MIPRO 2014, 26-30 May 2014, Opatija, Croatia

Cloud Based Laboratory for Distance Education

Sasko Ristov, Marjan Gusev and Aleksandar Donevski
Ss. Cyril and Methodius University,
Faculty of Computer Science and Engineering,
Skopje, Macedonia
Email: {sashko.ristov, marjan.gushev}@finki.ukim.mk, aleksandar.donevski@outlook.com

***Abstract*—Today's dynamic life has changed the traditional teaching from the classroom and laboratory based classical learning to an approach using online and distance e-Learning. Universities usually follow this trend and enable their resources as online utilities for the students. There are several ways to offer these facilities online and cloud is the most promising one when analyzing several criteria. The cloud technology provides many benefits reducing the overall cost and improving the business continuity. In this paper we present an idea how to transfer the traditional computer laboratory into a cloud based utility using open source cloud frameworks. This transformation creates a dynamic, flexible, elastic, reliable and modern laboratory that can serve the students as a tool for distance learning for many courses simultaneously. It acts on a "Lab as a Service" principle.**

***Index Terms*—Education, Cloud Computing, Online laboratory**

I. Introduction

Universities are faced with a huge problem when they design their data centers and laboratories. The hardware equipment's life-cycle is usually three to five years and the managers must be smart enough to choose appropriate hardware, that is, to choose the most powerful equipment within a given limited budget. However, the experience shows that most of the time the resources will be either over-utilized (for example, during assignment deadlines, assessments or enrollments), or underutilized (during holidays or weekends).

Another problem, which maybe the worst, is to choose a sufficient and appropriate laboratory equipment. That is, different courses require equipment with specific technical characteristics. For example, multimedia-based courses require computing power and available storage space, parallel programming and algorithms need multi-core CPUs and a lot of RAM memory, while some courses demand only a high-bandwidth Internet connection, regardless of the equipment's power.

Apart of the hardware equipment, the various courses require different system and application software. A diversity of operating systems limit the use of learning tools, some might need Unix or Linux, while others Windows or Mac operating systems. Even more, 16-bit programs are not supported, and many 32 bit programs do not work properly on 64 bit operating systems since they run in an emulator [1]. Another problem arises when installing a program for one course damages already installed programs for other courses. There are file version conflicts, registry value conflicts, and their unnecessary duplication.

University laboratories are deployed to allow the students to learn the material more practically. However, there are many part-time students, which are part-time employed and cannot attend the hands-on laboratory in specific hours. They demand a distance learning environment available 24h per day. European Credit Transfer and Accumulation System (ECTS) on the other hand, gives a recommendation to the universities to evaluate the students' homework assignments and projects, which usually are developed at home, and the regular students also need some distance learning environment.

A possible solution for all these challenges is to use the emerging technologies, such as virtualization and cloud computing. Virtualization allows a creation of separated virtual machine images for each course and instantiating arbitrary number of active instances with customized virtualized hardware resources (CPU, RAM, I/O, HDD). By using the cloud computing paradigm, the universities can either build their own private clouds in their data centers, or rent resources from some commercial public cloud service provider, or both. A para-virtual laboratory can even improve the students' performance [2].

Our idea is to realize the laboratory based on a service principle offered by the cloud technology. In this paper, we present an idea how to develop a cloud based laboratory for distance learning by using the emerging techniques without or with a little additional cost. This online laboratory acting as a service is intended to be used by the arbitrary number of students of several courses simultaneously, 24 hours per day, 7 days in a week, instead of university working hours only.

The rest of the paper is organized as follows. Section II presents the related work in the area of distance education based on cloud. In Section III, we describe the architecture of our cloud based laboratory for distance learning. The usage of the laboratory is presented in Section IV. Section V discusses about further development of the laboratory for distance learning and self assessment, apart of classical online laboratory. Finally, we conclude our work and present our plans for future work in Section VI.

II. Related Work

This section presents the state of the art in the area of distance learning, especially the cloud based.

Many online courses exist that offer distance learning. Udacity offers free and chargeable online courses, which can be started at arbitrary time [3]. Putting the Stanford's Introduction to Artificial Intelligence course online, Thrun got an enrollment of 160,000 students from all over the world [4]. StarHPC [5] (the Software Tools for Academics and Researchers) is one of the first projects where the cloud is used in distance learning, which "brings" arbitrary Amazon's EC2 (Elastic Computing Cloud) resources into the students' laboratory. StarCluster [6] is a similar project where the students can create a cluster computing environment in the cloud for parallel and distributed computing applications and systems. For more than 10 years, Cisco has a learning environment, which is migrated on the cloud [7].

Platform as a Service (PaaS) cloud service layer can be also useful in education, since it allows the students to focus in the tasks, rather than on spending a lot of time to set up the necessary software for course activities [8]. Tian's framework [9] manages PaaS in a virtual cloud laboratory and manages the users, resources and their access rights. Yin et al. [10] built a multimedia courseware sharing platform, which is based on Google App Engine. NVLab is another tool, which uses virtualization. It is a web-based laboratory for management of network designs [11].

Gusev et al. [12] developed an e-Learning and benchmarking platform for distance learning of the Parallel and Distributed Processing course. They proposed a cloud model for the platform, as well as [13]. Bastidas [14] proposed the implementation of the computer networking laboratory infrastructure to distance students in order to extend the learning.

III. The Online Laboratory Architecture

In this section we present our model of a distance learning lab working as a service on a cloud. The architecture consists of two open source cloud frameworks, which are dedicated with arbitrary number of physical cloud server nodes.

A. The Physical Equipment

The laboratory is based of the existing 20 workstations, one router and one switch, as depicted in Figure III-A. All workstations are grouped in several VLANs connected by a switch. A router is used to enable an access to the university internal network.

B. The Architecture

We have a lot of experience during the last several years with various open source cloud frameworks, such as OpenStack, Eucalyptus, OpenNebula and CloudStack. Realizing various cloud deployments we have faced several challenges, such as Java incompatibility with applications in the cloud, or interaction with the cloud interfaces. Therefore, our recommendation is to implement two cloud frameworks, i.e., OpenStack and Eucalyptus, as most appropriate to deploy our online laboratory. This provides a sufficient redundancy, as well as extension for research options.

Figure III-B depicts the architecture of this online laboratory offered as a service. Two workstations are used as Eucalyptus cloud and cluster controllers, and one workstation for OpenStack. All others are used as cloud node controllers.

In normal mode, the Eucalyptus cloud uses all other workstation to instantiate virtual machines, while all OpenStack's services are disabled. When necessary, the OpenStack's services will be enabled, while the Eucalyptus' services will be disabled on several cloud nodes.

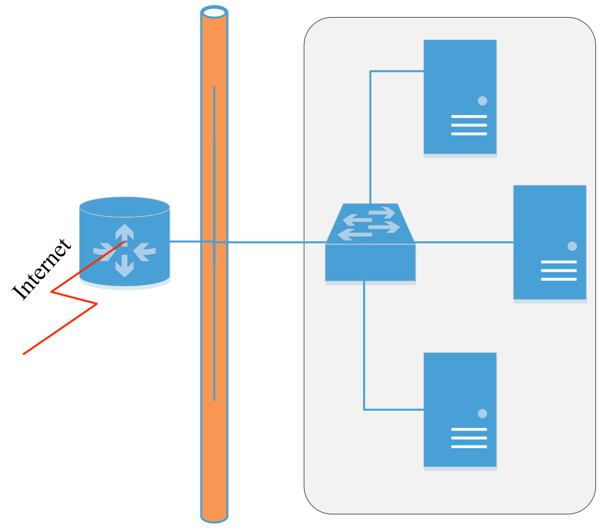

Fig. 1. The online laboratory equipment

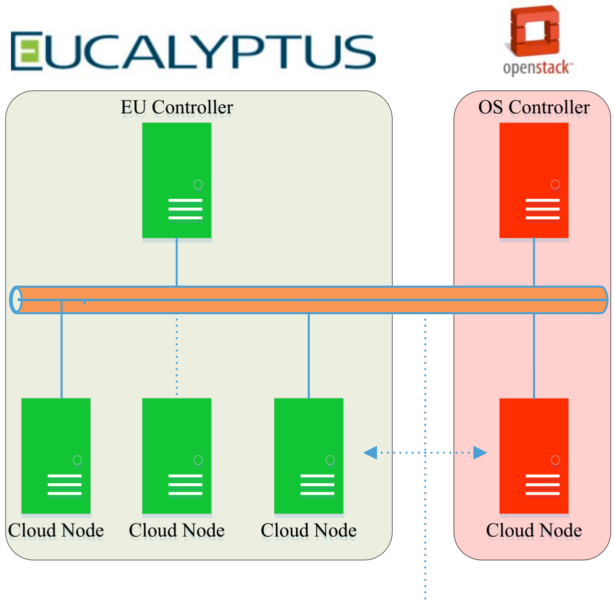

Fig. 2. The online laboratory architecture

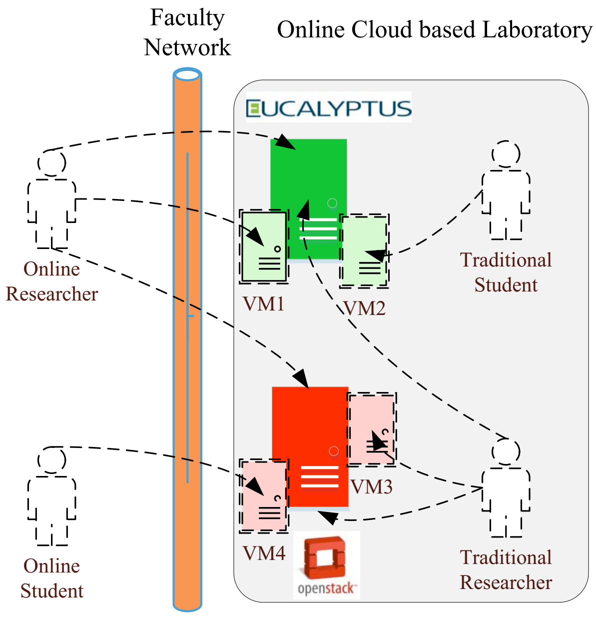

Fig. 3. The usage scenario

IV. Functional Description

This section describes the usage of our deployed cloud based online laboratory realized as a service. Figure IV depicts its three main purposes:

- *Traditional Physical Laboratory* opened for the students only in working hours;
- *Distance Learning Laboratory* available for the students 24/7/365; and
- *Research laboratory* [15], available both for the students and researchers.

A. Using as a Traditional Physical Laboratory

Since each workstation is installed with Linux with GUI (Graphical User Interface), the whole laboratory can be used as a traditional physical laboratory in the faculty's working hours. The students use the host operating system for those courses that require Linux operating system, while they can still run the virtual machine instance of the cloud for a particular course that requires Windows based applications.

B. Using as a Distance Learning Laboratory

Our currently prepared image with Windows operating system has 124 installed applications, which includes several IDEs (Integrated Development Environments) for various programming languages, simulators, network and database tools, etc. Each of the laboratory workstations is installed from this image. Although this is a huge list of installed applications, it is only a Windows platform, and something else is always missing, such as some plug-in or some configuration file is changed by other application.

Update of the image is conducted each semester, which limits the flexibility of the traditional laboratories. Therefore, we migrated one laboratory in the cloud to become a distance learning laboratory. We developed several images, each for a particular course. For example, the Computer Networks image is Windows based, which contains Cisco's learning materials, several network tools and simulators, etc, while the image for the High Performance Computing course is Linux based, which contains C++ compiler, OpenMP, MPI and BLAS libraries.

Since most of the regular students are at the faculty and work on the host operating systems, while the other busy students are at work, the laboratory is used mostly as a traditional physical laboratory in the working hours. Just in case, the administrator can limit the number of available virtualized resources through the cloud according to the requirements of the laboratory exercises of the current course. For example, if the current course requires two CPUs of four core cloud server nodes, the administrator can limit the cloud scheduler to instantiate virtual machine instances with maximum two CPU cores per physical server.

C. Using as a Research Laboratory

Additionally, apart of the already prepared customized virtual machine images for several courses, we prepared ”blank” virtual machines for the master and PhD students to realize research, or for the undergraduate students to realize a team-oriented project. These virtual machines are allowed to interact with the cloud controllers in order to develop the elastic and scalable applications as a service on the top of the cloud, according to the model for e-Assessment cloud solutions [16].

V. Discussion

This section discusses details of current and further lab development to realize the overall goal as a distance education lab providing its resources as a service to the students, teachers and researchers. The benefits of migrating the traditional laboratories in the cloud are elaborated along with description of possible challenges.

A. The Benefits

The university can achieve many benefits if it migrates some or all of its laboratories in the cloud and offer it on a service based approach. In this section we present the most important ones.

1) Isolated Course Applications: The online laboratory is used for several courses: Computer Networks, High Performance Computing, Parallel Programming, Teamwork, Computer Network Design, Microprocessor Systems, etc. Each virtual machine instance is independent of others and works isolated when it is instantiated. This improves the performance of the guest operating system because it has less system files, rather than our image with 124 installed programs.

2) Balanced Load of the Equipment: Since different courses require various hardware resources and cloud based online laboratory allows the students to work in the arbitrary time, the utilization of the laboratory equipment will be balanced instead of either over-utilized or underutilized. Even more, the laboratory can serve much more online students rather than a maximum of 20 if it is used as traditional laboratory only. That is, usually less than a maximum of 20 students are enrolled in the exercises, and not all of them attend all exercises.

3) Reducing the Cost: Migrating the laboratory in the cloud can reduce the costs in several ways.

E-Learning should be developed towards open access to learning, open source software, open standards, and OER [18]. The additional software that our pilot cloud based laboratory uses is open source, that is, OpenStack and Eucalyptus. Although the expert's assistance is required to setup a fully operational, open source workbench [19], the cost for man hours for the initial efforts for installing and configuring the clouds is much smaller than the cost for formating and configuring each computer at the beginning of each semester, and the administering during the semester (viruses, no storage place, deleted files, etc).

The reduced number of students in the laboratory will also reduce the cost for laboratory maintenance. The cost for electricity can be reduced because all physical machines (except the cloud controllers) can be started or deactivated dynamically, according to the students requirements.

B. Further Challenges

Despite the benefits, there are additional challenges for the online cloud based laboratory, such as security or availability.

All cloud based environments are more exposed than being on-premise due to virtualization and multi-tenancy [20]. However, the student exercises' data are less sensitive.

Another challenge is the laboratory availability. That is, the laboratory room is neither dedicated for mission critical services, nor its room has sophisticated climate and redundant power supply. Still, our design with two clouds and many server nodes offer good availability.

Maybe the most important challenge is the usage of the online laboratory for hardware based courses, which requires working on real equipment, rather than on simulators. However, the remote engineering is a new trend to share the lab equipment, which will allow the students with more time for learning, instead of traveling to the University [21].

C. Further Extensions and Improvements

Our pilot project is a huge step forward, both for the university and the students. However, we are not going to stop at this level, instead we are going to further improve and enhance our cloud based online laboratory. Our intention is to develop the laboratory not only for distance learning, but more wider, that is, for distance education.

Applying formative assessment in learning environments increase the benefits [22], [23]. The learning outcomes of students can be improved in a mobile learning environment [24].

Recently, we have developed a scalable and elastic cloud solution for e-Assessment based on OpenStack cloud framework [17] and E-Assessment system with interactive images [25]. Both of them will be hosted in our cloud based online laboratory in order to allow the students to learn through e-Testing. The following sections briefly describe them.

1) Scalable and Elastic e-Assessment Cloud Solution: The e-Assessment cloud system is deployed on OpenStack cloud, which allows to dynamically instantiate and deactivate the virtual machine instances. Figure 4 presents its architecture. The implementation creates an instance of already prepared virtual machine for assessment with particular size according to the number of assessed students, which is deactivated after the assessment is finished.

2) E-Assessment System with Interactive Images: This system uses sophisticated technologies for interactive images, such as Google Maps Engine. Interactive image technology offers a web based environment where the images are sent to the students. After loading the image, the students can navigate and zoom to an appropriate level to analyze the image details. The students answer by setting up one or more marks on some regions of the image. This system enriches the e-Assessment environment, enables more correct evaluation and prevents several methods of cheating and unfair grading.

VI. Conclusion and Future Work

This paper presents the architecture and the usage of the multi purpose cloud based distance education laboratory. It is deployed by migrating the existing traditional laboratory in the cloud by using the open source cloud frameworks. It is offered as a service free of charge for enrolled students and University researchers that demand more hardware resources. It acts as an extended Platform as a Service, since it offers more than standard platforms the conventional cloud providers offer. It is not a fully Software as a Service offer for the students, since it offers a limited set of software tools and hardware in comparison to the full software the conventional cloud providers offer. Finally, the students are expected to develop the final application code or realize experiments with the available tools and hardware.

The laboratory can be used in three manners. The students still can work on-site when they have hands on exercises, such as hardware based courses, which require working on equipment. Apart of being the traditional on-site laboratory, it allows the students to work remotely from home whenever they can and want, for each course. Finally, it is also used by the young researchers, such as master or PhD students.

The usage of the laboratory can be also extended in distance education, that is, it can host faculty's online learning and online self assessment systems. We will migrate our interactive e-Assessment and e-Learning systems in the laboratory in order to make them scalable and elastic capable to handle arbitrary number of assessed students.

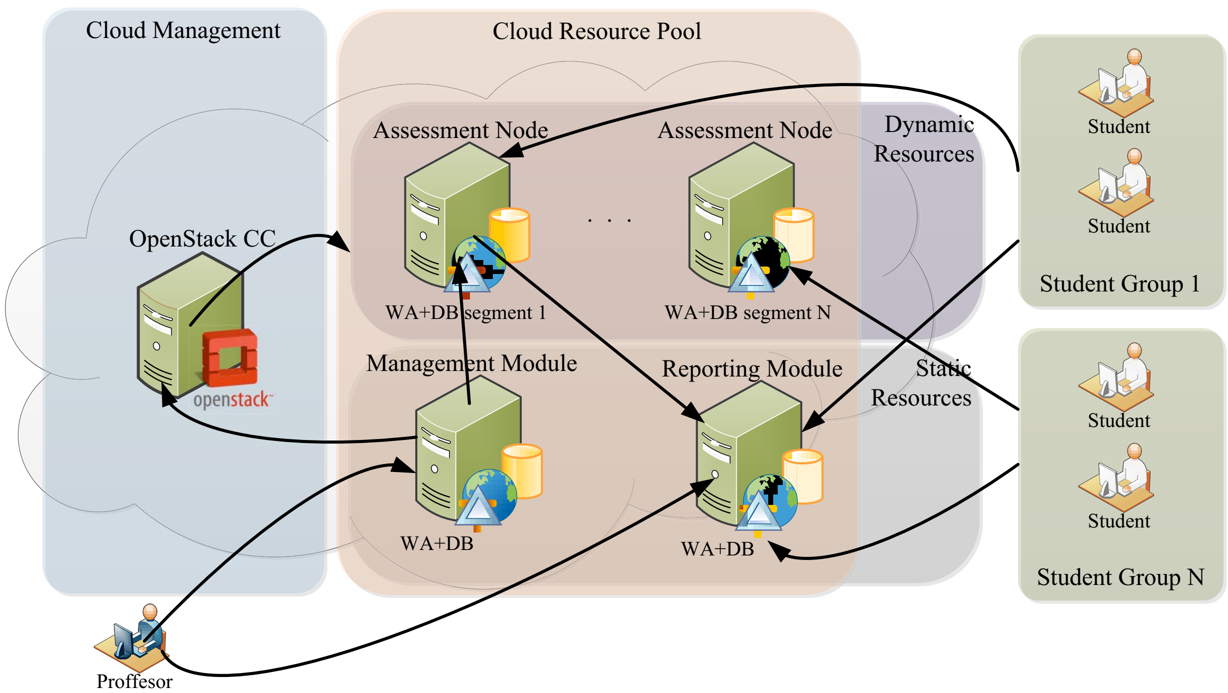

Fig. 4. e-Assessment cloud system [17]

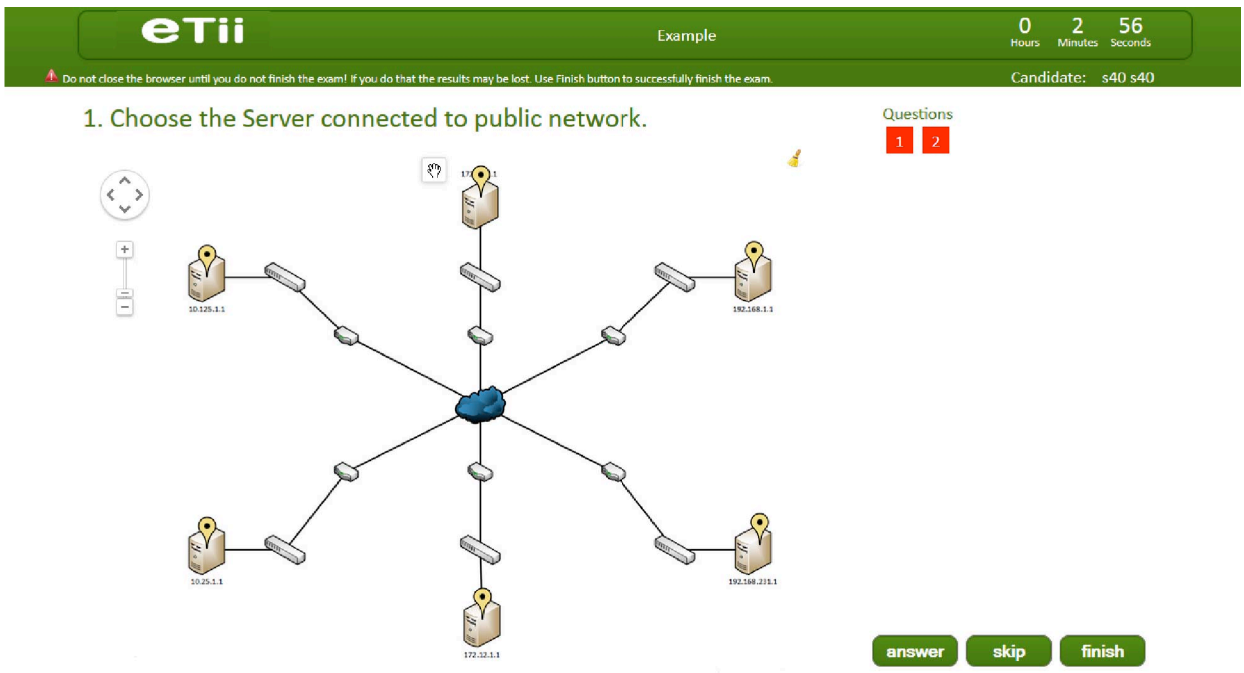

Fig. 5. An example of a MGC question for e-Assessment system with interactive images [25]

Our pilot laboratory will be extended and improved in several directions. We will develop and implement virtual machine images for more courses and we will test the performance of the increased number of the users. Also, we are challenged to integrate several distributed laboratories on several locations into one huge virtual online laboratory for distance education.

References

[1] Microsoft, "Running 32-bit Applications," [retrieved: Jan, 2014]. [Online]. Available: http://msdn.microsoft.com/en-us/library/aa384249(v=vs.85).aspx

[2] M. Anisetti, V. Bellandi, A. Colombo, M. Cremonini, E. Damiani, F. Frati, J. Hounsou, and D. Rebeccani, "Learning computer networking on open paravirtual laboratories," *Education, IEEE Transactions on*, vol. 50, no. 4, pp. 302–311, 2007.

[3] Udacity, "Courses," [retrieved: Jan, 2014]. [Online]. Available: https://www.udacity.com/

[4] F. Salmon, "Udacity and the future of online universities," 23 Jan. 2012.

[5] C. Ivica, J. Riley, and C. Shubert, "StarHPC: Teaching parallel programming within elastic compute cloud," in *Information Technology Interfaces, 2009. ITI '09. Proceedings of the ITI 2009 31st International Conference on*, 2009, pp. 353–356.

[6] MIT, "StarCluster," [retrieved: Nov, 2013]. [Online]. Available: http://star.mit.edu/cluster/

[7] CISCO, "Cisco networking academy," [retrieved: Nov, 2013]. [Online]. Available: https://cisco.netacad.com/

[8] L. Vaquero, "Educloud: Paas versus iaas cloud usage for an advanced computer science course," *Education, IEEE Transactions on*, vol. 54, no. 4, pp. 590–598, 2011.

[9] W. Tian, S. Su, and G. Lu, "A framework for implementing and managing platform as a service in a virtual cloud computing lab," in *Education Technology and Computer Science (ETCS), 2010 Second International Workshop on*, vol. 2, 2010, pp. 273–276.

[10] H. Yin, J. Han, J. Liu, and X. Hongyun, "Development and research of multimedia courseware sharing platform based on gae," in *E-Health Networking, Digital Ecosystems and Technologies (EDT), 2010 International Conference on*, vol. 2, 2010, pp. 289–292.

[11] M. Wannous and H. Nakano, "Nvlab, a networking virtual web-based laboratory that implements virtualization and virtual network computing technologies," *Learning Technologies, IEEE Transactions on*, vol. 3, no. 2, pp. 129–138, 2010.

[12] M. Gusev, S. Ristov, G. Velkoski, and B. Ivanovska, "E-learning and benchmarking platform for parallel and distributed computing," *International Journal of Emerging Technologies in Learning (iJET)*, 2014, in press.

[13] S. Ristov, M. Gusev, and G. Velkoski, "Cloud e-learning and benchmarking platform for the parallel and distributed computing course," in *Global Engineering Education Conference (EDUCON), 2014 IEEE*, Istanbul, Turkey, 2014, p. in press.

[14] C. Bastidas, "Enabling remote access to computer networking laboratories for distance education," in *Frontiers in Education Conference (FIE), 2011*, 2011, pp. F3C–1–F3C–6.

[15] LiiT, "Laboratory for Internet and Innovative Technologies," [retrieved: Jan, 2014]. [Online]. Available: http://liit.finki.ukim.mk/

[16] S. Ristov, M. Gusev, G. Armenski, K. Bozinoski, and G. Velkoski, "Architecture and organization of e-assessment cloud solution," in *IEEE Global Engineering Education Conference (EDUCON), 2013 IEEE*. Berlin, Germany: IEEE, Mar. 2013, pp. 736–743, best Paper Award.

[17] S. Ristov, M. Gusev, G. Armenski, and G. Velkoski, "Scalable and elastic e-assessment cloud solution," in *Global Engineering Education Conference (EDUCON), 2014 IEEE*, Istanbul, Turkey, 2014, p. in press.

[18] D. Dinevski, "Open educational resources and lifelong learning," in *Information Technology Interfaces, 2008. ITI 2008. 30th International Conference on*, 2008, pp. 117–122.

[19] C. T. Delistavrou and K. G. Margaritis, "Towards an integrated teaching environment for parallel programming," in *Proceedings of the 2011 15th Panhellenic Conference on Informatics*, ser. PCI '11, 2011, pp. 3–7.

[20] S. Ristov, M. Gusev, and M. Kostoska, "A new methodology for security evaluation in cloud computing," in *MIPRO, 2012 Proceedings of the 35th International Convention*, 2012, pp. 1484–1489.

[21] D. Pop, D. Zutin, M. Auer, K. Henke, and H. D. Wuttke, "An online lab to support a master program in remote engineering," in *Frontiers in Education Conference (FIE), 2011*, 2011, pp. GOLC2–1–GOLC2–6.

[22] L. Gardner, D. Sheridan, and D. White, "A web-based learning and assessment system to support flexible education," *Journal of Computer Assisted Learning*, vol. 18, no. 2, pp. 125–136, June 2002.

[23] P. Orsmond, S. Merry, and A. Callaghan, "Implementation of a formative assessment model incorporating peer and selfassessment," *Innovations in Education and Teaching International*, vol. 41, no. 3, pp. 273–290, 2004.

[24] G.-J. Hwang and H.-F. Chang, "A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students," *Comput. Educ.*, vol. 56, no. 4, pp. 1023–1031, May 2011.

[25] M. Gusev, S. Ristov, G. Armenski, P. Gushev, and G. Velkoski, "E-assessment with interactive images," in *Global Engineering Education Conference (EDUCON), 2014 IEEE*, Istanbul, Turkey, 2014, p. in press.