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Decision-making framework for user-based inter-cloud service migration

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ABSTRACT

Cloud computing has rapidly become the most effective computing paradigm for today's increasingly technology-dependent society. The emerging concepts of federated clouds with support for interoperability between different cloud providers and open standards in cloud middleware have opened up new challenges in cloud service management. One of the emerging research areas in cloud computing is the possibility of live virtual machine migration between different clouds. This is of importance when the quality of a cloud service currently used by a user degrades or a new cloud service is developed which is better in terms of quality, performance and cost than the current service being used. In such scenarios, the user needs to make a decision as to whether to continue with the currently used service or migrate to the newly available service. In our previous work, we presented a decision-making approach that assists a cloud service user in selecting a cloud service provider based on the QoS of its services. In this paper, we extend our previous work in the pre-interaction time phase and discuss the decision-making process involved in the migration from one cloud service to another cloud service through inter-cloud virtual machine migration.

1. Introduction

Cloud computing has become the chief computing paradigm for today's increasingly technology-dependent society. The advent of mobile handheld devices and the availability of faster broadband connectivity for such devices via new communication technologies such as 3G and 4G has further strengthened the role of cloud computing in today's world. However, the rapid growth and quick adoption has also unearthed several challenges in cloud computing (Dillon et al. 2010). From a service provider's side, these issues include resource management, energy efficiency, and Service Level Agreement (SLA) compliance. From a cloud service user's point of view, one of these challenges is how to select a service from amongst the multitude of cloud services and once a service has been selected, how to ensure that a cloud provider is delivering the promised computing resources by which the user's outcomes will be achieved. This process is called user-side cloud service management (UCSM) (Rehman et al. 2014), which consists of two phases, namely the pre-interaction phase and the post-interaction phase. In the pre-interaction phase, the user selects a service from the available services and in the post-interaction phase, the user monitors the selected service by using the early warning framework to verify that the desired or promised Quality of Service (QoS) levels are maintained. If the user determines that the selected service fails to meet these QoS levels, it needs to take appropriate steps for service management to ensure the achievement of the desired outcomes. The two parts of the user-side cloud service management have been explained in detail in our previous paper (Rehman et al. 2014, 2013c; Hussain et al. 2015) where we discussed a user-side cloud service management (UCSM) framework for cloud service selection, QoS forecasting and early-warning. In this paper, we discuss the next phase of decision-making in user-side cloud service management wherein the early warning system determines that the currently selected service fails to meet the user's required QoS levels and a decision has to be made to migrate from the currently subscribed service to another service. This is one of the steps required in the post-interaction phase of user-side cloud service management. The objective of this paper is to develop an approach that assists a cloud service user or an intelligent service management agent in decision-making in a service migration scenario.

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The migration between different cloud service providers has been made possible by the recent advances in interoperable cloud middleware, aimed at addressing the vendor lock-in problem. This has led to the emergence of Inter-cloud VM migration as a new research area in cloud computing (Messina et al. 2014, Liu et al. 2014, Kondo et al. 2014, Kurtadikar et al. 2013, Hirofuchi et al. 2009, Zhang et al. 2014) that enables the user to switch from one cloud provider to another.

In many aspects, the service migration decision-making process, which happens in the post-interaction time phase, is analogous to the service selection problem in the pre-interaction phase where the best service has to be selected from the available ones. However, in service migration decisions, apart from the decision-making criteria required in the pre-interaction phase, another additional criterion required is the migration cost which the user incurs. But migration cost is an additional parameter in the post-interaction phase. Our approach in this paper considers the additional parameters and based on the user's requirements, recommends whether or not it is advantageous to migrate to a different service than the currently used one; and if it is, then what is the most appropriate service to migrate to from the currently available ones. This paper is organized as follows. In the next section, we present a background of our related work in this area and briefly discuss the user-side cloud service management (UCSM) framework. In Section 3, we explain the working of the post-interaction decision-making process. In Section 4, we discuss the three different types of migration of cloud services and the metrics for determining migration costs are explained in Section 5. In Section 6, we explain how these metrics are used for multi-criteria decision-making. We explain this method by a case study in Section 7 and discuss the related work in Section 8. Section 9 concludes this paper.

2. Background

In cloud computing, multiple users share the same computing resources which results in variability of QoS with changing resource usage and load conditions (Wittern et al. 2012, Oberle et al. 2013, Iosup et al. 2011). This variability in QoS is a challenge for service management, both from the service provider and service user side. As mentioned earlier, in our previous work, we introduced the user-side cloud service management (UCSM) framework that is designed to assist a cloud service user in managing cloud services by suggesting intelligent decisions based on the QoS monitoring data of the available services and the user's QoS preferences. The user-side service management process is divided into two phases (pre-interaction and post-interaction phases). The UCSM framework (as shown in Fig. 1) consists of three modules, namely: (1) service monitoring; (2) QoS forecasting and early warning; and (3) decision-making.

Service monitoring: The service monitoring module is responsible for collecting the QoS data of all the available services in the cloud environment and also has a QoS repository that stores this information which is required by the other modules in the framework. There are several possible sources of this QoS information, such as third party QoS monitoring services and feedback from existing users (Rehman et al. 2012). In the pre-interaction phase, the user can only have access to QoS monitoring data obtained by other sources (indirect monitoring), whereas in the post-interaction phase, the user is also able to record the QoS history of the selected service himself (direct monitoring). The cloud service monitoring module collects user-feedback-based QoS information from both direct and indirect sources and stores it in the QoS repository. This QoS data is available to cloud service users who can assess all the available services against his/her multiple performance criteria. This data forms a QoS history of a service and contains valuable information about the QoS at any instance and its variability with time.

QoS forecasting and early warning: The QoS forecasting and early warning module is responsible for forecasting the future QoS values on the basis of previously observed QoS values (stored in the QoS repository) by using time series forecasting techniques. In our previous work, we determined that the exponential smoothing and Autoregressive Integrated Moving Average (ARIMA) techniques provide a reasonably accurate forecast of the expected QoS values for up to 8 h in advance (Rehman et al. 2014). The early warning mechanism is a fuzzy inference system which relies on the user's risk propensity and generates service degradation and failure alarms when the current and forecasted QoS values fall below a defined threshold. As a result, the service migration part in the post-interaction decision-making process is initiated. Service degradation and service failure are two different events in our framework. Service degradation occurs when the service level declines below its previous level recorded at the time of service selection and service failure occurs when the QoS of a service falls below the user's minimum requirement.

Decision-making: The decision-making module in this framework comprises the pre-interaction and post-interaction phases. The pre-interaction phase is based on multi-criteria decision-making on the basis of the past QoS of the available services and recommends the best cloud service to the user (Rehman et al. 2013c). Once the user selects the recommended service, the QoS early warning module is activated to inform the user of impending service degradation by triggering an alarm so that a decision may be made to migrate to another service. The role of decision-making in each phase is discussed in the next sub-section.

2.1. Overview of decision-making in the pre-interaction phase

Cloud service selection involves multiple selection criteria which consist of QoS factors and cost criteria, each of which must be considered while selecting a service. Furthermore, the importance of each criterion is not the same for a cloud service user and hence the relative difference between the importance of these criteria must be taken into account. Multi-criteria decision-making (MCDM) techniques can be effectively used to develop a mechanism to assist the user in this decision-making process as these techniques have the capabilities to meet the above mentioned requirements. There are several techniques for MCDM, but we have found that the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and *ELimination Et Choix Traduisant la REalit* (ELimination and Choice Expressing REality), commonly known as ELECTRE, are the best techniques for decision-making on the basis of past QoS history (Rehman et al. 2013c).

Most of the MCDM methods utilize a decision or evaluation matrix, and a corresponding set of criteria weights. For example, if $S_1, S_2, \ldots, S_m$ are the available services in the cloud environment and $C_1, C_2, \ldots, C_n$ are the criteria on the basis of which the services have to be ranked, then the decision matrix is of the form:

$$D = \begin{array}{c} \\ S_1 \\ S_2 \\ \vdots \\ S_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots & C_n \end{array} \\ \begin{pmatrix} q_{11} & q_{12} & \ldots & q_{1n} \\ q_{21} & q_{22} & \ldots & q_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ q_{m1} & q_{m2} & \ldots & q_{mn} \end{pmatrix} \end{array} \quad (1)$$

In this decision matrix, the numerical values (q_{ij}) are the measured performance of a service i against criterion j. In addition to QoS-related criteria, this matrix can also include the cost criterion which reflects the service usage cost. Each of these criteria has a