Future Generation Computer Systems 28 (2012) 1158–1167

Contents lists available at SciVerse ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

A business-oriented Cloud federation model for real-time applications

Xiaoyu Yang *,[1], Bassem Nasser, Mike Surridge, Stuart Middleton

IT-Innovation Center, School of Electronics and Computer Science, University of Southampton, Southampton, UK

ARTICLE INFO

Article history:
Received 8 May 2011
Received in revised form
28 July 2011
Accepted 20 February 2012
Available online 10 March 2012

Keywords:
Federated Cloud computing
Cloud federation
Cloud computing
Service Level Agreement (SLA)
On-demand resource provisioning

ABSTRACT

Cloud federation can allow individual Cloud providers working collaboratively to offer best-effort services to service customers. However, the current federated Cloud computing model is not appropriate for computationally intensive Real-time Online Interactive Applications (ROIA). This paper discusses how we propose and develop a business-oriented federated Cloud computing model where multiple independent infrastructure providers can cooperate seamlessly to provide scalable IT infrastructure and QoS-assured hosting services for ROIA. The distinct features of this proposed Cloud federation model is its business layer that can provide an enhanced security features and can trigger the on-demand resource provisioning across multiple infrastructure providers, hence helping to maximize the customer satisfaction, business benefits and resources usage.

1. Introduction

Cloud computing has become a new computing paradigm as it can provide scalable IT infrastructure, QoS-assured services and customizable computing environment. Although there are many research activities or business solutions for Cloud computing, most of them are focused on single-provider Cloud. This single provider Cloud within an administrative domain has a limitation of being able to work cooperatively with other Cloud providers to maximize the usage of available resources. The customer has to stick to a single Cloud provider and there is no flexibility to switch to different Cloud providers for more available resources and usage satisfaction. This single Cloud provider model is not appropriate for multi-user Real-time Online Interactive Applications (ROIA) applications which are compute-intensive and usually co-hosted across different organizations [1]. A ROIA application is characterized by the high rate of interaction between users, requiring very fast updates of information being passed from one computer to another [1]. For example, in the game world, there is an online game called Massively Multiplayer Online Role Playing Games (MMORPG), which is a typical ROIA application. MMORPG is divided into zones that are hosted on different machines. A large numbers of users may participate in a single instance and can join or leave at any time; hence MMORPG has extremely dynamic distributed workloads, making it difficult to host them efficiently [2]. There were some initiatives such as Butterfly Grid [3] and Bigworld [4] which have tried to apply Grid computing to enable 'scalable' or 'elastic' features for hosting such games. However, these 'scalable' hosting services are only as scalable as the Hoster supporting them, and the quality of service cannot be guaranteed [5]. There is no clearly defined business model for these Hosters to support 'co-hosting' the online game.

Federated Cloud computing presents a promising approach for effectively hosting ROIA applications and provision of QoS-assured services. Federated Cloud computing aims to federate disparate data centers or Cloud providers, including those owned by separate organizations to enable a seemingly infinite service computing utility. One of the well-known federated Cloud computing researches is an EU FP7 funded project reservoir which proposed a RESERVOIR model for open federated Cloud computing [6,7]. The RESERVOIR model is based on the virtualization technology, and the virtualization layer was divided into several Virtual Execution Environments (VEE). However, hardware virtualization (e.g. virtual memory, virtual CPU) is not very appropriate for compute-intensive application which usually requires dedicated servers to host them. Furthermore, the RESERVOIR model does not consider the network link virtualization, and cannot constrain the communication parameters (e.g. bandwidth, latency, and jitter), which are critical for real-time applications. Hence the RESERVOIR-alike federated Cloud computing model is not appropriate for ROIA application.

In the EU-funded Edutain project [8], we proposed a business-oriented federated Cloud computing model based on Service-Oriented Architecture (SOA) to suit the real-time, online interactive applications, providing a service-oriented infrastructure with enhanced security features to support a business model

* Corresponding author. Tel.: +44 118 3785126; fax: +44 118 3786413.
E-mail addresses: k.yang@reading.ac.uk, kev.x.yang@gmail.com (X. Yang).
1 Present address: University of Reading, RG6, 6AL, UK.

0167-739X/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.future.2012.02.005

where multiple independent infrastructure providers can co-operate seamlessly to provide a scalable IT infrastructure and QoS-assured ROIA service to customers. This service-oriented federation Cloud computing model introduced a mediator, namely the Coordinator, which plays a role of coordinating individual infrastructure providers for provisioning QoS-ensured services, and interfacing with service customers. In this model, the Coordinator itself may not have any physical infrastructure for running the application hosting service, instead it outsources the hosting services to one or more dedicated infrastructure providers. Each infrastructure provides metered hosting services to the Coordinator, and establishes a Service Level Agreement (SLA) with the Coordinator to guarantee the quality of service. The Coordinator provides an integrated user frontend (e.g. portal) to make ROIA instances accessible to consumers. A service customer needs to open an account with the Coordinator to obtain a Security Assertions Markup Language (SAML) [9] token, and then uses this SAML token to get connection details of associated ROIA instances. Hence the participating infrastructure provider and Coordinator form a federated private Cloud. This federated Cloud can jointly provide dynamic, multi-site, on-demand, QoS-assured hosting services for ROIA applications, allowing the ROIA application to run according to the actual service customer demands.

This paper presents how we develop a security-enhanced federated Cloud model with associated business infrastructure to support the federation of multiple autonomous infrastructure providers to provide a scalable IT infrastructure for delivering ROIA application as QoS-assured services. The structure of the paper is as follows: Section 2 presents an overview of Cloud computing and open federated Cloud computing. Key features of Cloud computing are identified and some existing federated Cloud computing models are reviewed. In Section 3 we propose the service-oriented federated Cloud computing model for ROIA application and discuss this model from the perspective of Software-as-a-Service, Platform-as-a-Service and Infrastructure-as-a-Service. Section 4 describes the mechanism of on-demand resource provisioning and security in the proposed federated Cloud computing model. Section 5 gives a case study to evaluate the proposed federated Cloud computing model in a local test bed environment. Section 6 is discussions and future work.

2. Literatures of Cloud computing

This section presents a literature of general overview on Cloud computing and open federated Cloud computing. Major challenges in Cloud computing are also discussed.

2.1. Cloud computing overview

According to Foster et al., the Cloud can be defined as a large-scale distributed computing paradigm where a pool of virtualized, scalable, and manageable computing power, storage, platforms and services can be provisioned on-demand to customers over the Internet [10]. This definition has indicated the key features of Cloud computing. The Cloud can be further illustrated from the following perspectives:

SPI model—Cloud computing originates from the concept "Hardware as a Service" (HaaS), "Software as a Service" (SaaS) [11]. Cloud now advances from HaaS, SaaS to "Platform as a Service" (PaaS) [12] and "Infrastructure as a Service" (IaaS). In Cloud computing, customers can avoid capital expenditure on hardware and software by renting the usage from the service provider of a third party, rather than owning the physical infrastructure by themselves. The hardware and software are rendered to customers as IT services.

Scalability/elasticity—Klems and Gaw in [13] claim that automatic scale of infrastructure for load balancing is a key element in Cloud computing. The delivered services can elastically/dynamically grow its capacity on an as-needed basis so that the Quality of Service (QoS) can be guaranteed. "On-demand services are all Cloud computing based" [11].

"*Pay-per-use*"/"*Pay-as-you-go*"/"*Utility computing*"—There is also a vision that Cloud computing is more like a business revolution, rather than a technology evolution. The business model, or what we call "pay-per-use", "pay-as-you-go", and 'utility computing' is another feature of Cloud computing (Kaplan and Cohen in [13]), [14,15]. The usage of the resource will be metered and service customers will pay a bill to the service provider for the actual resource usage.

Data center—Another view of Cloud is that it is a powerful computer and data center is the basic unit of the infrastructure [16]. Data center can offer huge amount of computing power and data storage. The capacity of the data center can dynamically grow when handling a task. According to [17], this is associated with the concept "massive data scalability" proposed by Hand [18].

Virtualization—Cloud computing can also be regarded as a "virtualized hardware and software" (Gourlay and Sheynkman in [13]). This perspective emphasizes the use of virtualization technology in Cloud computing.

Cloud Service Computing or Cloud Computing?—Our vision is: would it be more appropriate to call it "Cloud service computing", rather than using the term "Cloud computing", as eventually everything delivered by Cloud is presented as a service, e.g. storage service, computing service.

2.2. Open federated Cloud computing

2.2.1. RESERVOIR model

Currently many research and development works relating to Cloud computing focus on a single provider Cloud within an administrative domain. This single provider Cloud has inherent problems of scalability and interoperability with other Cloud providers in order to use different types of Cloud resources. Also, this single provider Cloud cannot scale through business partnerships across different Cloud providers [7]. The usage of these disparate Cloud resources cannot be maximized.

More recently, "federated Cloud computing" is emerging. There is no global definition for federated Cloud computing but the aim of the federated Cloud computing is to federate disparate data centers or Cloud providers, including those owned by separate organizations to enable a seemingly infinite service computing utility. An EU FP7 funded project reservoir is a main project which proposed a RESERVOIR model for open federated Cloud computing [6].

In the RESERVOIR model [6,7] the entity of "service providers" and "infrastructure providers" are clearly differentiated. The "service providers" understand customer needs and offer associated services to address customer needs. But "service providers" do not own any computational resources by themselves; instead, they rent resources from "infrastructure providers" for service applications. The computational resources of each infrastructure provider (called "site" in the RESERVOIR model) are partitioned by a virtualization layer into several Virtual Execution Environments (VEE). The VEE Host is responsible for the basic control and monitoring of VEEs and their resources (e.g., creating a VEE, allocating additional resources to a VEE, monitoring a VEE, migrating a VEE, creating a virtual network and storage pool, etc.). The upper-level VEE Manager is responsible for the federation of remote sites by placing and moving VEE to remote sites. The federation of sites forms a RESERVOIR Cloud, where a service application will be deployed. The service application can be regarded as consisting of a set of software