Design of a Latin American and Caribbean Remote Laboratories Network

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Abstract **— Recent advances in technology have allowed the development of laboratory experiments that do not require the physical presence of a student in a physical laboratory. These experiments are conducted using the internet, using simulation, or actual control and monitoring of real equipment located remotely, or a hybrid of both. This allows potential sharing of resources that could result in reduction in budgets for equipment, personnel and brick-and-mortal space. Remote labs can facilitate offering lab courses online. Besides the technical challenges, there are safety, security, connectivity and scheduling concerns. The IEEE Education Society has formed a Working Group that is developing the Standard for Networked Smart Learning Objects for Online Laboratories (IEEE-SA P1876). Once the standard is adopted, there will be more opportunities to connect resources among universities, potentially producing distributed online laboratories. This paper looks at the design of a network of remote laboratories for Latin America and the Caribbean (LAC). The LAC regions adds to the complexity of the proposed network because of its great diversity. Languages, educational systems, academic schedules, time zones are just some of the aspects in which the diversity is appreciable. This creates a challenging environment to develop collaborative strategies which generate benefits to all. The Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) is participating in the IEEE P1876 Standard Working Group; with plans to develop a Remote Laboratories Network for the LAC region, collaborating under the Engineering for the Americas initiative and the OAS Ministers of Science and Technology's Working Group 2: Human Capacity Building and Education. This paper presents some existing networks in the region, and proposes a general design and architecture specification of administrative and technical aspects for the LACCEI network for remote laboratories.**

Keywords –e-Learning Standards, Engineering for the Americas, STEM Education, Remote Laboratories, UML Models

I. INTRODUCTION

The internet infrastructure and remote access and control of equipment allow the establishment of networks of distributed remote laboratories for science and technology, which in turn allows K-12 and higher educational institutions to collaborate in regional projects and to share their laboratory resources and learning materials. Implementing networks of remote laboratories for science and technology topics, such as physics or electronics, would require collaborations among the faculty in the network to develop remote experiments and supporting learning materials and give access to students to equipment not available at their institution. This should result in more exciting experiments for students and could potentially motivate them to pursue careers related with science and technology. This paper shows the general design and the architecture specification of administrative and technical aspects for the creation of a remote laboratories regional network.

II. BACKGROUND

Remote laboratories have benefited from the advances in technology during the last decade, such as processing speed, video codification algorithms, better controllers and hardware devices [1], new cloud repositories [2] and the increase of the bandwidth, guaranteeing reliability, stability and adequate response times during experimentation. Cloud services allow configurations of laboratory as a service (LaaS) [3, 4] simplifying the administration of the laboratories provided by companies, research and laboratory centers, and allowing configuration of experiments that satisfy different needs.

Regardless of the technological advances, there still exist a lack of standard definition in terms of access, operation, security, among others. To try to solve the standardization problem, the Education Society of the Institute of Electrical and Electronic Engineers (IEEE), proposed to the IEEE Standards Association (SA) the formation of IEEE-SA P1876 Working Group (Standard for Networked Smart Learning Objects for Online Laboratories) [5] to develop the standard that will define the architectures and implementation processes.

III. MOTIVATION

Currently, most educational institutions have their own independent physical laboratories with their respective equipment. Some of the main problems of this independence are: the costs of equipment acquisition, maintenance and upgrade; of personnel

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needed to maintain, secure, and supervise the laboratory; of building and maintaining the physical space that houses the laboratory. These laboratories commonly are unused for long periods of time. There is an increased demand for e-Learning classes, and the classes with laboratories are normally not available in this format. The Massively Open Online Courses (MOOCs) are growing in popularity and need alternatives that can accommodate the 24x7 flexibility required by these students. Online laboratories hold great promise in reducing the cost of laboratory courses yet providing the flexibility and access to shared distributed equipment.

In the case of Latin American and Caribbean institutions, due to their limited budget, especially for the public institutions, many of the Electronics, Physics and Chemistry courses are taught just with the theoretical concepts or with a very limited part of the experimentation. This problem can be mitigated in part using remote laboratories that allow institutions to connect remotely to other institution of the same country, region or even in another continent.

The Latin American and Caribbean Consortium for Engineering Institutions (LACCEI) [6] has been working during the las 14 years to generate collaboration in engineering education initiatives between Latin American and Caribbean universities. It works with the Ministers of Science and Technology of the 34 countries members of the Organization of American States (OAS) with the charge of launching and leading educational innovation under the Engineering for the Americas initiative and the OAS Working Group 2: Human Capacity Building and Education. One of the more recent initiatives of LACCEI is to create an open multi-language network of remote laboratories for Latin American and Caribbean institutions to centralize the access and optimize finding and using of the available shared resources and educational materials. To this end, LACCEI representatives actively participate3 in the IEEE-SA P1865 Standard Working Group. This paper focuses on the general architecture LACCEI is developing, and presents technical aspects of the models for laboratory classification and roles of collaboration using remote laboratories. This can be useful in building the standard, and also provide documentation for developers and users in the academic context.

IV. LABORATORY TAXONOMIES AND EXISTING LATIN AMERICAN NETWORKS

The proposed UML model describing the taxonomy of laboratories are shown in Figure 1. Laboratories can be Physical Laboratories, or Online laboratories, or a Hybrid combination of Physical and Online Laboratories. Remote laboratories are a type of online laboratories, as are Virtual laboratories. Remote laboratories consists in the use of real physical equipment connected to a network that can be controlled remotely [7]. Hybrid configurations are a mix of Physical and Online laboratories, or a mix between Remote and Virtual laboratories.

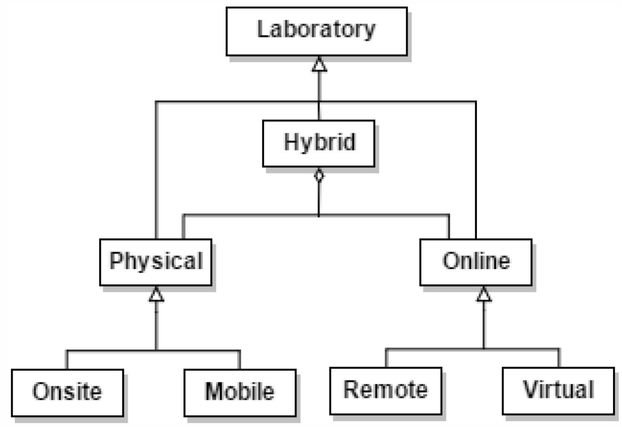

Figure 1. Proposed UML Model of laboratory taxonomy [8]

Some initiatives have been developed in Latin America and Caribbean. For example the network RedCLARA [9] is an international organization whose goal is to connect Latin America's academic computer networks. They have the participation of institutions in 13 Latin America countries, and are connected with the United States Internet2 [10], a network that connects research, academia, industry and government institutions. This network is also connected with the Latin American Interconnect with Europe (ALICE, for its acronym in Spanish) [11], which is a project co-funded by the European Commission and Latin American countries, created to stimulate the creation and development of the Information Society in Latin America. The third connection is with the European Network (GÉANT)[12]. RedCLARA has offices in Tijuana, Miami, Panama City, Sao Paulo, Santiago de Chile and Buenos Aires. Their current network topology is presented in the figure 2.

Figure 2. RedCLARA International network of Latin American academic computer networks. Source: [9]

In Colombia, the Minister of Education created the initiative RENATA e-lab [13] "Network of Remote Laboratories and tele operated of Colombia", this is a national network of remote laboratories. Annually institutions can participate to receive funding for developing their network infrastructure and remote laboratories technology to make their labs able for remote access through this national network. RENATA e-lab is part of the RedCLARA network which centralizes the laboratory access and provides interfaces to manage the schedules for the periods of experimentation.

Figure 3. RENATA e-lab "Network of Remote Laboratories and tele operated of Colombia." Source:[13].

V. PROPOSED ARCHITECTURE FOR A REMOTE LABORATORIES NETWORK

This section develops an architecture for a network of distributed remote laboratories, the architecture elements expands and includes some of the elements proposed by Tawfik, Salzmann, Gillet and Lowe, who proposed delivering remote labs using Laboratory as a Service (LaaS) approach [14].

The proposed architecture model for the Regional Remote Laboratories network is a service oriented architecture (SOA) with five layers. The first layer is the user layer, it gives users the interface to interact with the remote laboratories. The user layer includes interfaces for all types of users, such as administrators, teachers and students.

The second layer include the processes required for user management and those required for the remote laboratories management. Every process is composed of one or more services described in the next layer.

The third layer is the services layer which includes atomic functions implemented to support the operation of the remote laboratories. The interaction of these services makes accomplishing the process possible. Examples of the services are: in the case of the management user process:

- Authenticate users
- Validate the authorization rights
- Open and close session.

In the case of the remote lab management, examples are:

- Check the schedule
- Reserve the remote lab
- Check the availability of resources
- Create, update or remove a specific resource (remote lab).

The fourth layer is the logic level. It is responsible for providing support for the service execution and includes all the software support for communications, security, the general operation management, application servers, and operating system that make possible the operation of the upper layers.

The bottom layer is the data storage and infrastructure layer. This contains all the support for the databases, network connections and network devices. Additionally it supports control and interface connections with the laboratory equipment. The main benefit of this layered architecture is that it allows making changes or upgrades to one layer without affect the top layers.

Finally the architecture implements 3 orthogonal components which are security, communications and operational management. These are important in all levels of the architecture, see figure 4.

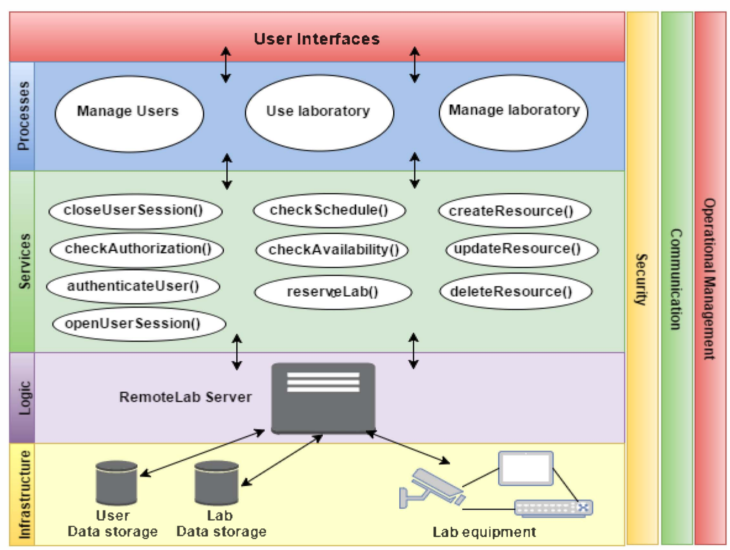

Figure 4. Proposed SOA General Architecture

The remote laboratories can be integrated to the learning environments, such as Learning Management Systems (LMS) [15, 16] and also to the educational standards [17] to integrate the remote laboratory servers and the learning environment. For that purpose two standards have been developed.

The first is learning tools Interoperability (LTI) [18]. This standard provides an XML interface for the applications connection, in this case the remote lab has an interface in the LMS, giving the user the feeling of having all the resources in the same interface. The second standard is xAPI [19], it is also known as the Tin Can API, or experience API, it is an e-learning software specification that allows learning systems or general purpose applications to communicate with each other in order to record and track the experiences, in this case learning experiences, allowing the development learning analytics.

The students will have available the laboratory access inside a learning unit for their course within the LMS using LTI standard, and in this case, within a scheduled class meeting. Access to the laboratory experiments should be configured previously by the teacher for the students in the course. During the session of experimentation with the laboratory all important interactions (from the point of view of the teacher), will be stored in the Learner Record Store (LRS) system. Students also can find in the same learning environment, the laboratory guide with instructions to perform the experiment and to make the report with the results of the experimentation process.

The following class diagram, figure 5, shows the classes of the remote laboratories network in the software level. It shows how the users, which in the case are students teacher and administrators of the Latin American and Caribbean universities, can interact with the remote laboratories available in the network through an LMS platform using the standards or simply connecting directly to the service.

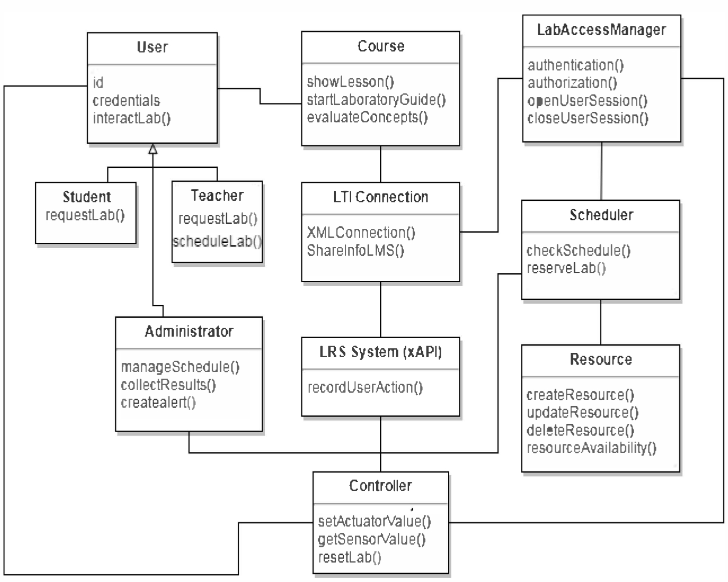

Figure 5. Proposed Class Model

CONCLUSIONS AND FUTURE WORK

The establishment of a strong regional network for the development of remote laboratories and resources in STEM can help poor or remote communities to have access, not only to the theoretical information available in books and in the web, but also to have the opportunity of experimenting with the latest technology available. This provides equity of access and inclusion in innovation.

Previous initiatives have not been very successful because of lack of standards to scale up remote For the user management this architecture implements the access control using Role Based Access Control (RBAC) having three main roles: administrators, teacher and student, in the case of administrators, they have the control of the platform, update the schedules, report changes about availability of the resources, and create maintenance and security alerts. In the case of the teacher, they are responsible for the administration of the course, and are the only one that have the possibility of requesting and scheduling resources (experiments), as well as enabling access to resource for the students. Teachers also can assign different roles to every member of a group of students to use one remote laboratory in a collaborative way.

Laboratories and because of a lack of funding by government agencies. LACCEI provides an opportunity to catalyze the efforts and resources of the LACCEI member institution and to take advantage of the experience of leading initiative with the collaboration of a multinational governmental organization, such as the OAS, and its Ministers of Science and Technology. Currently few countries in Latin America and Caribbean have a national network for the development of remote laboratories, this is something that LACCEI can help to promote by taking advantage of the relationship with more than 150 institution in the region associated with LACCEI.

The future work includes: the implementation of a functional prototype that can be used as an experimentation scenario. For that purpose we are going to invite a group of Latin American and Caribbean engineering institution that want to participate of the first pilot of this regional network.

The integration of this initiative with other global initiatives in Europe, United States and Asia will allow this network to take advantage of the time differences between regions, to use the resources and personnel supervising safety and security of the laboratories 24x7.

REFERENCES

[1] Salzmann, C.; Govaerts, S.; Halimi, W.; Gillet, D., "Smart Device Specification for Remote Labs", International Journal of Online Engineering, 11(4): 20 August 2015, pp. 20-29. DOI: 10.3991/ijoe.v11i4.4571

[2] Zutin, D.G.; Auer, M.E., Maier, C.; Niederstatter, M., "Lab2go – A repository to locate educational online laboratories," IEEE Educon Education Engineering 2010: The Future of Global Learning Engineering Education, Madrid, Spain, 14-16 April 2010, IEEE, pp. 1741-1746. DOI: 978-1-4244-6571-1/10.

[3] Tawfik, M.; Salzmann, C.; Gillet, D.; Lowe, D.; Saliah-Hassane, H.; Sancristobal; E.; Castro, M., “Laboratory as a Service (LaaS): A Novel Paradigm for Developing and Implementing Modular Remote Laboratories,” International Journal of Online Engineering 10(4): 13 June 2014. DOI: 10.3991/ijoe.v10i4.3654

[4] Tawfik, M.; Salzmann, C.; Sancristobal, E.; Ros, S.; Hernandez, R.; Robles, A.; Caminero, A.; Tobarra, L.; Latorre, M.; Garcia-Loro, F.; Carro, G.; Diaz, G.; Castro, M. "Middleware solutions for service-oriented remote laboratories: A review", Global Engineering Education Conference (EDUCON), 2014 IEEE, pp: 74 – 82.

[5] Saliah, Hassane, H., et al. “IEEE Education Society Standards Committee Report,” presented at the Frontiers in Education Conference, El Paso, Texas, USA, 20-23 October 2015, IEEE. Available online: http://ieee-edusociety.org/sites/ieeeedusociety.org/files/Standards%20Committee%20-%20EdSocStandardsReport1015.pdf

[6] LACCEI The Latin American and Caribbean Consortium for Engineering Institutions (Online): http://www.LACCEI.org/

[7] Callaghan, Harkin, Maguire (2007). "Paradigms in Remote Experimentation”, International Journal of Online Engineering (iJOE), Vol 3, No 4 (2007)

[8] Zapata-Rivera, L.F., Larrondo-Petrie, M. M. “Models of Remote Laboratories and Collaborative Roles for Learning Environments ". 11th international Conference on Remote Engineering and Virtual Instrumentation (REV) 2016.

[9] 8624 http://www.redclara.net/index.php/en/

[10] Internet2 Community. (Online): http://www.internet2.edu/about-us/

[11] ALICE (Online): http://alice1.archive.dante.net/

[12] GÉANT community (Online): http://www.geant.org/

[13] Renata e-Lab Red de laboratorios virtuales y teleoperados de Colombia (Online): https://www.renata.edu.co/index.php/comunidades-renata

[14] Tawfik, M., (2014) "Laboratory as a Service (LaaS): A model for developing and implementing remote laboratories as modular components". 11th international Conference on Remote Engineering and Virtual Instrumentation (REV) 2014.

[15] Moore, M.; Kearsley, G., Distance education: A systems view. CA: Wadsworth Publishing, 1996.

[16] Carlson, P., Advanced Educational Technologies – Promise and Puzzlement. Journal of Universal Computer Science, 4(3), 210-215, 1998.

[17] IMS Global Learning Consortium. (Online): https://www.imsglobal.org/

[18] Learning Tools Interoperability LTI, IMS Global Learning Consortium. (Online):https://www.imsglobal.org/activity/learning-tools-interoperability

[19] Experience API - TinCanAPI. (Online): http://tincanapi.com/