Use of Heterogeneous Hardware Distributed Systems on Ecuadorian Public Universities: ESPOL

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***Abstract*—This paper presents an ongoing project in undergraduate engineering education which goal is to provide students with practical knowledge and fundamental skills of parallel and distributing computing and systems area using low cost and easily accessibly hardware and laboratories. Initial results show that the use of low cost laboratories allow students to put in practice the theoretical knowledge they had gained while performing real world scenarios and applications. Preliminary results seem to prove that the use of those technologies provide an advantage in employability while having a very positive reception by the student who took them.**

I. Introduction

Parallel computing and distributed systems are the future of computer sciences. The first, parallel computing consist on processing simultaneously, and concurrently, different parts of a single problem so the result is reached faster than in a sequential matter. The second one, distributed system, is defined as a set of autonomous devices that are located apart from each other but are logically connected to do some tasks. Both technologies have become popular for many reasons: low budget for infrastructure, minimalist systems designs, or to take advantage of underused resources on academic environments. Adding or removing heterogeneous components to provide scalability, failure handling, and security among other advantages, are some of the challenges that emerge when building distributed systems [1]. At the same time, big data and embedded systems are important elements of the technology curricula. These applications can be based on distributed systems which implementation in undergraduate education is part of this work. While big data needs high-performance hardware, embedded systems have less consuming processors. However embedded system can be used to process big data, using a collect of those devices to cover the appropriated requirements. A distributed system is a good option to accomplish the task, being cheaper and smaller than a common high-performance server.

Since technology is entwined in every aspect of our lives, it influences how we socialize, play, connect, collaborate, shop, learn, and even how we teach. This means that the way how professors teach needs to be improved. Information and Communication Technologies(ICT) provide us with tools to enhance the educational system and mitigate, or even eliminate, critical barriers such as distance, access, and time [2]. On this premises, several governments, including latin-american ones, have defined promising policies to be applied in the education system.

According to [3], the Ecuadorian undergraduate education system has 55 universities and 260 technical colleges. These institutions can be public (state funding, 39%), or private (state co-funding, 12%, and self-funding, 49%); which are properly evaluated and accredited by the same Board of Assessment (CEAACES). This board uses five evaluation criteria: Academy, Academy Efficiency, Research, Organization, and Infrastructure [4]. Based on the evaluation's results, universities are located in one of 4 categories: A, B, C or D as shown in Fig. 1. Obviously, A is the best category, while D is the worst; institution within D category will be taken over by the government in order to address fundamental concerns. At present, there are 6 universities and 2 technical colleges with A category; 26 universities and 1 technical college with B category; 16 universities with C category; and 4 universities with D category in the accreditation process [4]. Our case of study is Escuela Superior Politecnica del Litoral (ESPOL), a public university, and one of the six institutions already accredited in category A.

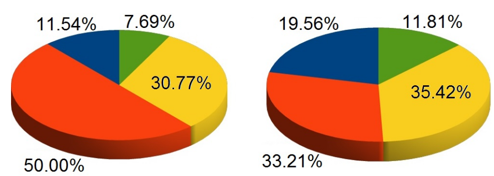

Fig. 1. Distribution of Universities and Technical Colleges in Ecuador by Category Level according to CEAACES [4]. Left side represents the Universities distribution; Right side shows the Technical Colllege distribution. Categories: A (blue); B (red)); C (yellow); D (green).

One of the indicators for the academic excellence, of an Ecuadorian high educational institution, is the access level to technology. All the A category universities have invested in laboratories and infrastructure in order to accomplish with international standards and local governmental guidelines. ESPOL has excelled those requirements, specifically the Electrical and Computer Engineering Faculty (FIEC) has updated several labs to obtain the ABET Accreditation. The Telematics Engineering Department, as part of this process, has focused its efforts on the Distributed Systems Laboratory (DSL) since 2010 using heterogeneous hardware.

When implementing parallel computing and distributed systems in education, designers have to consider the pervasive networks, user mobility and ubiquitous computing, in addition to interaction and multimedia services [1]. Low cost is also an important feature, the idea is to take advantage of all hardware resources and maximize the systems' performance. Parallel computing, with unlimited targeted platforms and distributed programming through all cores, is a growing trend [5]. Additionally, distributed systems have to be easily adaptable to smart devices, specially devices with embedded microprocessors. This is considered part of the new electronic recycling initiatives.

Nowadays there is a global trend to implement parallel computing and distributed systems labs in universities with undergraduate technical programs. For example, the Computer Science and Software Engineering Department at the University of Melbourne, Australia, has implemented a laboratory where the students improve their skills in developing solutions over heterogeneous infrastructure using basic informatic resources [6]. Other universities, such as the University of Pennsylvania, the University of Texas at Austin, or Iran University of Science and Technology, have invested in deploying distributed systems laboratories for broadening research topics like Distributed Computing, Wireless Sensor Networks (WSN), and Cloud Computing. The use of these labs allows students to acquire skills consider fundamental for our globalized and competitive working world. However, the cost of implementing those labs in a traditional approach, make it difficult for developing countries such as Ecuador. In our case study, the implementation was done using heterogeneous hardware and thus limiting the general cost while maintaining the benefits of the lab into education.

This work is divided as follows: Section II describes the Ecuador situation focusing on the barriers and the outreach initiatives; Section III describes the implementation done at ESPOL, including the specific practical classes selected for the senior students; Section IV presents the preliminary results of education and employability. Finally, conclusions and future works are presented.

II. An Optimistic Future

The implementation of a heterogeneous hardware distributed system lab sought to demonstrate that it was possible to reduce the cost of distributed systems and virtualization simulation environments. In order to optimize the use of the labs, it was necessary to design specific practices so students understood how parallel code worked among distributed systems, and acquired basic distributed systems, virtualization and networking design skills.

A. Barriers in delpoyment Technology

In the case of Ecuador, all these technologies had been imported since, due to lack of local knowledge, no indigenous implementation was possible. Before 2014, automatic machines for industrial processes and digital data processing, and basic ITC equipment was not produced locally and rarely available. This competitive disadvantage affected even more the economy since only 6% of the importations, due to the scarcity of resources, are technology based [7]. By lacking the knowledge, further implementation and developing of technology is almost impossible. Therefore, the inclusion of this knowledge is of great importance for the general development of the country.

The second large barrier, for developing countries, to deploy technology is its real cost. In one hand, integrating ICT into educational systems, at any level, can be expensive; the investment would include not only the infrastructure, the premises and equipment but also the training and the socialization of the new techniques. On the other hand, the funding for these initiatives must be taken from another critical part of the budget, such as health care, which politically difficult.

B. Outreach Initiatives

Current governmental effort usually are unwilling to invest in infrastructure or technology implementation that are not generally perceived as quick-return investments. Economic crises, high importation taxes and several other organic deficiencies, impact even more in the lack of investment on these technologies. However, in the last several years a few good news have come into efect. For exameple, the effects and potencial of distributed systems laboratories, better technology understanding and further scientific development, has been taken into account [8]. According to the 2014 CEAACES report [4], laboratories and infrastructure in a high education institution has become an important area of evaluation. These criteria have been selected by the government in order to introduce the concept of technological excellence, to facilitate potential international accreditation of the local educational programs and to assure that the next generation of Ecuadorian technical professionals will have better and more useful skills.

III. Implementation

Due to constant and fast technology improvement, the Distributed Systems Laboratory (DSL), as shown in Fig. 2 has done use of heterogeneous hardware which include low and high cost servers, mid-range switches, among others devices, as shown in Table I. That means that students interact with a heterogeneous computing architectures.

TABLE I
Hardware Quantity and Type

Quantity	Type
4	HP Proliant DL320 Gen.8 Servers
1	HP Proliant DL160 Gen.6 Server
2	HP Proliant DL120 Gen.7 Servers
4	Clone Type Desktops (Used as servers)
10	Clone Type Desktops
6	Remote Desktop Work Stations
1	Switch Dlink DES3028

The lab uses open source software to accomplish the laboratory practices such as CentOS 7, Octave, and XenServer.

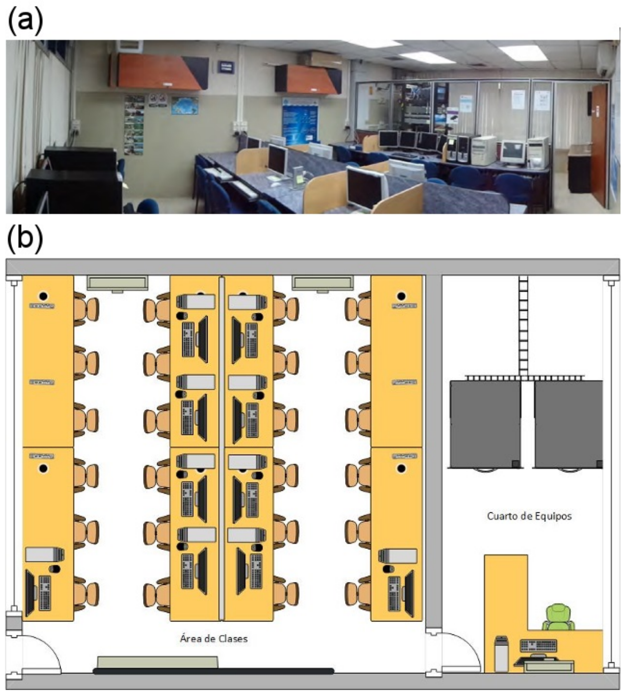

Fig. 2. Distributed System Laboratory. (A) ESPOL Distributed Systems Lab panoramic photo. the server racks can be observed at center-top-right of the picture through the glass division. Thin clients and regular computers working as thin clients can be seen at the center of the picture/room. (B) room schematic blueprints. The picture was tacken from the bottom-left corner perspective in the blueprints.

Fig. 3. Students Working in the practices. (A) Student working in virtalization exercises though a Zen Server platform. (B) Student configuring a Linux cluster for HPC. (C) Student running remotely a simulation using a tablet as the access device.

A. Methodology

The designed lab notebook satisfied the current distributed system syllabus and integrated several tools in order to solve standard implementation problems that the student may address in real job situations. Practices are divided in two main parts: On the first part, students have to identify the devices and analyze how they can build a cluster. Latter on, students test the cluster, compare the difference between high-performance cluster and low-cost devices cluster. Students also analyze the load distribution among the different elements of the cluster and virtualizations (See Fig 3(a) and (b)). On the second part, students test virtualization environment in order to decide which ones are the best hardware options and learn about trend topics like virtual storage, virtual desktops, backups, and virtual network configuration. These practices represent real world situations or new technology problems solutions [9], to allow students to innovate and always distinguish better options, and also exploit new technology to be sure and disposed to emerge new projects (See Fig 3(c)).

IV. Preliminary Results

Since May 2016, students have been using the DSL to complete their practical knowledge in two hours seasons per week. Through the use of these practices, an important increase in the students understanding of the topics covered was achieved. Moreover the students acquired, according to their own opinion, ”real” knowledge of how other related technologies, such as networking, worked. Students found the distributed systems laboratory interesting and motivating and were willing to approach more technically difficult problems in their work environment. The training received also has increased their work perspectives reaching a job placing of up to 95%; since the acquired set of skills is greatly appreciated in the local market where workers with that profile rarely exist.

The infrastructure of distributed systems laboratories also provided advantages for the project's implementation. Students were able to use the equipment for web hosting, database services, scripting, applications development among other education related task. An example of this is that one server is used for a research project, when a basic monthly cloud server lease is about $23. This means ESPOL has been saving at least $276 annually, just for one project. Since ESPOL has many research projects and courses that will benefit from this infrastructure, the savings can be considerable.

Conclusion

In order to decrease the lab implementation investment, we used heterogeneous hardware and proved that it worked as expected. Special attention was payed to the compatibility of the old servers architectures and the software used.

Involving technology in education systems is not as easy as it appears. It requires considerable government support and investment. However, it helps considerably to improve education, specially in the engineering field.

The initial results were positive; demonstrating that a lab provides the students with the opportunity to apply the theoretical concepts learned as well as acquire real world experience.

Further test of the infrastructure created should be done, specially using students from a wider background, to determine the effects that the use of these kind of labs have in their learning experiences. Finally, tracking the graduates job situation will help prove the advantages these kind of labs have in their employability.

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