AC 2012-3678: A GRID OF ONLINE LABORATORIES BASED ON THE ILAB SHARED ARCHITECTURE

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A Grid of Online Laboratories Based on the iLab Shared Architecture

Abstract

Active learning or working by means of online laboratories is especially valuable for distance working or education. Users in the workplace can access remote laboratories without having to travel. This flexibility is important for teleworking, education and lifelong learning.
The implementation and maintenance of online labs is expensive and partially associated with high administrative efforts. These are reasons, why sharing online lab resources via different universities worldwide is a current necessity. Therefore we started at the Carinthia University of Applied Sciences together with partners a project to establish a network of interconnected online laboratories in Europe and, in a second stage, worldwide. This network is based on MIT's iLab Shared Architecture (ISA). ISA is a software architecture that offers online laboratory developers and users a common framework for using and sharing online laboratories.

Introduction

Online laboratories are necessary for distance or mobile learning for the same reason laboratory practices are important in traditional educational scenarios. Learners can acquire theoretical knowledge and experience by manipulating or viewing the behavior of real world phenomena.

Online engineering laboratory practice can be delivered by means of online laboratories that permit workers to access knowledge and experience from remote colleagues or institutions who share similar problems. In this way, an individual problem can become a shared problem to be resolved with the experience of homologues for different places. Among other things, remote laboratories are important because they provide real-world results, not simply knowledge or resources. Persons using remote lab resources can view how objects actually behave under a certain set of circumstances, providing them with a better insight as to what needs to be done. Online engineering in the workplace is becoming increasingly important because of the growing complexity of engineering tasks, the need to share resources among different companies (equipment, simulators etc), especially for short-term trouble shooting that does not warrant the purchase of equipment, the potential collaboration among workers in different companies who share the same problems and can contribute to collaborative solutions, the increased linkage among SMEs and larger enterprises, etc.[1]

Also, importantly, online laboratories offer the additional advantage of not being subject to the limitations imposed by time and location, as persons can synchronously collaborate, experience, and obtain results in a collaborative synchronous manner. This, along with expanded access to broadband internet, is transforming the way e-learning is carried out, allowing increased levels of interactivity and providing virtual environments closer to real ones. Virtual environments provide the opportunity for students to freely practice various scenarios in quick succession without the fear of actually damaging resources, which often hinders real-life practice. This 'safe' way of gaining practice also encourages initiative, experimentation and creativity as students do not have to face real-world practical restraints.

Learning in Online Laboratories

Synchronous active interaction with experiments and problem-solving helps individual or collaborative learners directly acquire applicable knowledge that can be used in practical situations, which is why pedagogical theory and practice considers laboratory experimentation an essential part of the educational process, particularly in the sciences and engineering. Synchronous interaction is also important because it provides immediate feedback so that students can interact with experiments in real-time, thus obtaining numerous potential results, instead of running one experiment and waiting for the results at a later time.

Online (Remote) laboratories make all this shared use available via the internet and are becoming increasingly important applications in the new domain of Online Engineering.

Online Engineering can be defined as an interdisciplinary field utilizing the areas of engineering, computing and telematics, where specific engineering activities like programming, design, control, observation, measuring, sensing, and maintenance are provided to both remote and local users in a live interactive setting over a distributed, physically-dispersed network (for example: an intranet or the internet).

The availability of high bandwidth internet connections world-wide and other derivative capabilities in the areas of real-time communication, control, teleconferencing, video streaming and others have made multi-site collaborative work, utilizing state-of-the art equipment in remote laboratories across the globe a current reality.

Learning situations in laboratories can be highly complex, although they have the advantage of usually being well structured. How the particular experiments and learning strategies of specific practices provided in laboratories must be tailored to the knowledge students possess in the theoretical realm and in function of the abilities and competences that are explicitly stated in educational objectives of each individual practice. Although self-directed learning is the most common learning strategy used, a mix of self-directed and collaborative learning is also very common. It is important to mention that this mix in learning strategies is important as it favors both field independent and field dependent learning styles respectively.

The iLab Shared Architecture

It is still difficult to share instrumentation and experiments among laboratories. Each one has its own security policy and adopts an own technology for accessing and controlling real devices. A common integrated framework, offering indexing facilities, unique logins, file sharing and the seamless access and run of experiments, is the main challenge in order to create a network of online laboratories. Grid technologies can be used to set up an effective network of remote laboratories for education purposes by sharing instrumentation and resources. However, the evolution of remote laboratories from the current client/server architecture to grid-based architecture requires well-defined tools for location, security, and integration of resources, and further research is currently being conducted to examine this issue.[2-4]

As Universities and other institutions are likely to develop their own solutions and standards to deliver online laboratories to their users, no trend to a unique standard is observed, creating an obstacle against sharing these online labs. Considering the current scenario, a migration towards

standardized solutions for delivering online labs becomes necessary to ensure software reusability and therefore facilitate online labs development and sharing.
At this point, the ISA (iLabs Shared Architecture) comes into play. ISA is a software architecture developed at the MIT (Massachusetts Institute of Technology) that facilitates a cross institution sharing and management of online labs. ISA provides a framework for the maintenance of a lab session, lab users management and experiment data storage. It establishes clear rules governing the communication between clients and their respective online lab servers by means of an API (Application programming Interface) based on Web services SOAP calls.
ISA proposes a classification for online experiments. On one side there are the batched experiments and on the other the interactive experiments. Batched experiments are those in which all parameters necessary to run it are specified before execution. On interactive experiments, the course of the execution can be changed at any time by the user.

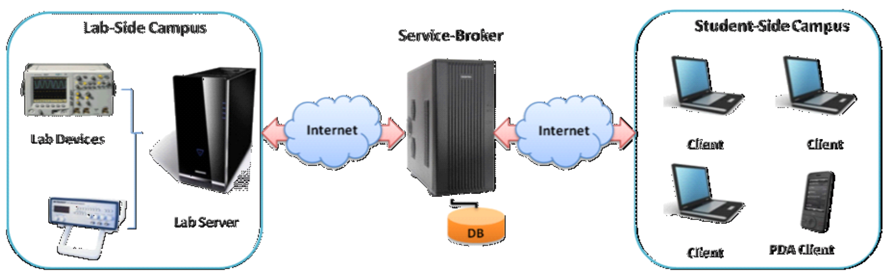

Figure 01. The iLab Shared Architecture

In this architecture the communication between clients and laboratory is mediated by a middleware server (Service Broker), a Web application that manages users' accounts, data storage and can provide different clients with access to several different lab servers in a "many to several" mode and delegates to experiment server only the experiment execution.
The interface that provides the communication between clients with service broker and service broker with lab servers is implemented with Web services, and is therefore platform independent. That means that clients and lab servers can be developed in any platform supporting Web services.

The iLab Europe Initiative

The iLab Europe started as an initiative from "Carinthia University of Applied Sciences" and counts now with six partners throughout Europe who agreed to share their online experiments within the network. The software architecture used to maintain the lab sessions as well as scheduling service and experiment data storage is the iLab Shared Architecture (ISA) described in the previous section. ISA has an important characteristic namely its distributed topology what made it the ideal solution for the implementation of such a network of interconnected online experiment.

ISA has already built in mechanisms that allow to setup trusted connections between its autonomous network nodes (service brokers) so that online laboratories can be seamlessly shared between them. This means that the institutions are free to manage their own online laboratories and their own user accounts and deliver these labs via their own server. In this way, access for their users to their own labs does not depend on the status of other service broker. In the other hand in order to be able to use labs from other universities a user has to authenticate himself in the main service broker as depicted in Figure 2.   Each institution member of the network is expected to setup one service broker and deliver at least one experiment via this server. This means that from a pool of labs available at one institution it is up to them to decide which labs will be available to the other members of the network.

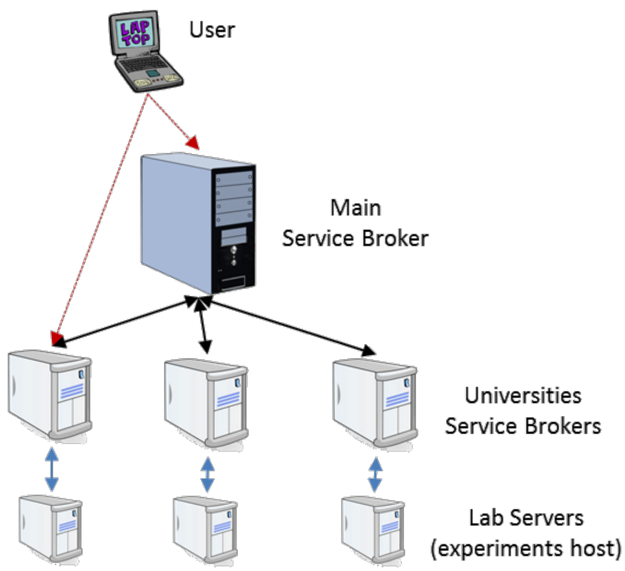

Figure 2. iLab Europe network topology

The topology presented in Figure 2 was chosen because, in this first stage of implementation, it seemed to be the most suitable one from the network management point of view. It is a general consensus that online laboratory providers should manage their own labs and their own users. A user can access the online laboratories available at his/her institution either by authenticating himself in the main service broker or in his institution's service broker. In this way each service broker from an institution can be considered a subset of the whole iLab-Europe experiment poll.

In spite of all the efforts and the technology available, the idea of sharing remote or online laboratories has still to mature. If in one hand it is very appealing, on the other it might be complicated to setup all the policies to share these online labs. These constraints are not related to the technical aspects associated to the practice of sharing labs as a number of software architecture focus in providing services for online lab users already address these issues. The constraints lie in the lack of an economy of online laboratories and a business model to govern the practice of a cross institution sharing of labs considering implementation and equipment maintenance costs.

The iLab-Europe network is, in this context, a step towards a broader usage and dissemination of online laboratories and helped to raise the issues that must be addressed for the implementation of a more efficient model to govern the practice of sharing labs in a cross institution basis. It has

shown that the administrative efforts are high and it assumes the adoption of a specific technology by the different online lab providers.
The efforts for the future will be to implement a network with such autonomous nodes as a peer-to-peer architecture, however to some extent. Administrators of each node should be able to decide which resources will be available for others and at which costs, provided that an agreed business model exists. The client-server model should still be maintained for users to carry out experiments and for any other communication between the lab servers and laboratory client (user).
In the proposed architecture each node should manage its own users. This means that the user database will be maintained distributed one. Authentication is necessary only once in one of the network nodes, but available are all resources and services from the whole cloud. Another advantage is: If any node of the proposed network happens to be offline this would have no consequences for the remaining nodes.

Conclusion

Scalability is the capacity of a system to support a growing load of users and in terms of the network, the ability of it to grow without extra efforts. Although the iLab Shared Architecture is highly scalable, its deployment to implement a network such as the proposed one becomes complex. The setup of trusted connections between service brokers has to be done manually for each new server added to the network. This process involves the exchange of information between administrators of both servers. In fact that was the reason why the implemented topology was chosen. One of its drawbacks is that users from one institution have to authenticate themselves in the main service broker to run experiments available at other institutions.
As previously mentioned the future work will be to implement a network with autonomous nodes (service brokers) and no main server, such as a peer-to-peer architecture. In this ideal architecture each service broker should manage their users. This means they would need to authenticate themselves in their own service broker. If any node of the proposed network happens to be offline this would have no consequences for the remaining nodes. That is not the case in the current network. If the main service broker fails all users are limited to the labs provided by their own institution.
Beyond the technical aspects, sharing experiments can offer several advantages, such as providing access to potential expensive laboratory hardware to students from universities with scarce financial resources by means of a cooperative network of remote systems. Furthermore, online controlled systems can be very useful when applied to situations involving the often substantial costs of transporting people or equipment. Different institutes and schools could share experiments and knowledge in a collaborative manner that parallels real-life working conditions. Importantly, online labs can be also used in workplace settings where there is a pressing need to apply these systems to continually provide learning opportunities for workers who must adapt to rapidly changing conditions.

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