the composition, such as the response time, availability, reliability, and cost. As the number of cloud services offering similar functionalities increases, identification of the cloud service composition plan with the best quality becomes a critical problem (Mostafa et al., 2014). This has led to proposals of effective methods for selecting the best service composition plan.

Taking all of these problems into account, the objective of this paper is to propose an adaptable approach to cloud service composition in open and decentralized cloud environments where services can dynamically join or leave the environment and the QoS may improve or deteriorate at any time, with a reduced amount of exchanged messages. To this end, the proposed approach incorporates self-organization mechanisms. Self-organization is a process in which a system changes its organization in response to environmental changes, without external control (Zertal, Miles, & Batouche, 2014). There are several self-organizing mechanisms: a) GOSSIP, which is based on chattering and is an effective mechanism for the diffusion and collective treatment of information, considering its simplicity, robustness, speed, and especially the absence of a central controller; b) cooperation, which is a collaborative work process for achieving a common goal; c) the immune system, which is an excellent model of adaptive functioning at the micro level and emergent behavior at the macro level; and d) stigmergy, which is a coordination process between individuals of the system via changes in the environment (indirect coordination), such that the work done by an individual depends on the work done earlier, either by that individual or by fellow individuals (Serugendo, Gleizes, & Karageorgos, 2011).

The inherent characteristics of these decentralized and open environments provide two additional challenges: (a) knowledge of each agent’s neighborhood is limited, that is, there is no centralized service to provide a global view of all services in the cloud environment and therefore each service has incomplete information about the other services; and (b) on a large scale, an unlimited number of services can be deployed in the cloud (Mostafa et al., 2014).

In order to be adaptable for a large-scale and open environment, the approach proposed in this paper uses the stigmergy-based self-organization mechanism as a method of communication and coordination between the services. This mechanism is inspired by the concept of a digital pheromone and is based on the deposit and evaporation of the pheromone. In this mechanism, the amount of pheromone deposited at each service presents the quality of the service. The stigmergy mechanism
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