Sharing the remote laboratories among different institutions: a practical case

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***Abstract*— The interest on educational remote laboratories has increased, as have the technologies involved in their development and deployment. These laboratories enable students to use real equipment located in the university from the Internet. This way, students can extend their personal learning experience by testing with real equipment what they are studying at home, or performing hands-on-lab sessions at night, on weekends or whenever the traditional laboratories are physically closed. A unique feature of remote laboratories when compared to traditional laboratories is that the distance of the student is not an issue, so remote laboratories can be shared with other schools or universities. In this contribution, authors present and discuss a widely spread remote laboratory (VISIR, present in 6 european universities + 1 in India) shared among 3 institutions (2 universities + 1 high school). During the exhibition, demonstration of the laboratories being shared will be shown.**

***Index Terms*— visir, federation, remote laboratories**

I. INTRODUCTION

A unique feature of remote laboratories when compared to traditional laboratories is that the distance of the student is not an issue, so remote laboratories can be shared with other schools or universities.

In this sense, MIT iLabs have been effectively sharing remote laboratories around the world for years. Different universities can use the MIT iLabs framework to develop, maintain and share their remote laboratories with other universities. In the federation model defined by the iLabs Shared Architecture (ISA), there are two types of remote laboratories that can be shared: batch laboratories (using queues) and interactive laboratories (using a calendar-based booking system).

The architecture behind this mature system lacks of two features relevant for this contribution: 1) load balance among different copies of a remote laboratory and 2) transitive sharing.

The first feature refers to the fact that behind every remote laboratory there is a physical hardware, which is usually the bottleneck for many concurrent students using the same hardware. If the provider university replicated this hardware (for instance, having 4 copies of an electronics board instead of 1), the load of users could be balanced among all the copies. Furthermore, if two universities have two copies of this hardware, it could be possible to first use the local resources and only if all the local resources were busy. This could be called federated load balance.

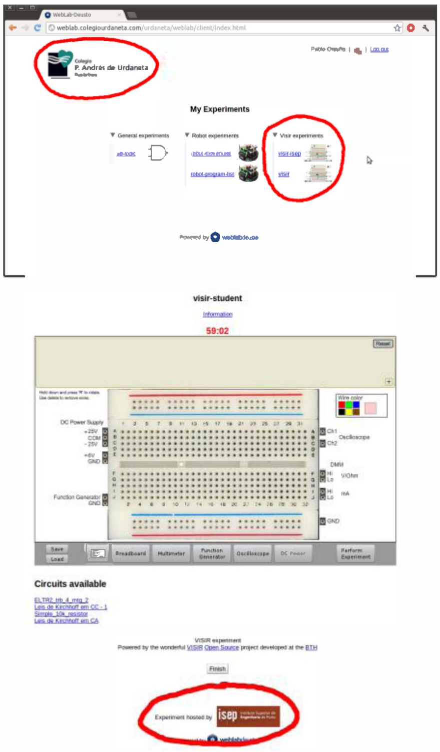

Figure 1 Screenshots of a secondary school (top) consuming a laboratory located in other university (bottom)

The second feature (transitive sharing) refers to the capability of re-sharing a remote laboratory to a third university. For instance, one university could share 10,000 accesses to other university, and this other university could split these 10,000 accesses on two: the first 7,000 are only for their students and the other 3,000 could be re-shared to a third university interested in consuming that laboratory. This would work in the same way a real market works, with prices adapting to the offer, demand and requested quality of service.

In this contribution, the open source WebLab-Deusto framework, which supports both features, is presented and analysed for a particular case of study: the VISIR remote laboratory.

II. BACKGROUND CONCEPTS

This section summarizes the underlying concepts.

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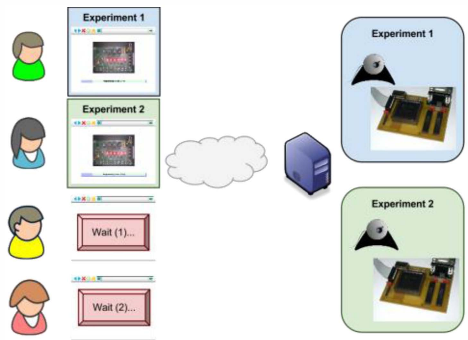

Figure 1 Load balancing

Figure 2 Load balancing

A. Remote Laboratory Management Systems

Many of the features developed in a remote laboratory (authentication, authorization, scheduling, user tracking...) are reusable from one remote laboratory to other. Due to this reason, information systems that provide these services have been created. As already mentioned, examples of these systems are: MIT iLabs, Labshare Sahara and WebLab-Deusto. These systems are independent of a particular setting, so they may be refered as general purpose remote laboratories in contrast to specific purpose remote laboratories. However, given that most of their work is adding management layers, these systems will be refered as Remote Laboratory Management Systems (RLMS). RLMSs come with guidelines and software development toolkits to develop remote experiments. This way, RLMSs speed up the development process of remote laboratories: teachers aiming to create a remote laboratory do not need to work on scheduling, authentication, authorization, etc. but focus on making the experiment available through the Internet. Additionally, RLMSs provide administration tools, so teachers can use them to add students, grant permissions on certain laboratories, track students, etc. The advantage of embracing these systems is that once they add a new transversal feature, all the experiments developed with that RLMS will automatically have it. For instance, if a RLMS did not support LDAP (a directory protocol common in universities which is used to authenticate and authorize users), and in the next release it supports it, automatically all the experiments developed with that RLMS will support it. Indeed, this flexibility of RLMSs is interesting enough to create efforts to integrate existing remote laboratories on RLMSs. For instance, in [5], the VISIR remote laboratory is integrated in MIT iLabs, or in [4] it is integrated in WebLab-Deusto.

One of the things that RLMSs make experiment development easier is scheduling. There are two main approaches: queueing or calendar-based booking. Nowadays, the iLab RLMS supports queueing for batch laboratories and booking for interactive laboratories. Labshare Sahara supports both booking and queueing for the interactive laboratories. WebLab-Deusto supports queueing for both interactive and batch laboratories. In any case, the concept of granting exclusive access to a laboratory for a certain amount of time persists in every RLMS. In order to offer more available slots in the calendar or to make the queue move faster, the load of users can be balanced among different copies of the experiment, as long as the experiment costs makes this possible. Figure 2 represents this concept: a RLMS is managing two copies of the same experiment, and four students attempt to use it, so the first two users will use the experiment, and the other two will wait in a common queue. This feature, called local load balance, is implemented in both Labshare Sahara and WebLab-Deusto.

B. Remote Laboratory federations

A unique characteristic of remote laboratories when compared to traditional laboratories is that the distance of the student to the real equipment is not an issue, so remote laboratories can be shared with other institutions. One entity can share a laboratory to other entity. We refer to entities rather than universities since they do not need to be universities: research centers may be interested in sharing local resources as part of an agreement, and secondary chools would reasonably be consumers.

This sharing can be managed in a direct, simple way: the provider entity (the one where the equipment is located) creates accounts of users of the consumer entity (the one interested in using the provider university's equipment for their students). Students of the consumer entity directly access in the provider entity and the provider entity does all the work: it authenticates the user, authorizes him to use the laboratory and provides the laboratory.

There are multiple problems with this solution. First, the provider entity must create and manage the user accounts of all the interested consumer universities. In a complex scenario, where a wide variety of consumers are involved -such as foreign universities and even secondary schools that simply do not speak the provider entity's language-, this approach does not scale. Second, the management of this approach is cumbersome: consumer universities would need to notify providers every change, and local databases or protocols such as LDAP would not be available. Third, the consumer entity cannot carry a proper accounting of the uses performed: it must trust the provider entity.

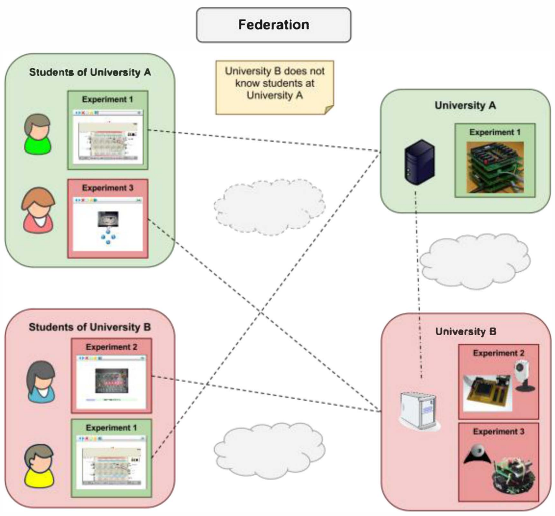

Figure 3 Federation

Figure 4 Robot experiment in WebLab-Deusto

If both institutions come to an agreement where users of the consumer entity can access up to 10,000 times, there will be no way for the consumer entity to audit this if the provider entity at some point says “you have already reached the limit".

In order to handle these and other problems, a two-side model is required (see Figure 3), where both universities have the same software framework that manages this sharing. The consumer entity can authenticate and authorize local students, and once authorized, the local framework will contact the provider entity and request a slot. This way, the provider entity does not need to manage students and courses of the consumer entity, and the consumer entity can track all the requests performed to the provider entity, being able to track students and audit the overall use. In this sense, MIT iLabs have been effectively sharing remote laboratories around the world for years [1]. Different universities can use the MIT iLabs framework to develop, maintain and share their remote laboratories with other universities. In the federation model defined by the iLabs Shared Architecture (ISA), two types of remote laboratories can be shared: batch laboratories (using queues) and interactive laboratories (using a calendar-based booking system).

C. WebLab-Deusto

WebLab-Deusto is an open source Remote Laboratory Management System, developed in the University of Deusto, and built on top of open source technologies. It has been used by students as part of their courses since February 2005 through different versions. On top of it, teachers can develop remote laboratories, benefitting from all the features provided by the system, and then deploy them in their university. Furthermore, they can even share these laboratories with other WebLab-Deusto instances deployed in other universities or secondary schools.

A detailed description of the features of WebLab-Deusto has already been addressed in the literature [4]. They can be summarized in that it manages authentication (checking if the user is who claims to be), authorization (establishing who is granted to use which laboratories), scheduling (enqueuing the users among the copies of the laboratories available) user tracking (reporting who used what) and sharing (enabling other WebLab-Deusto instances to use certain laboratories).

As Figure 5 shows, WebLab-Deusto uses a layered architecture. Students connect to the core servers, which manage the transversal features, and these servers finally rely on a set of experiment servers that could be spread the campus. There are two approaches for developing laboratories in WebLab-Deusto: using managed experiments and using unmanaged experiments. In the former, the communication is managed by WebLab-Deusto, so it is secured and tracked by the system. However, it must be based on exchanging messages, and since this is not always possible (with protocols such as Remote Desktop, VNC or LabVIEW Remote Panels), WebLab-Deusto supports unmanaged experiments. On these experiments, the communication with the Experiment Server is direct, avoiding latency but decreasing the level of security and user tracking.

As seen on Figure 6, it has been deployed in different educative institutions apart from the University of Deusto.

III. CASE OF STUDY: SHARING VISIR

The VISIR remote laboratory is an electronics remote laboratory, deployed in 7 different universities. One of the most interesting features of this laboratory is that it supports concurrent students using independent sessions. This means that, given that each access is very fast (tenths

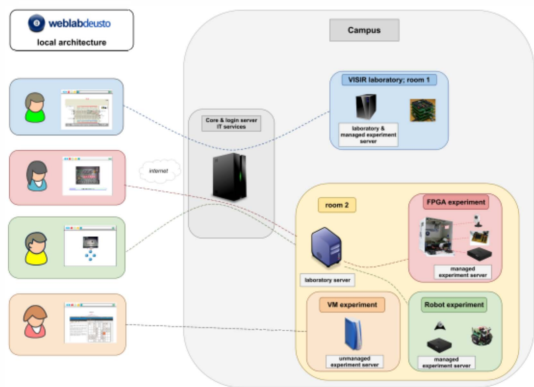

Figure 5 Local architecture of WebLab-Deusto

of second), the accesses are multiplexed with relays, so final users do not realize that other users are using the same equipment.

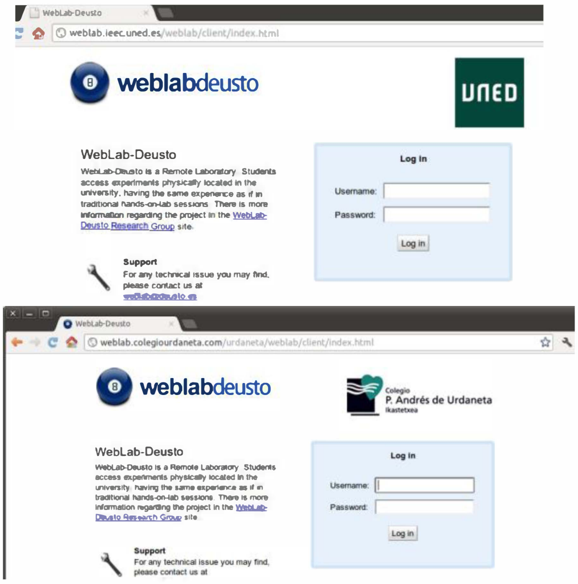

Figure 6 Different independent instances of WebLab-Deusto

In the University of Deusto, authors use it regularly with up to 60 users through WebLab-Deusto[1]. If more students aimed to access, WebLab-Deusto would create a queue so they will enter whenever some current students log out or their assigned time passes.

Other VISIR is deployed in Polytechnic Institute of Porto - School of Engineering (ISEP), and one WebLab-Deusto instance has been deployed in the University of Deusto configured to access the VISIR at ISEP[2]. This WebLab-Deusto instance could technically be deployed in ISEP, but this contribution only presents a proof of concept. Finally, there is a high school (Colegio Urdaneta) has also deployed WebLab-Deusto[3], but they do not have any VISIR deployed, becoming a consumer-only institution.

Given the described features of WebLab-Deusto, the following schemes can be used:

1. Any student (of ISEP, Deusto or the high school) can access the VISIR at Deusto for a particular configuration only available in Deusto.

2. Any student (of ISEP, Deusto or the high school) can access the VISIR at ISEP for a particular configuration only available in ISEP. ISEP does not need to know the high school thanks to the transitive sharing, since ISEP can share VISIR to Deusto and Deusto re-share it to the high school.

3. Any student (of ISEP, Deusto or the high school) can access any of the two VISIR equipments for a particular configuration available in both VISIR equipments. For instance, if 90 students were attempting to use the system, 60 could be using one VISIR system and the other 30 the other VISIR system.

[1] https://www.weblab.deusto.es/weblab/

[2] https://www.weblab.deusto.es/isep/

[3] http://weblab.colegiourdaneta.com

Indeed, in the theorical situation that the 6 european universities hosting VISIR systems would share them in the described way, it would be possible to support 6 different configuration with 60 users each, or 3 different configurations with up to 120 users each, or even a single configuration with 360 users.

IV. Conclusions and Future Work

This contribution describes the federation capabilities of WebLab-Deusto and how they can contribute to the VISIR community in sharing it efficiently under different constraints both with other partners as well as with other universities which are not part of the VISIR community. In the same direction, it is possible to use this system and community to launch other remote laboratories that have been integrated in WebLab-Deusto.

Regarding future work, a detailed evaluation measuring times in this federation environment should be built, stress testing the system. It would also be useful to have a formal nomenclature to describe these situations.

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