Interoperating Cloud Services for Enhanced Data Management

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Abstract—Cloud Computing has reached a maturity state and high level of popularity that various Cloud services have become a part of our lives. The Internet of Things provides a way to improve social networking by interdisciplinary efforts that can be effectively supported by Cloud Computing solutions. In this article we propose novel approaches for composing and interoperating Cloud solutions to support IoT functionality. We exemplify how to manage, share and process user data produced by mobile devices in different IaaS clouds.

Keywords—Cloud Computing; IoT; Data Interoperability; Personal Clouds; Mobile Computing

I. INTRODUCTION

Nowadays Cloud Computing has reached a maturity state and high level of popularity that various Cloud services have become a part of our lives. These services are offered at different Cloud deployment models ranging from the lowest infrastructure level to the highest software or application level. Within Infrastructure as a Service (IaaS) solutions we can differentiate public, private, hybrid and community Clouds according to recent reports of standardization bodies. The previous two types may utilize more than one Cloud system, which is also called as a Cloud federation [3]. One of the open issues of such federations is the interoperable management of data among the participating systems. Another popular family of Cloud services is called Cloud storage services or Personal Clouds. With the help of such solutions, user data can be stored in a remote location, and can be accessed from anywhere. Mobile devices can also benefit from these Cloud services: the enormous data users produce with these devices are continuously posted to online services, which may require the use of several Cloud providers at the same time to efficiently store and retrieve these data. The aim of our research is to develop a solution that unites and manages separate Personal Clouds in an autonomous way to provide a suitable solution for these user needs.

The Cluster of European Research Projects on the Internet of Things considers the Internet of Things as a vital part of Future Internet and they defined it as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols. Things in this network interact and communicate among themselves and with the environment by exchanging data and information sensed, and react autonomously to events and influence them by triggering actions with or without direct human intervention [4]. Gubbi et al. [2] have identified that to support the IoT vision, the current computing paradigm need to go beyond traditional mobile computing scenarios and Cloud Computing has the potential to address these needs, and it is able to hide data generation, processing and visualization tasks. M. D. Assuncao et al. [1] also highlighted that there are many open challenges in applying Clouds for Big Data management. Our work addresses one of their raised issues: how to store information in a way that it can be easily shared between Cloud providers.

In this paper we propose novel solutions for interoperable personal data management in Clouds to partly contribute to the evolution of Clouds, the Internet of Things and Big Data management. Our approaches enable to manage and process user data produced by mobile devices in different Clouds transparently, and to share this data among Cloud providers in an autonomous way.

II. MANAGING MOBILE DATA IN CLOUDS

Though the computing capacity of mobile devices has rapidly increased recently, there are still numerous applications that cannot be solved with them in reasonable time. Our approach is to utilize cloud infrastructure services to execute such applications on mobile data stored in Personal Clouds. The basic concept of our solution is the following: services for data management are running in one or more IaaS systems that keep tracking the cloud storage of a user, and execute data manipulation processes when new files appear in the storage – see Figure 1.

We have identified real world scenarios that require interoperable data management among cloud infrastructures to manage user data produced by mobile devices. In general, services running in IaaS Clouds can download user data files from the cloud storage, execute the necessary application on these files, and upload the modified data to the storage service. Such files can be for example a photo or video made by the user with his/her mobile phone to be processed by an application unsuitable for mobile devices. In our solution currently developed for Android devices, there is a possibility to configure the processes to be performed on the data with a separate configuration file, which is automatically created and managed by a mobile application running on
Figure 1. Enhancing data management of mobile devices by interoperating Clouds

the users device. This application is also responsible for communicating with the cloud storage, which is Dropbox in our case. The file manipulation applications have been created as a virtual appliance, and have been pre-deployed in the participating IaaS Clouds.

In order to exemplify the usability of this generic approach, we have developed an Android application, which can be used to manipulate pictures produced by mobile devices. This program creates thumbnails of each image of the appropriate folder then ensembles them into a single image that represents the folder and gives an overview of its contents to the user. This app can be really useful by providing a glimpse of a directory, when a user has thousands of pictures spread over numerous directories, and she is looking for a specific one. We conducted a performance evaluation with an academic IaaS solution called the SZTAKI Cloud [5], where we deployed the ImageConverter VA in two different types of virtual images, meanwhile we have also tested the Android application on two different mobile devices: on a phone (Samsung Galaxy Mini) and a tablet (Asus Slider). The results clearly showed the differences: the local execution on the Android devices are significantly slower (more then 100 times) then the image generations performed in the cloud. These measurements fulfil our expectations, therefore it is worth both in terms of computation time and energy efficiency to move computation-intensive tasks to clouds from mobile devices.

To increase heterogeneity, and to show a scenario when academic and commercial IaaS Clouds are interoperated through a Personal Cloud, we created another evaluation by using Dropbox, OpenNebula and Amazon. For this scenario we ported a biochemical application to this environment that generates conformers by unconstrained molecular dynamics at high temperature to overcome conformational bias then finishes each conformer by simulated annealing and energy minimization to obtain reliable structures. The end users of this app are biologists or chemists, who need to examine molecular modeling for QSAR studies for drug development, and the execution of the whole application in a single PC takes around 5-8 days.

By using our approach, users only need to make available their data in a Personal Cloud, and to specify with a configuration file the order of data processing (by linking VM methods to data). Once this configuration file is available and at least one VM (executing the necessary service for processing user data) is running in an IaaS Cloud, the autonomous data processing starts and goes on till all data is processed. We used the former SZTAKI Cloud and Amazon to deploy the VMs of our biochemical application, while Dropbox were hosting the application data. With this solution we managed to reduce the execution time to less than a day.

III. CONCLUSION

The enormous data users produce with mobile devices are continuously posted to online services, which may require the use of several Cloud providers at the same time to efficiently store, process and retrieve these data. The aim of our research was to introduce Cloud-based approaches that contribute to the evolution and proliferation of the Internet of Things. Our proposed solutions store, process and share user data produced by mobile devices by managing separate IaaS and Personal Clouds in an interoperable and autonomous way.

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