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A semantic interoperability framework for software as a service systems in cloud computing environments

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ABSTRACT

In cloud computing environments in software as a service (SaaS) level, interoperability refers to the ability of SaaS systems on one cloud provider to communicate with SaaS systems on another cloud provider. One of the most important barriers to the adoption of SaaS systems in cloud computing environments is interoperability. A common tactic for enabling interoperability is the use of an interoperability framework or model. During the past few years, in cloud SaaS level, various interoperability frameworks and models have been developed to provide interoperability between systems. The syntactic interoperability of SaaS systems have already been intensively researched. However, not enough consideration has been given to semantic interoperability issues. Achieving semantic interoperability is a challenge within the world of SaaS in cloud computing environments. Therefore, a semantic interoperability framework for SaaS systems in cloud computing environments is needed. We develop a semantic interoperability framework for cloud SaaS systems. The capabilities and value of service oriented architecture for semantic interoperability within cloud SaaS systems have been studied and demonstrated. This paper is accomplished through a number of steps (research methodology). It begins with a study on related works in the literature. Then, problem statement and research objectives are explained. In the next step, semantic interoperability requirements for SaaS systems in cloud computing environments that are needed to support are analyzed. The details of the proposed semantic interoperability framework for SaaS systems in cloud computing environments are presented. It includes the design of the proposed semantic interoperability framework. Finally, the evaluation methods of the semantic interoperability framework are elaborated. In order to evaluate the effectiveness of the proposed semantic interoperability framework for SaaS systems in cloud computing environments, extensive experimentation and statistical analysis have been performed. The experiments and statistical analysis specify that the proposed semantic interoperability framework for cloud SaaS systems is able to establish semantic interoperability between cloud SaaS systems in a more efficient way. It is concluded that using the proposed framework, there is a significant improvement in the effectiveness of semantic interoperability of SaaS systems in cloud computing environments.

1. Introduction

According to Sosinsky (2011), cloud computing is distinguished by considering that resources are limitless and virtual, and the details of physical systems on which software runs are abstracted from the user. As stated by Buyya, Broberg, and Nski (2011), one of the keywords that has recently emerged in Information and Communications Technology (ICT) industry is cloud computing, and also Sosinsky (2011) points that the term cloud intends to demonstrate the future of modern computing. Cloud computing relates to the services and applications running on a distributed network that use virtualized resources, and are accessed using networking standards, and common Internet protocols. Referring to Gartner's Hype Cycle for Emerging Technologies (Fenn, Raskino, & Gammage, 2009), currently cloud computing is at the "peak of inflated expectations". Several attributes of cloud computing motivate organizations to adopt cloud computing (Lewis, 2012; Strowd & Lewis, 2010):

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- Availability: refers to the users access to applications and data globally.
- Collaboration: organizations consider clouds as a method that members could work on common information and data simultaneously.
- Elasticity: depending on changing needs, organizations could use, request, and release as much resources as required.
- Lower infrastructure costs: the pay-per-use model permits organizations to pay for the required resources only, and without minimal investment in physical resources, which means moving towards variable costs, from the fixed costs. Besides, there are no costs of upgrade, or maintenance of infrastructures for these resources in the organizations.
- Reliability: in order to support service level agreements (SLAs), cloud providers offer much more robust reliability mechanisms, rather than single organizations which are cost effective providers. Though, it is essential to consider that organizations often view reliability as a barrier, since cloud providers intend to rely on commodity hardware that is known to fail.
- Risk reduction: before producing major investments in technology, organizations could use clouds, with the purpose of testing the concepts and ideas.
- Scalability: being scalable according to the users demand, allows organizations accessing numerous resources.

Based on services provided by the cloud computing, three types of cloud computing models are defined: SaaS, platform as a service (PaaS), and infrastructure as a service (IaaS) (Lewis, 2012; Mell & Grance, 2009). SaaS is a software deployment model that the third party offers applications for customers to use as a service based on their demand (Lewis, 2012). The examples of SaaS providers are Zoho, SurveyTool, Salesforce, NetSuite, Microsoft Office 365, and Google Apps (Lewis & Strowd, 2010).

As mentioned by Sosinsky (2011), the SaaS systems in the cloud will be replaced with local systems in the next 10 years, thus, it will be easier to create new SaaS systems which is based on standard modular parts. Having the SaaS model, offers the consumers the capability to use the provided systems running on a cloud infrastructure. By using a thin client interface, such as a web browser, various client devices could assess the systems (Liu et al., 2011). In this model although there is a limited setting on user specific system configurations, it is not required for the consumers to control or manage the underlying cloud infrastructure, such as storage, operating systems, servers, networks, or even individual application capabilities (Mell & Grance, 2009).

One of the most important organizational concerns can act as barriers to the adoption of SaaS systems in cloud computing environments is interoperability (Lewis, 2012; Lewis & Strowd, 2010; Rezaei, Chiew, & Lee, 2013; Rezaei, Chiew, & Lee, 2014a). Generally, the interoperability is defined as the ability of ICT systems and of the business processes they support to exchange data and to enable the distribution of information and knowledge (European-Commission, 2004).

Cloud interoperability is the ability of resources on one cloud provider to communicate with the resources on another cloud provider as consumer (Fig. 1). Cloud computing systems define interoperability as cloud providers' capability to collaborate or interoperate with each other and to create a federation of clouds (Cohen, 2009). Accordingly, collaboration and cooperation require interoperability. Therefore, cloud interoperability is much more than the capability to exchange data between SaaS systems. It also requires a shared understanding of that information and how to act upon it. Interoperability is the ability of a collection of communicating entities to (a) share specified information and (b) operate on that information according to an agreed operational semantics (Brownsword, Carney, Fisher, Lewis, & Meyers, 2004; Lewis & Wrage, 2006). The ability to exchange data is called syntactic interoperability, and the ability to operate on that data according to agreed-upon semantics is termed semantic interoperability. Both varieties are necessary prerequisites to achieve interoperability (Lewis & Wrage, 2006; Rezaei, Chiew, & Lee, 2014b).

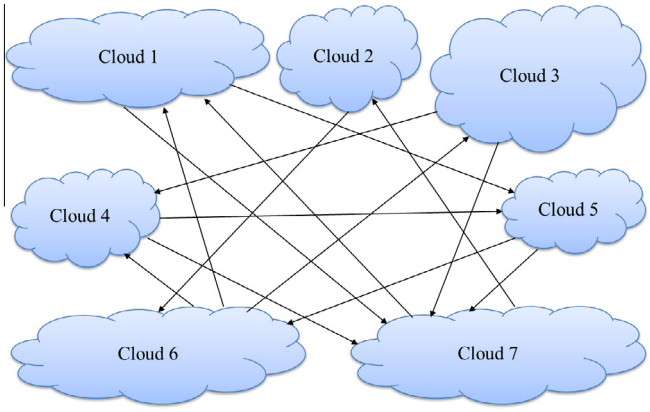

Fig. 1. Cloud computing interoperability.

The two brief definitions below truly differentiate interoperability from portability. It is shown in Fig. 2.

- Interoperability: it alludes to a situation in which a number of connecting sections are able to exchange particular information and execute on that information based upon a set of consented functional semantics (Brownsword et al., 2004; Javanbakht, Rezaie, Shams, & Seyyedi, 2008; Rezaei, Chiew, Lee, & Shams Aliee, 2014c).
- Portability: it is the capability of transferring workloads and data between providers (Cohen, 2009; Rezaei & Shams, 2008a).

How users' worries about interoperability and portability are handled greatly influences in true implementation of cloud computing systems. What portability means in cloud computing environments is that probable customers are eager to realize if they are able to transfer their data or applications within multiple cloud environments with reasonable expense and minimum disturbance. As far as interoperability is concerned, users want to be able to connect with each other across various clouds. Some frameworks have to be designed by cloud providers in order to develop data portability, service interoperability and system portability (Buyya, Ranjan, & Calheiros, 2010; Rezaei & Shams, 2008b). What data portability refers to is the capability of cloud consumers to transfer data items in or out of a cloud and/or to apply a disk for transferring huge data. When cloud consumers are able to apply their data and services within various cloud providers through a unified management interface, service interoperability can be achieved. The transfer of a thoroughly-stopped virtual machine version or a machine image between providers can be accomplished by system portability.

An approach in delimitating cloud computing interoperability is presented by Sheth and Ranabahu (2010a) and Sheth and Ranabahu (2010b), where cloud computing interoperability is closely associated with the type of heterogeneity that arises during the interoperation of clouds. Clouds interoperate to meet the needs of client applications using infrastructure, platforms or services coming from different clouds. Therefore, interoperability is divided in three subcategories: (1) interoperability in IaaS level; (2) interoperability in PaaS level; and (3) interoperability in SaaS level. In particular, in SaaS level, interoperability refers to the ability of SaaS systems on one cloud provider to communicate with SaaS systems on another cloud provider. Therefore, the interoperability of SaaS