Cloud Computing in Science and Higher Education

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This paper presents a model of IT infrastructure systems for scientific research and education in higher education institutions based on the concept of cloud computing. Cloud computing is an area of computing where IT capacity provides scalable service delivery over the Internet. In the theoretical part a model of IT infrastructure which, in addition to the control and data security, fully scalable in relation to requirements changes in educational and scientific-research activities. The model fully supports the new standards in economics of data centers, Green IT, by optimizing the operating costs of users for electricity, air conditioning and space. In the practical part of the work described is part of a system of e-learning on Faculty of Organizational Sciences, distance learning, which is an implemented virtualization technology. This solution is based on the proposed model of IT infrastructure systems for scientific research and electronic education.

1. Introduction

The research processes nowadays need a most advanced computing technique in order that we should accomplish the activities of processing a large number of data, as well as the activities of intensive calcualtions and ensure a simple and fast communication among the researchers. Due to the lack of access to expensive computing infrastructure and software tools many a researcher remains far from the mainstream of international scientific events and activities. The development of IT equipment and software tools only deepens this digital gap daily, however, it is perceived in many fields of science [1].

With the rise in the number of users and their needs for new services and educational contents, the electronic education systems in the higher education institutions face problems of scalability, reliability and optimization of allocated resources, with the requirements for dynamic competitiveness, with an increasing need for data storages or repositories and the need to control the costs of such systems. All these results in the requirements for the electronic education system architecture designing and implementation becoming increasingly complex [2] [3].

In this paper we attempt to analyse a possible approach to ensure a realiable and scalable computer environment for scientific research and educational processes in higher education by introducing the concept of Cloud Computing (hereinafter: CC) as a technological platform. The major goal of this work is to devise an efficient and cost-effective solution using the resources that are already at disposal.

2. Technological background

The CC concept is an entirely new business model and technological platform, a result of evolution and convergence of many seemingly independent computing trends (Utility Computing, Commodatization, SaaS, PaaS, IaaS, XaaS, Distributed computing, Internet Delivery, Web 2.0, Virtualization, IT Outsourcing, Grid Computing SOA, Storage, Data Center Automation). CC is defined as a model that allows for a network access, to configurable computer resources, at request (e.g., networks, servers, storage, applications) from available community resources that can be easily provided or destroyed with minimum management or interaction from the part of service providers [4]. Basically, the CC is a style in computer using in which dynamic and virtualized resources are offered via the Internet as a service.

One of major properties of the CC concept is scalability, and the key technology that ensures it is virtualization [2]. Virtualization separates the physical IT infrastructure from the services and applications it contains, thus allowing for a greater efficiency and flexibility. The fact that the hardware capacities of a large number of servers are far from being used up to their optimum capacities makes the basis for the implementation of virtualization. The virtualization allows for a simultaneous launching of a large number of systems on one and the same server, which results into a higher amount of utilisation of the existing hardware and reduces the need for new physical servers. The implementation of virtualization reduces the costs – fewer physical servers require less space, lowers the expences for electric energy supply and air-conditioning of server rooms. Launching virtual servers on a smaller number of physical servers results into a surplus of servers that can then be discon-

nected and thus save directly. Thus disconnected physical servers can be used or connected to the system in the periods of higher demand for a service or when any available resource is needed to deliver a service to clients [1] [5].

Depending on which technologies are delivered to the user, the CC services can be classed into three basic categories, as shown in Figure 1:

a) IaaS – Infrastructure as a service comprises delivery of standardized infrastructure services via the network such as servers, data storage systems, routers,

b) PaaS – Platform as a service is an integral computing platform consisting of operating system, middleware and a set of application solutions,

c) SaaS – Software as a service is the realization of a complete application solution used as a service at the request of the user.

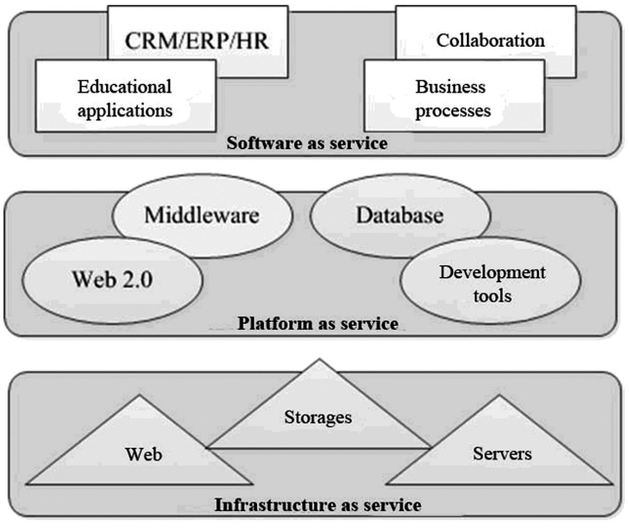

Figure 1. *CC categories*

CC is merely the latest step in the process of computing centres virtualization and server consolidation, the process of data storage and networking devices in order to, among other things, dispose of the surplus of the equipment and reduce the space it occupies. In literature, technologies related to the migration of the computing centre into the CC environment, in addition to the collaboration related technologies, are described as technologies that will ensure a continual improvement in the field of information technologies, regardless of economic conditions [11].

The CC introduction and implementation models , Figure 2, are the following:

- Public CC – publically available services are actually an outsourcing concept, i.e., the idea that organizations (institutions, companies, ...) should only rent cloud services from the providers, without being engaged in administration and maintenance. It is in this way that one CC is used by a number of organizations, hence its title: public;

- Private CC (internal cloud or compan's cloud) – internal services that take advantage of the CC technologies, where they themselves are owners of their own private CC and administrate, maintain and use it by themselves;

- Hybrid CC – a combination of public and private clouds. Certain services make use of outsourcing, using a public cloud, other are still in the internal control domain.

- Community CC – services are controlled and are used by a group of organizations sharing mutual interests. The community members share the access to data and applications in the cloud.

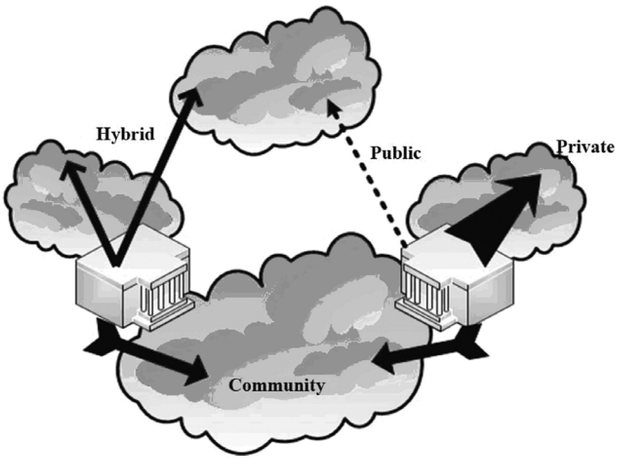

Figure 2. *CC introduction and implementation models*

3. Cloud computing in science and higher education

Electronic education is a complex system that includes distance learning, distance teachning, teachning materials in various electronic formats, individual and group learning processes, tutorial and interactive work.

Nearly every higher education institution has its own computing centre designed and constructed for its particular use and whose capacities become inadequate over time to meet the requirements of scientific research and educational activities, and are at the same time ex-

pensive to maintain. In every term (semestre), laboratory practice and practical projects the students are engaged in require a hardware with specific software requirements and a large number of computers, mainly with a most advanced hardware. The key issue is how we can ensure the scalability and reliability of hardware and software applications of such information systems indispensable in lecturing and research and educational processes. The problem becomes especially alarming when such a system of electronic education is accessed by an increasing number students and lecturers [6] [7]

The best answer that information technologies can give to users of higher education institutions and their computing centres is to develop an IT infrastructure model based on the CC concept. The CC concept and its characteristics can aid a higher education institution to improve its productivity and ease the management of various hardware and software resources necessary for a smooth flow of electronic education, scientific and research activities and students' projects [8].

Simultaneously, the introduction of distance studying and the way of higher education institutions financing will soon result into higher education institutions being positioned as market subjects. In such conditions, the establishment od the IT infrastructure model to ensure educational and scientific and reasearch activities using the advantages of CC will become an interesting orientation of any institution that wishes to achieve competitive advantage on the educational institutions market.

The implementation of CC, contrary to hosting and resource management on a local level, such as faculty or university computing networks, offers numerous advantages to educational institutions. In higher education, CC can ensure a direct access to a broad range of different educational resources, research applications and tools. In October 2007, IBM and Google joined forces to aid students master the skills necessary for the development of Cloud applications. In 2009, IBM launced the IBM Cloud Academy, a global forum for teachers, researchers and staff from the information technologies in educational institutions in order that they should continue the research and the development of the CC. IBM and Goolge provided a large cluster of several hundreds of servers for this program; this cluster is planned to expand to include several thousand servers over time.

The majority of higher education institutions face the problem of substantional costs, on an annual basis, to maintain and innovate the computing and software infrastructure. The CC implementation would reduce these costs to a minimum. The development of the computing centre for a higher education institution implementing the internal CC concept would enable all students and lecturers in the institution to have their own data and applications in a manner that is considerably more economic, safer and simpler to manage compared to the classic approach in using computing resources. The private CC offers the opportunity of data control and security, with the flexibility that requires continual changes in the present education, at low maintenance costs. Each user of the higher education institution would thus have his/her own virtual computer that is less expensive than the standard computer, and where the functionality and comfort of the virtual and the physical computers are identical. The students will access their virtual computers both from their higher education institution and from their home, even using their mobile phones. The logical architecture of the private CC model is presented in Figure 3.

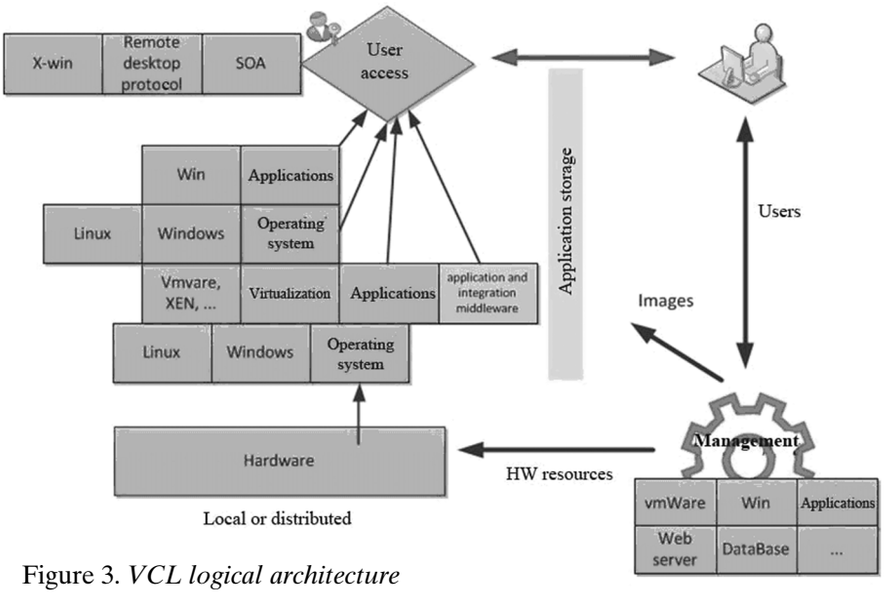

Figure 3. *VCL logical architecture*

The implementation of this system allows for constructing virtual classrooms with students sitting behind their computers or in their higher education institutions, enjoying the advantage of having the best lecturers and using the most advanced hardware and software. Such an electronic education model will enable students to work on a variety of projects which their teachers will be able to manage in a simple way and assign tasks to all students from one source. This would allow for collaboration between various higher education institutions throughout the country in the teachning, research and educational activities for the purpose of shaping a unique European higher education field and thus contribute to achieving the goals of the Bologna process [9] [15]

4. IT infrastructure model in higher education institution

The teaching process at the Faculty of Organizational Sciences at undergraduate academic studies level in the distance education regime is organized with the implementation of the virtualization concept. The distance education system is conducted via the implementation of the Moodle LMS software solution. The Moodle (Modular Object-Oriented Dynamic Learning Environment) is an open-source system of managing a learning process. It is implemented by universities, schools and individual instructors, for the purpose of improving teaching. According to the research findings, Moodle is an LMS with the largest number of functionalities and services [9] [14].

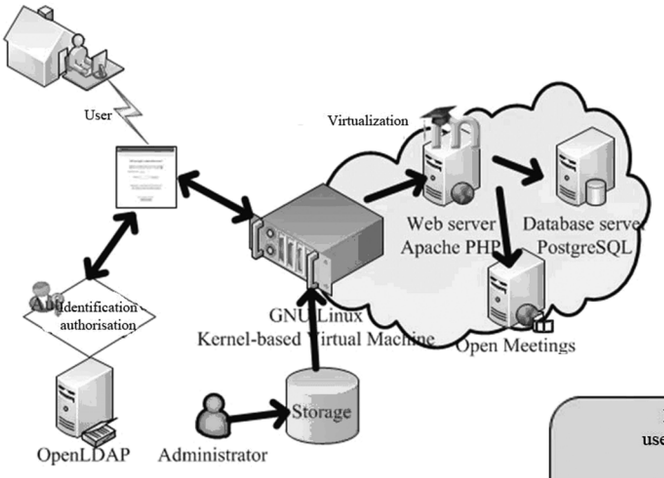

Figure 4.
The present distance learning IT infrastructure model

The present system, presented in Figure 4, has functioned successfully for the past year and is currently used by the first-year undergraduate studies students, teachers and associates at the FOS. The infrastructure for the realization of the distance learning education system is made up of one computer – server with the Fedora operating system with a Linux kernel module KVM (Kernel Virtual Machine) that allows for the creation of three virtual servers:

- Database server on which the PostgreSQL is installed;
- Web server on which Apache with the PHP and the Moodle LMS are installed;
- Server for web conferences on which Open Meetings is installed.

The server has: an adequatly powerful processor, a large memory and storade space. The system also includes the network storage that serves to transfer digital materials for the lectures as well as to store the safety copies of the base and the Moodle code itself. The implemented electronic education model on the FOS we present is based on the server virtualization [10] [12]. In this way a server consolidation is achieved and the "one application – one server" paradigm is avoided. Even with the organization of a database for storing all the options and information concerning a thus established system, the management and tuning of the virtual infrastructure remains a problem. Evidently, it is necessary that a virtual machine management layer be implemented into the system, as presented in Figure 5, all in order that scalability and reliability of the system should be achieved [5].

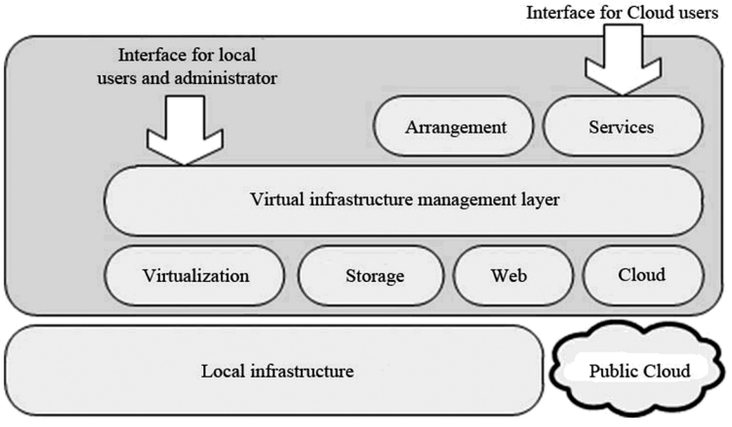

Figure 5.
Virtual infrastructure management layer

The model proposed, presented in Figure 6, consists of: front-end server and one or more node servers that can be in a cluster. The front-end server is used in managing the nodes, i.e., virtual machines. The user accesses the front-end computer and his/her claim is automatically transferred to one of the nodes by the cloud controller. The node then performs all the actions. If, however, the claim to make changes in the database is sent, the change is effected by the storage controller on the front-end computer. The model is expected to provide support for the transfer of the virtual machine from one physical node to another without any failure in the work of the service or a downtime of the virtual machine, which would help solve a large number of the present problems in server environment management. The proposed model would enhance the IT system agility, since it is possible to transfer the virtual machine to another physical node and thus gain on the performance and response of the operating system and applications, without any negative impact upon the users connected to that virtual machine at the moment [13].

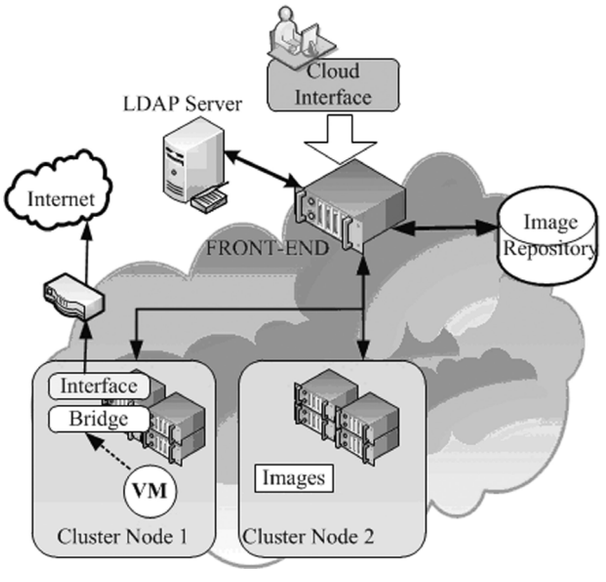

Figure 6. *Proposed distance studies IT infrastructure model*

The key advantage of the model described is that, due to the front-end server, i.e., virtual machine management layer, it allows for an efficient implementation and management of virtual infrastructure. The presented model offers an opportunity for a comprehensive management of virtual machines in the cloud, having in mind that the virtual infrastructure as a whole have to be ensured.

5. Conclusion

This paper presents an analysis of new opportunities and solutions in the CC area related to scientific, research and educational activities in higher education institutions. CC is realized as distance studying infrastructure at the FOS, with the implementation of the existing infrastructure and without additional investments. We presented an IT infrastructure model that is expected to become a dominant manner of linking resources of educational and scientific and research institutions in the future. The aim of this work is to highlight the evident advantages CC offers, but also the threats emerging on the way. Also presented are the steps made which are necessary for such a model to function, and this is the model that fully supports new standards in the economics of computing centres and helps achieve scalability and enhances the reliability of the IT system. Further work will require that the implementation of the proposed model be effected and the mechanisms that secure the confidence into the CC architecture be devised. The future trends of development mean launching interinstitutional initiative fo build a prototype of the CC infrastructure that can be divided and organized for educational and scientific and research purposes.

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