# Virtualization environment for IT labs development and assessment

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***Abstract*—In this contribution, the advantages of using a virtualization platform for IT laboratories is demonstrated. The platform used is based on free (open-source) software and present important advantages with respect to previous virtualization solutions since the new platform provides the students with greater control over their virtual machines. In addition, a WWW application has been developed that assists the assessment of the labs done by the student allowing a mostly automatic grading of the labs.**

***Index Terms*—Virtualization, self-assessment, automatic assessment, IT, open-source software.**

## I. Introduction

This contribution is related to the course *Tecnologías Avanzadas de la Información (TAI)* (Advanced Information Technologies) taught in the Computer Engineering Degree – Information Technologies at the Escuela Técnica Superior de Ingeniería Informática (ETSII) of the University of Seville, Spain. This is an optional course of the third year and it covers fundamental practical and theoretical skills in the degree.

An important characteristic of this course is the high number of students enrolled, that makes it necessary to split the single theoretical group into five lab groups. For a correct lab development, every student needs to configure three computers, thus the lab realization with real computers would require addition group splitting that is not feasible with the available resources. For this reason, when the course started to be taught a few years ago, a computer virtualization solution based on *VirtualBox* [1] was set in place. With this solution, every student had to setup three virtual machines starting with a generic virtual machine (VM) image provided by the instructor. The three VMs where then used to complete different lab exercises along the course. The students were responsible of taking care of their own VMs, which includes copying the VMs to the laboratory computer at the beginning of the lab session, and copying the machines back to removable media after the lab in order to continue with the exercise in the next lab session. Often, the copying processes were done with errors and students had to repeat part of the exercises.

Regarding the practical contents, the course includes five lab exercises related to Information Technology (IT) including aspects as packet filtering (firewalls), secure networks services configuration, virtual private networks (VPN), quality of service (QoS) and traffic control. A Project-Based Learning (PBL) [2] methodology is used. The students are provided with five lab manuals that include the tasks to be done by the students out and during the practical lab sessions. The instructor main activity is to guide the students through the project by making suggestions and solving doubts.

The instructor also defines an assessment period in which the student can book an appointment with the instructor to get its project evaluated in the lab. During the assessment, the student will have to start up its virtual machines and the instructor will collect various assessment items from the project under evaluation. The instructor will also ask questions to the student and may request that changes are made in place in order to evaluate the real outcome of the learning process.

This was the methodology in place using *VirtualBox* software and on-site assessment up to the 2019/20 academic year. From them on, and mainly due to the COVID-19 health emergency, on-site classes and lab session were drastically reduced and there arise the problem porting the methodologies to an on-line teaching and assessment mode. The theory part was easily ported by using the video conferencing facilities of the university's virtual teaching platform (*Enseñanza Virtual* or EV) but adapting the practical activities normally done in the lab was a real challenge. The following questions had to be answered:

1) Was it possible to keep the same teaching methodology? That is, use a PBL methodology with the instructor assisting the students remotely.
2) Was it possible to carry out the same project planned for the on-site learning mode? It was key in order to not to

have to make important modification to the lab manuals already edited.

3) Was it possible to keep roughly the same assessment procedures? It means, a method that allows the instructor to evaluate a big number of projects and students, but remotely.

In order to answer these questions, previous on-line solutions used by other instructors before the COVID-19 emergency were investigated. There is plenty literature about this area, as expected. As an example, only in the *Congreso de Tecnología, Aprendizaje y Enseñanza de la Electrónica* (TAEE) celebrated in Porto, Portugal in 2020, many contributions dealing with remote laboratories were included [3] or about FPGA implementation [4]–[6], process-control teaching [7], instrumentation teaching [8] or digital-signal processing [9]. Nonetheless, as it is stated in the contribution from García-Loro et. al. [10] a distinction between a remote and a virtual laboratory must be done. Remote laboratories are real laboratories that can be accessed and controlled remotely through a communication network like the Internet. It was concluded that our objective was not that of setting up a remote laboratory but a virtual laboratory.

The next step was to look for virtualization tools for an easy deployment of a virtual laboratory. Many alternatives were investigated, including *VMware ESXi* [11], *Docker* [12] and *Proxmox Virtual Environment* (Proxmox) [13]. Finally, Proxmox was selected because it offers a complete platform and is based in free software, which makes it easier a deployment in our own servers.

Proxmox solved the problem of providing the students with a virtual remote environment, but remote assessment still needed a solution. Because the assessment methodology is very specific, it was decided to create a Web platform that includes a set of tools to easy the assessment process for both students and instructors.

From what has been said so far, this contribution presents the innovative aspects introduced by the virtualization and assessment platforms. It will be done using the demonstrator format of the conference including a practical case.

The rest of the contribution is organized as following: section II introduces the general characteristics of the virtualization and assessment platforms, section III describes the demonstrator through a working example, in section IV some results are collected and analysed and section V derives the most important conclusions.

## II. Virtualization and Assessment Platforms

In this section, the main characteristics of the selected virtualization platform (Promox) and the developed WWW-based assessment platform are introduced.

### A. Proxmox Virtual Environment

Promox is very complete and advanced virtualization platform that can be installed in dedicated user-owned servers. Two important characteristics are the use of different types of virtualization technology (*Kernel-based Virtual Machine (KVM) hypervisor* and *Linux Containers*-LXC-) and the fact that it is distributed as an independent Linux distribution based on Debian, which makes its installation very easy and uncomplicated from a licencing point of view because it is completely free software under a *copyleft* GNU AGPL licence. This characteristic has made it possible to install the platform in the university's own servers and full control by the teaching stuff of the courses.

To easy remote usage, Proxmox includes a web interface from where all the virtualization resources can be administered. The DTE server cluster has three nodes or servers as shown in Fig. 1. Total resources are 56 CPUs, 314.37 GiB of RAM memory and 3.86 TiB of storage space. Currently, the cluster holds about 500 virtual machines.

The administration panel in Fig. 1 includes different options. Options to create new virtual machines and containers are at the top-right side of the panel. The options at the centre of the panel control the overall configuration of the cluster like adding storage units or permission management. Permission management in Proxmox is very rich: users, groups and roles can be defined so that resources (virtual machines, storage, etc.) and privileges (actions over the VMs) can be assigned in a very specific ways to users and groups. It makes it possible to distribute the resources into different courses and subjects without interference and is being currently used in this way. On the left side of the panel there is a list of the available VMs.

As seen in Fig. 2, after selecting one of the virtual machines in the main panel, a number of actions can be executed: 1) to start and close the VM, 2) to open a console to interact with the VM, 3) to migrate a VM from one cluster node to another node, 4) to generate a template VM from a created VM and 5) to clone or delete a VM. The VM console in Proxmox integrates Virtual Network Computing (VNC) system called noVNC [14] in order to access any machine remotely through the web interface. However, more advance console systems like SPICE [15] can be configured in a simple way. Templates

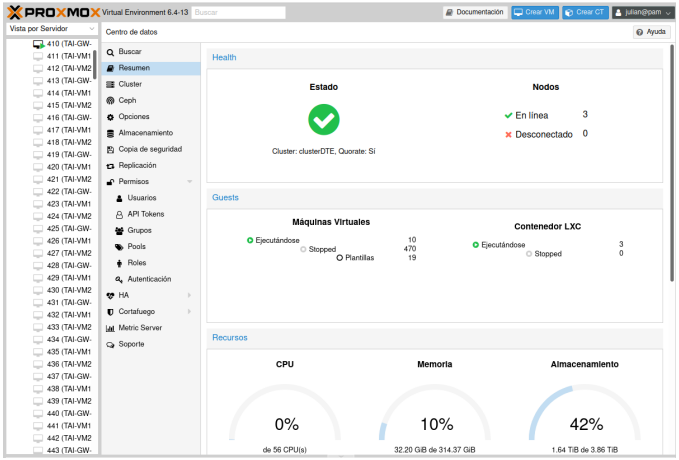


Fig. 1. Access to the administration panel of the Proxmox virtualization environment. General cluster data at Departamento de Tecnología Electrónica.

make it easier to clones machines and save resources. In addition, on the left side, there are other useful options like: 1) a summary of the resources used by the VM, 2) the checking and editing of the hardware resources assigned to the VM, 3) the history of tasks (start and stop) of the VM, 4) a VM backup tool and 5) permission control for users and groups.

### *B. Web platform for assessment support*

Deploying a virtualization platform does not solves the problem of assessing the work done by the students. A web platform for assessment support have been developed as a complement to Proxmox that simplifies and greatly speeds-up the remote assessment of groups with a high number of students.

The web assessment platform has been developed using Django [16] (Fig. 3). Django is a high-level web development framework written in Python, that simplifies the creation of safe easy-to-administer web sites. The integration of Proxmox and the web assessment platform is done through Proxmoxer [17], a Python wrapper for the Proxmox Application Programming Interface (API). Even though the TAI course has a high number of students, the use of Proxmoxer has made it possible to automate the generation and configuration of the virtual resources that are assigned to each student (user, VM creation from a template, network interface creation, resource assignment, etc.). All the necessary information to automate the process is imported from the students class lists provided by the University of Seville. In addition, as will be detailed later, Proxmoxer plays a key role in the assessment of the students projects since it makes it possible to automate actions like starting or closing the VMs.

As it can be seen in Fig. 3, the menus available to the student in the assessment platform are:

1) Inicio (Init). Basic information about the student (name, e-mail, etc.).
2) Recursos (Resources). Detailed information about the resources available to the student: network configurations, VM identifiers, access credentials and remote access recommended software. Same menu elements are marked in a different color as in Fig. 3.
3) Laboratorios (Laboratories). For each lab exercise there is specific information: lab description, recommended submission date, weight on the final grades, configuration data and files, recommended software and additional bibliography.
4) Evaluaciones (Assessment). Within this menu the students can make two actions: check the requisites and ask for assessment. In general, the evaluation objective consists on assessing a set of tasks that are enumerated in lab's manual. Among these tasks, some of them are considered mandatory and need to be done correctly before continuing with the exercise. For example, if the student do not configure the network interface correctly (one of the tasks) will not be able to check if the firewall rules work correctly or not (another task). Because the tasks in different labs are correlated, the checking have to be done in an incremental way. The students will find here the grades of each lab project one the instructor has assessed them.
5) Calificaciones (Grades). Here is where the result of each lab assessment is shown, together with the final grades after applying the evaluation criteria.

## III. Demonstrator description and example of use.

In this section we take one of the labs and use it as a demonstrator of the complete evaluation process.

The first step when a lab starts is to prepare the virtualization environment. The virtualization resources for each student are generated automatically from the student list ast already describe in the previous section. After that, the students can access the material for lab 1 and start to work on the project. The objective of this first lab is to introduce the students to the virtualization environment and setup the network interfaces and the machine's host name.

Once these tasks are finished and before the students apply for assessment, they must check if al requisites are fulfilled. As it can be seen in Fig. 4, the requisites for lab 1 are that all network interfaces must have been setup correctly and that the user's password have been changed from the default one. It can

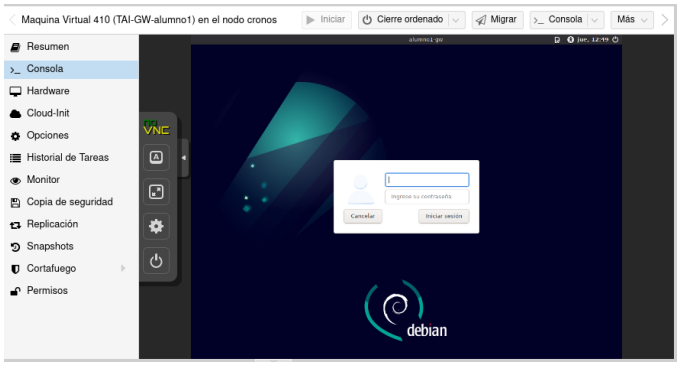


Fig. 2. VM administration panel.

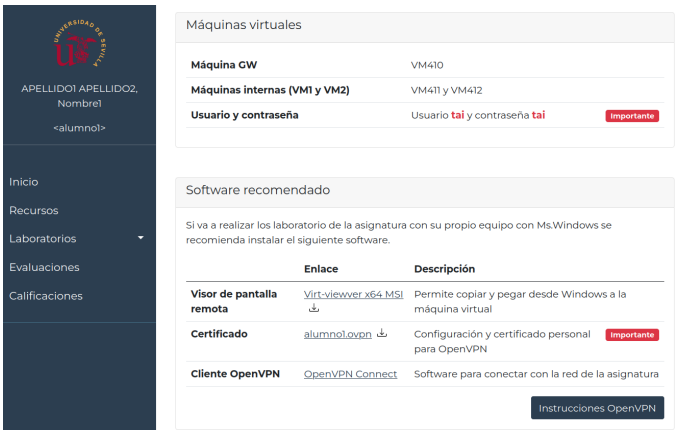


Fig. 3. Administration panel of the web assessment platform.

be seen in the figure that requisite R5 is not fulfilled since the connectivity check to one of the VMs does not get an answer. Thanks to this feedback, the students can review the task and make the necessary corrections without the instructor's intervention. After all requisites are met, the student may ask the instructor to assess the exercise.

In the next evaluation step, the instructor checks the queue of assessment requests made by the students. Technically it is possible to assess most if not all the tasks automatically, but it was decided tha the instructor had to trigger the assessment routines manually (see Fig. 5) in order to maintain a complete control on the evaluation process. Hence, after the manual execution of the evaluation process, and only if the requisites are met, the assessment and grading procedures are executed and left in a Draft state. These procedures are automatic and consist of a set of tests executed through the network: VMs starting, network connectivity tests, remote connection and information gathering and VM shut down.

Once the assessment is in Draft state, the instructor has a few options available before sending the results to the student. The results can be pre-viewed in the same format that the student will see so it can be checked that the assessment is correct (action "Ver" in Fig. 5). The "Logs" action shows the complete assessment data, the instructor can analyse the results of individual tasks and include personalized comments for the students so they can fix possible errors in the tasks. In any case, the student will get standard comments generated by the automatic assessment procedures. The instructor can also delete any assessment.

Finally, the instructor will publish the student's assessment result and it will be notified to the student by e-mail. At this point, the student maight check the instructor's comments and can make another improved submission of the lab project. The same applies to all the labs in the course.

## IV. Analysis of Results

We are now able to answer the main questions motivating this activity, as commented in the introduction.


Fig. 4. Lab 1 requisites checking from the studen's menu.

Regarding the teaching methodology, it can be concluded that roughly the same methodology have been used because the technical changes introduced have made it possible to assess a high number of students remotely. Both students and instructors had the VMs available remotely all the time so the student could advance in the project and the instructor could provide the needed support.

In addition, this alternative has incorporate some advantages with respect the previous virtualization technology in use (*VirtualBox*): 1) students do not need to care about their own VMs any more, 2) work lost due to problems with VM export and import have been eliminated, 3) backup copies are integrated in the virtualization environment, 4) the problem of that were not able to execute the VMs in their own computers because a lack of resources has been eliminated, and 5) the students can work in their projects remotely as long as they have an Internet connection.

Nonetheless, the new environment also presents some inconveniences: 1) a working Internet connection is necessary all the time, but no problem about it has been reported by the students so far, 2) the virtualization environment is a centralised service that can become unavailable by a number of reasons, stopping the work of all students, but the downtime of the system have had a negligible impact in the course development so far, and 3) if more courses start using the VM cluster, its resources may become saturated, which can be solved by adding more resources to the existing servers of installing additional physical machines.

The answer to the question about if the same projects previously done on-site can be done on-line, the answer is affirmative and only minor changes have had to be made to the lab manuals previously used by the students.

With respect the evaluation system, the same one used previously have been basically preserved. In fact, it has been improved since the automatic tests provides results much faster than the previous personal interview with the instructor, much more evidence about the student's work is now collected, the assessment is more detailed now and the instructor can provide any feedback in a personalised way if necessary as before.

## V. Conclusions

In summary, we can conclude that the methodology based in virtualization environments and the application of a web as-


Fig. 5. Lab 1 assessment from the instructor's menu.

sessment platform has been successful because it has improved the evaluation process when passing to an on-line teaching mode, while preserving these advantage after returning to the on-site mode. In addition, the new methodology has introduced important improvements like the recording of all the evaluation data, that can be exported conveniently in a platform-independent format, in case it is required by teaching evaluation agents, for example.

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