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Abstract
In this paper we present an application which is used for cloud computing infrastructure management. The application is based on web services and it is integrated with an existing e-learning system. Main users of the applications are teachers and students and the application consists of two main parts which are web application and mobile application. The application is successfully implemented at the e-Business Laboratory of the Faculty of Organizational Sciences in Belgrade.

Keywords: cloud computing, e-education, web services, application

1 Introduction

Modern information and communication technologies (ICT) are applicable in many areas nowadays. New paradigms in educational process are created due to the development of these technologies. A lot of universities all around the world use distance-learning systems. A number of users and quantity of available teaching materials in these systems are increasing and distance-learning systems are becoming more complex. New services which enable easier and more efficient usage of educational infrastructure are introduced. Using these services, students are able to access to all teaching resources they need. Main problems during the phases of designing and implementation of the e-learning infrastructure are scalability and reliability. The problems can be solved by introducing the cloud computing infrastructure.

This paper presents an overview of technologies that can be used for designing and implementing an application for managing the cloud computing infrastructure. The infrastructure implemented in scope of the Laboratory for E-business at the Faculty of Organizational Sciences in Belgrade is presented.

The application for cloud computing infrastructure management at the Faculty of Organizational Sciences in Belgrade is deployed in the Laboratory. It is based on web services and contains the web and mobile application. The aim of developed application is to improve teaching process at the Laboratory and to simplify use of different software packages running on different operating systems by students. In this way, actual installation of operating systems on students' computers is eliminated. Students use software packages for solving assignments related to specific courses.

2 Literature review of used technologies

Service-oriented architecture (SOA) is a set of principles which enable the development of distributed applications (Vescoukis, Doulamis, & Karagiorgou, 2012). It includes all aspects of creation and usage of business services (Yang, Sun, & Lai, 2011). SOA provides application platform which integrates business processes with operating resources. It also provides interfaces for a new service based on semantic of an enterprise and functional requests and it maps them to existing systems. Finally, the highest and the lowest levels are linked together for creation of the application level, via service composition.

Web service is software which enables interoperable interactivity between devices connected on a network. Web services could be implemented using one of several

different technologies. Using the REST architectural style is one possible approach. REST represents an architectural style used in distributed systems, such as World Wide Web (Hamad, M., & Abed, 2010). Roy Thomas Fielding first defined this architectural principle in his PhD dissertation (Fielding, 2000). In REST, all objects are resources and each object has its unique identification. Data can be represented using XML, JSON, HTML or any other technology (Wang, Mao, & Cai, 2009).

Implemented web services should satisfy the principles of scalability and reliability, which are necessary for servicing a large number of users simultaneously. Cloud computing enables scalability and reliability and it also introduces working with distributed resources. Cloud computing refers to providing and using computational resources via the Internet (Sultan, 2010). It enables the access to technology in the form of service on demand. Services and data coexist in shared and dynamically scaled set of resources (Hai, Shadi, Tim, Wai, Dachuan, & Song). The concept of cloud computing is based on technology of virtualization (di Costanzo, de Assuncao, & Buyya, September/October 2009).

There are four types of cloud computing models (Hai, Shadi, Tim, Wai, Dachuan, & Song): Private cloud, public cloud, hybrid cloud and community cloud. Roles in cloud computing are (Bakhshi & Deepak, 2009): enablers, delivery agents and consumers. There are several cloud computing approaches based on the way the technology is delivered to the end-user (di Costanzo, de Assuncao, & Buyya, 2009): Infrastructure as a Service (Iaas), Platform as a Service (Paas), Software as a Service (SaaS).

3 Cloud computing infrastructure in the Laboratory for e-business

3.1 Problem description

The Laboratory for e-business at the Faculty of Organizational Sciences in Belgrade conducted a large number of courses for both undergraduate and master studies. Laboratory's work is based on the use of modern methods and technologies, as well as permanent innovations. Laboratory uses blended learning which is a combination of the classic education in classroom and teaching using information and communication technologies (ICT). Course management tool that is used in the Laboratory for e-business is Moodle.

Courses studied by the Laboratory for e-business require the use of very heterogeneous software packages that can run on different operating systems. Different kinds of system and application software can be run on a virtual machine. Cloud computing infrastructure enables simultaneous running of a large number of virtual machines. We

need to create an application that could manage the resources of Cloud Computing infrastructure to provide new services to students. The application would be developed for the Android mobile platform, relying on the existing Cloud Computing infrastructure. The application would be integrated with the user directory (LDAP) containing student accounts and it is based on web services, which is enabling the future development of other applications of similar purpose. At the same time, a web application with the same purpose would be developed.

The application would be used primarily by students of the Faculty of Organizational Sciences, which would allow them to make reservation and run predefined image with preinstalled operating system and any necessary software used in some of the courses.

3.2 Description of the realized infrastructure

Laboratory for e-business introduced cloud computing infrastructure to provide greater scalability of the system and to introduce new student services. This infrastructure is managed by OpenNebula software.

Two network interfaces are used in this infrastructure, external and internal one for providing faster data bandwidth between nodes. External network interface uses public range of IP addresses which are assigned to Faculty of organizational sciences in Belgrade. Internal network interface uses private range of IP addresses. There are four nodes in the existing cloud computing infrastructure, which are intended for running virtual machines, and there is one Cloud controller.

Software solution OpenLDAP, which is an open-source implementation of LDAP server, is used for storing user data. OpenLDAP contains predefined classes with their attributes. These classes can be used during creating new user accounts. It is also possible to define custom attributes.

Moodle LMS is an important component of the system. It represents the core of the e-learning infrastructure of Laboratory for e-business. All student activities are tracked in Moodle LMS.

4 Development of the application

4.1 Designing the application

The application uses service-oriented architecture, which enables development of web and mobile application. This approach also enables creating a desktop application in future as well as the integration of the application with some other system. In Figure 1, the architecture of the system is shown. Web service is the main part of the application

logic and the integration of system components. It integrates the cloud computing infrastructure, OpenLDAP directory with user accounts, Moodle LMS and MySQL database. Web service represents the application logic of the application.

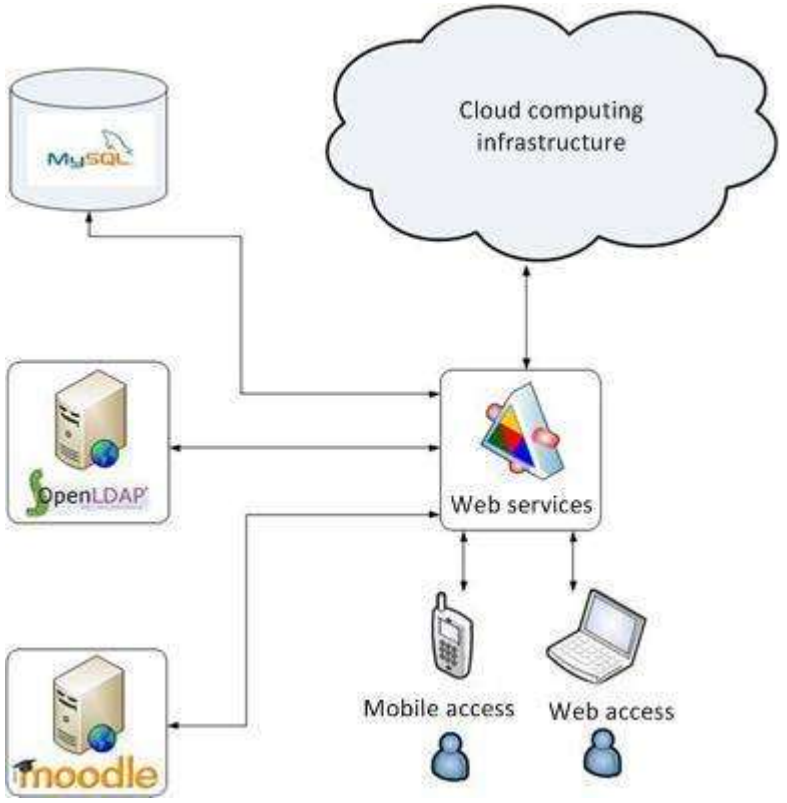

Figure 1: The system architecture

Web service consists of two main components which are two smaller web services. One web service integrates the system with OpenNebula's external web service and the other one integrates the application with Moodle LMS. Both services are integrated with the OpenLDAP user accounts directory and with MySQL database.

The main web service integrates the system with OpenNebula. OpenNebula has its own API which enables cloud computing infrastructure management. This web service is based on the XML-RPC protocol. The service communicates with OpenNebula and returns all available images and running instances on the cloud.

The other web service integrates the system with Moodle LMS. It returns all Moodle courses where the user is enrolled in. Moodle LMS has a support for external web services. All modern architectures and protocols are supported (XML-RPC, SOAP and REST). Web service for the integration with Moodle LMS calls Moodle service's methods and returns its responses.

The use cases of the application are presented in the Figure 2.

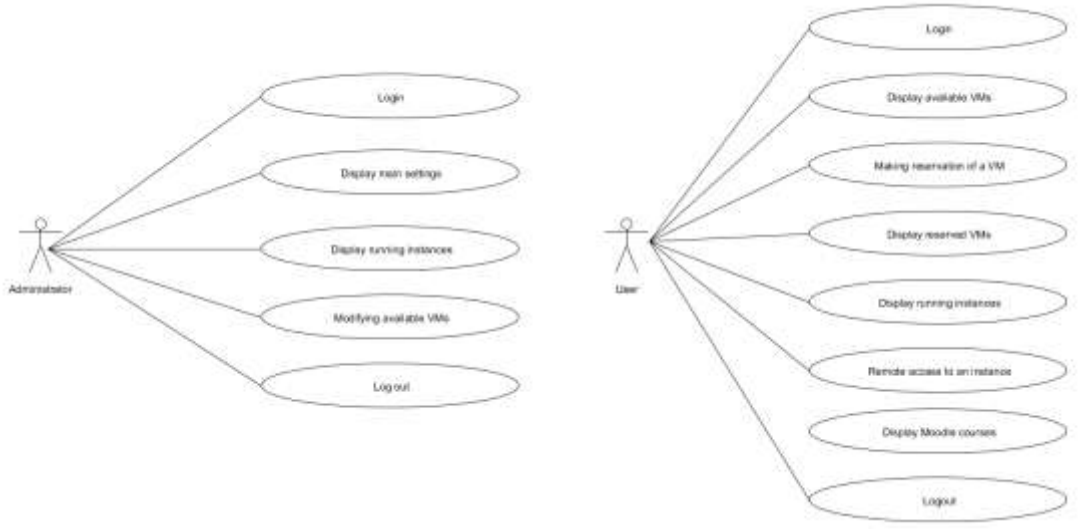

Figure 2: Use case diagram

User authentication is implemented using the LDAP protocol. All user accounts are stored at the OpenLDAP server. LDAP authentication enables single sign-on for all services available at the Laboratory for e-business.

4.2 Implementation of the application

Web application is implemented using different technologies. For application appearance, a combination of HTML5 and CSS technology was used. For realisation of application logic, programming language PHP and the Codelgniter framework were used. MySQL server is used as data storage. Mobile application was developed for the Android operating system. Java programming language and Android SDK were used.

Figure 3 shows the front page of the web application. For accessing the application, a user must be logged into the system. The system checks the privileges of the user and displays the appropriate options, depending on the assigned privileges. If the user does not have a role of the administrator, he is only able to make a reservation of the desired virtual machine and choose the date and time when the virtual machine will be available. When the user logs into the application at the time the reservation was made earlier, he can access the virtual machine which was previously reserved. The user can access the virtual machine using the VNC (Virtual Network Computing) protocol. Web

application is integrated with the TightVNC program written in Java which enables remote accessing the virtual machine from the web browser.

Figure 3: The home page of the web application

Web application administrator is able to review the settings that are defined in the application configuration files. For safety reasons, it is not possible to edit configuration files from the application interface. That is only possible by directly modifying the text configuration file. In these settings, the address of the server of the OpenNebula's frontend and the port where the XML-RPC interface of OpenNebula is started are defined. The address of the Moodle LMS installation is also defined, as well as the address of the host where the OpenLDAP server is installed. The administrator can determine which virtual machines are provided to users for each of the courses where they are enrolled. First, the administrator selects a course, then virtual machines which are available to users who are enrolled to the selected course (Figure 4).

Figure 4: Administration of the available virtual machines

The mobile application is developed for the Android platform. All phones with installed version of Android 2.2 operating system or later are supported. The main menu of the mobile applications is displayed after the user successfully logs onto the system (Figure 5). Using this application, the user can make a reservation for the available virtual

machines, and also to view his reservations. The integration with Moodle LMS is also fully supported, since mobile application uses exactly same web services as the web application. Currently, the VNC access from mobile devices is not supported.

Figure 5: Main menu in the mobile application

5 Conclusion

The basic concepts of service-oriented architecture and cloud computing were presented in this paper.

The application which was presented allows management and usage of the resources of the cloud computing infrastructure powered by OpenNebula. The application integrates OpenNebula software solution, OpenLDAP directory of the user accounts and Moodle LMS. For the integration of these solutions, principles of web development services were used. REST architectural approach was used.

The main users of the application are students and staff of the Laboratory for e-business at the Faculty of Organizational Sciences in Belgrade. The application also can be used by other research institutions.

In future, the application can be improved in several ways: improving integration with Moodle LMS, improving the algorithm for reservation of virtual machines, creating a single sign-on service, based on the LDAP directory and creation of modules for analytics and statistics.

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