ENHANCING TECHNICAL TRAINING QUALITY
Complementing the e-Learning Solutions with Virtual Laboratories

Joanna Kosinska, Jacek Kosinski

Department of Computer Science, AGH – University of Science and Technology, Al. Mickiewicza 30, Krakow, Poland

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Abstract: Nowadays, while the evolution of computer science technologies is amazing, the companies' CEOs face the challenge of keeping their employees competence on the highest level. In order to enjoy high prestige, the managing directors have to craft an innovative corporate image. This is not possible with the lack of suitably trained staff. E-learning offers modern ways of training employees, but to benefit from it, it has to be properly deployed and ensure that learners gleaned good knowledge, fully understood the material and what is most important gained proper practical skills. The virtual laboratories included in e-Learning platforms fill the gap arose from the lack of practical exercises that are available in instructor-led trainings. Moreover, the individuals have the ability to do exercise by oneself and develop their practical skills when they want. This paper presents an original project of a virtual laboratory developed at the Department of Computer Science AGH-UST. The virtual networking laboratory is an e-Learning platform extension, aiding the process of computer network training.

1 INTRODUCTION

The proliferation of Internet technologies has significantly changed the ways one is obtaining knowledge. The traditional classroom-based training is still an effective way of achieving new skills, but often it is too expensive to participate in it. The expensiveness means not only the charges/fees (course, travel, hotel costs) but also the lost amount of time related to reaching the course place. In most cases the exponentially growing amount of information gathered in the internet is sufficient to gain an extensive knowledge in some areas. But this kind of self-learning requires self-discipline and the necessity to find appropriate materials. e-Learning solutions offer different, often competitive compared to traditional learning, opportunities for broadening knowledge. Its one of the most important goals - "Anytime, Anywhere, Anyplace" is accomplished through the diverse available tools as discussion boards, electronic chats, virtual classrooms, demonstrations, supporting document materials, multimedia all available from a single place. e-Learning, applied to the right problem in the right way, can deliver enormous efficiency and effectiveness gains to an organization. Being able to produce an accurate and defendable return on investment has long been the Holy Grail of the training industry (GEO Learning).

A well designed e-Learning material is interactive and engages the learner. The included documents, simulations and tests expand the learners' theoretical knowledge. However, the multimedia demonstrations of the running system began to be insufficient in the process of technical training. For the company, a well trained employee is not the one possessing the highest education, but the one that is able to put the knowledge into practice. Therefore the e-Learning techniques are often supplemented with classroom-based practical exercises (aka blended learning). The technical training in most cases requires many hours work, spent on testing lots of possible configurations. The AGH-UST Department of Computer Science, with the cooperation of Cisco Systems company delivers Cisco Academy Trainings (http://cisco.netacad.net/). These trainings are characterized by long course cycles and the necessity to assure the access to the modern hardware and software. The scenario of a typical course is made up of a short introductory lecture followed by many hours of practical laboratories. To decrease the staff load and speed up the course, keeping up at the same time the high substantial level, the Virtual Networking Laboratory

(VNetLab) training infrastructure has been developed. This is an original project, disparate from other similar solutions.

The Cisco Academy trainings are based on multimedia educational materials (delivered by Cisco company) in the form of HTML pages with Macromedia Flash additions. Simultaneously the Moodle (http://www.moodle.org) e-Learning platform is used to enhance the quality of courses. In order to engage the learner and increase its retention and satisfaction, new forms of education have to be embedded into e-Learning platforms. If online learning is to seriously compete in the educational marketplace, the challenge of offering robust and highly interactive, asynchronous laboratory courses which include learner interaction with the task by inserting information, decision-making, and executing steps, also the selection of equipment and instrumentation, data collection and analysis and the capability to make mistakes must be met (Meisner *et al.* 2005). Those virtual laboratories (VLab) fill the gap arose from the lack of practical exercises that are available in instructor-led trainings. Moreover, the learner has the ability to do the exercise by oneself, and what is important a several times that is not often possible during group trainings, where usually one person is doing the task on the only one set of equipment and the rest are just observers.

This paper presents the architecture of the Virtual Networking Laboratory developed at the AGH-UST Department of Computer Science. This laboratory is developed as an extension of Moodle platform, enabling the access to physical laboratories devices, in order to allow learner's training of the material introduced during the lecture. Moreover, the training is not tight to a single location, it can be done remotely from any place. The laboratory is integrated with the e-Learning platform and enabled as one of its activity. Its concept is ready for the adoption and implementation of e-Learning in the business solution in order to enhance the quality and performance, and also reduce costs of technical training. The section 2 comes with the benefits of incorporating virtual laboratories into trainings. Next section lists the features a well organized virtual laboratory should posses. The described architecture and its implementation are based on experiences from designing VNetLab, a robust platform for providing arbitrary networking trainings. The paper ends up with a summary including a future works that should be done.

2 THE BENEFITS

Due to the higher and higher number of learners accessing the courses, the cost of laboratories for didactical applications is going to be very high. As a consequence, a number of software tools and environments must be developed to help users to share laboratory resources and realize experiments (Colace *et al.* 2004). A virtual laboratory can be thought as an online access to real systems where learners are able to practice in a controlled and safe environment without the risk of destroying the production components. Learners have the opportunities to revisit tasks and consolidate the material.

Many companies, both large and small are migrating towards offering e-Learning courses to their employees. The reason, simply put is that through e-Learning, you can train more people and spend the least amount of money (Seamless Technology, 2006). The business benefits from e-Learning in many aspects. The most convincing argument is the tremendous cost savings comparing to traditional trainings. The savings are not only in terms of money, but also the reduced time away from job. The just-in-time training opportunities and 24/7 availability cause that more and more companies are investing in this form of training. If the e-Learning course includes an environment where the learner can also practice, the taken decision is all the more justified. The further part of this section describes the advantages of virtual laboratories based on our experiences with VNetLab.

At the beginning of VNetLab deployment into Cisco Academy trainings, the hybrid model of trainings was chosen. Hence, the theoretical introduction was followed by two kinds of practical exercises. The first category included virtual exercises in VNetLab, where learners got used to the set of new commands and there arguments. These exercises consisted of short tasks that as a solution included 2-3 new commands. The difficulty consisted in the fact that the learner had to find by himself the proper commands. Doing these exercises guaranteed significant speed up of exercises in the classroom. The instructor had only to instruct what to do, and not how it should be done. From the observations clearly followed that these preliminary virtual exercises let to shorten about 20% of the duration of classically led trainings. This gives the possibility of introducing more material into the training. The second category included virtual
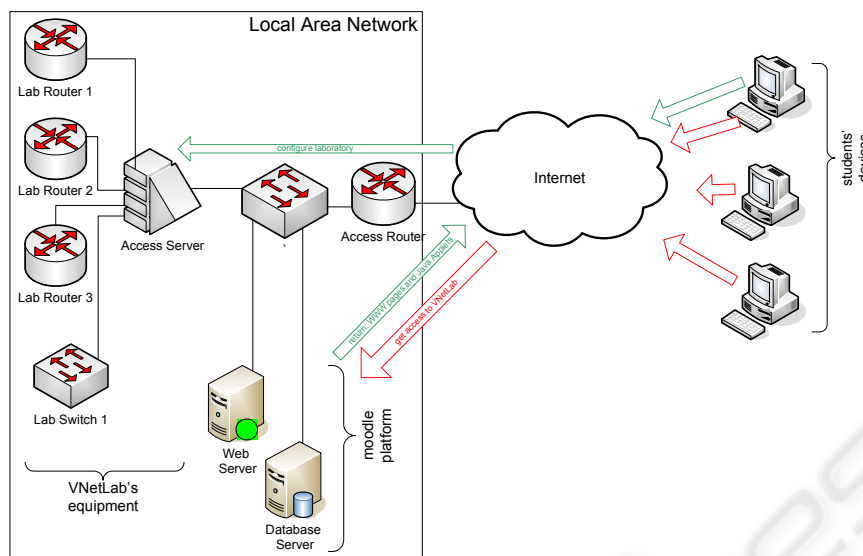
Figure 1: Scheme of communication in VNetLab.

exercises realized after the classroom ones. The purpose of these exercises was to solidify gained knowledge. They consisted of laboratories addressing more complex problems, different variants of those done in the classroom. This part of training enabled to effectively extend the time of training to 30-50%, what linearly translates into additional learner knowledge. Summing up, with the support of virtual laboratory it was possible, without decreasing the course quality, even with noticeably higher knowledge retention rate, to reduce the number of meetings to 60%.

Developing own laboratories is often very costly, both in time and money, especially when the intention is to prepare a several of workstations. Taking into account the price of the equipment and also the fact it is ageing very quickly, the investment might occur unprofitable as the training infrastructure really grows in costs. The virtual laboratory approach enables to create lots of training workstations, while fully exhausting only one set of equipment. This is achieved through reservation and time sharing techniques described in the following section. The VNetLab infrastructure is a software that enables realization of fully automatic access to physical networking devices for further usage. This software is able to virtualize any kind of networking device, assuming this device is equipped with console port, enabling the devices management.

Observation of learners undertaking a virtual exercise may be a part of a formative assessment. It is likely that within the e-Learning platform, final assessment will involve applying the skills learnt in

the virtual laboratory to real life tasks (FlexibleL). The learners engaged in performing tasks in a virtual laboratory, develop their technology skills and can safely test intriguing configurations, feel more relaxed and comfortable in the VNetLab than in real situations. Virtual experiments could potentially allow learners to improve skills in deductive reasoning, hypothesis formation and testing as effectively as through real experiments (Dalgarno *et al.* 2003). However, the work on remote devices is quite different than the work in the physical laboratories. The learner does not have the access to the wirings, hence is not able to change devices cross connections. The learner cannot rely on the LED signalling connection status. The inability to power cycle the devices might also present problems. Sometimes it is necessary to reset the device's configuration, especially when some wrong learner's commands caused the loss of the ability to execute commands.

3 DESIGNING A VIRTUAL LABORATORY

The process of composing a virtual laboratory requires to virtualize devices that are to be exposed. Figure 1 presents a scheme of user interaction undertaking an exercise in the VNetLab. Firstly, the learner has to authenticate in the e-Learning platform. If this process succeeds, the page with exercise description and Java applets is being

displayed. The started applets initiate the connection with Access Server device. This connection is used for managing the devices included in the VNetLab topology.

The proposed solution is an internet based application using a notion of a thin client architecture that requires possessing only a web browser with Java VM on board. The Java Applet technology provides access to exposed equipment via Telnet or SSH protocol from a single Web browser window.

In most of this kind of systems, the main stress is put just on the possibility to remotely expose the existing infrastructure. The instructor has only the possibility to enable devices where learners could practice and check previously acquired theoretical knowledge. The instructor however was unable to check what the learner is actually doing on enabled devices, hence there was no possibility to verify and include in the assessment the degree of the acquired practical knowledge. The VNetLab system overcomes these inconveniences. It assumes the strict definition of the tasks that the learner has to do during the course. Additionally, the form of the answers is strictly defined simplifying the further assessment. The course appraisal, both automatic and subjective made by the instructor can be one of the factors taken into account and affecting the final score achieved at the end of the course.

The architecture of the VNetLab carried out at the AGH-UST arose from the made assumptions to mostly imitate its operation to traditionally led trainings. The virtually led training should not generally differ from the classroom-based training. The only noticeably difference should be the remoteness, being more precise the distance between the instructor, learner and the equipment. The

presented approach distinguishes following steps while carrying out exercise in virtual laboratory:

1. Slot reservation – reserving the time period when the equipment in laboratory is free and can be utilized by the requesting learner. The learner specifies the beginning and the end time during which the task will be performed. Depending on the set configuration of the exercise, the learner might decide how many slots will be reserved, the length of the slot, etc.
2. Preparation of the infrastructure - includes preparation of devices, both that would be configured by learner and that are responsible for defining connections. This phase includes loading devices' (that are going to be configured) initial configurations. The whole task is done without learner's knowledge, just before the learner begins to do the exercise.
3. Carrying out the exercise - gaining access to the virtual laboratory. Learner gets the detailed description of the task and a set of applets enabling to configure particular devices. After submitting the work (or after the timeout) the system retrieves the configurations from devices and stores it in a database for further assessment.
4. Removing unnecessary work results - this step restores the devices to their initial state, more precisely removes the configuration the learner has done and restarts the device. This step is often a time consuming task and has to be done much earlier before a learner attempt.
5. Assessment of the learner's results - the overall learner's work is being evaluated.
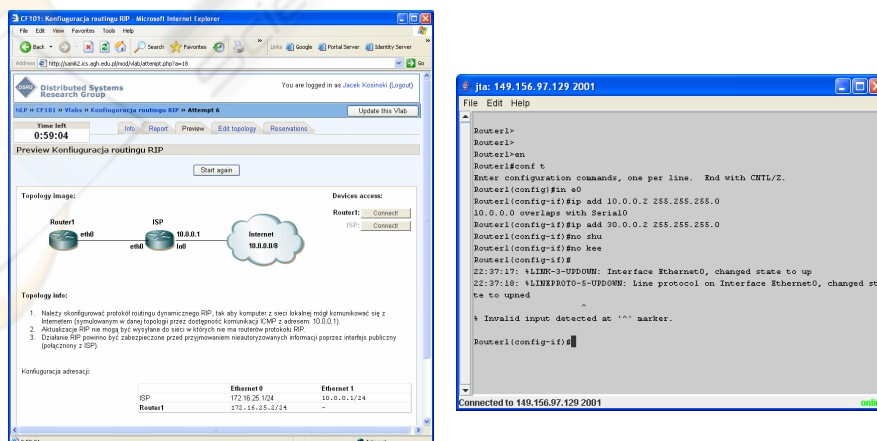

Figure 2: Web access to the VNetLab devices.

The saved solutions are retrieved from the database and presented to the instructor. The system also possesses a base configuration that is a listing of ideally solved task. The instructor receives both listings with highlighted differences. This simplifies finding the potential mistakes especially in long configuration files. The comparison is generated as a HTML file from the result of operating system command 'diff'. Formatting it into HTML, including different background colours that depicts differing fragments, improves the readability and speeds up the assessment phase. The learner receives a score, a feedback from the instructor and the listing of the model solution. The built-in linking mechanism that automatically searches for strings in text and links them to glossary terms, replaces all commands appearing in the listing with the links to glossary terms (includes its definition, usage example, meaning of particular options). This capability significantly shortens the time learners spent on tracing and understanding the idea of the solution.

All these phases are mapped to implemented modules that accomplish virtual laboratory functionality. The following layers (as depicted on
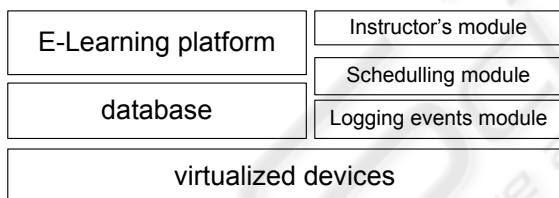

Figure 3: Architecture of VNetLab.

Figure 3) can be distinguished within the VNetLab:

1. Virtualized devices layer - This layer is comprised of physical devices and the interfaces that enable access to those devices and their management. The implementation of this layer is dependent of the possessed equipment and the e-Learning platform technology.
2. The database layer – Gathers all data that are related to devices configuration and its current state. Also learners training results are stored there.
3. The e-Learning platform layer – This layer is responsible for handling authentication and authorization mechanisms. It also has to posses such features as grade book, chat,

and glossary. VNetLab uses this module as a learner's interface.

4. Logging event layer – Is responsible for tracking all events in the VNetLab and storing them in the database. Additionally it has the ability to inform via email the administrator about all critical events from the infrastructure perspective.
5. Scheduling layer – Checks the availability of all devices. Defines and manages the time period within which learners can undertake trainings. Assigns access permissions to devices and checks the exclusiveness of access.
6. Instructor's layer – The level that enables the management of the physical topology of VNetLab, creation of configurations and exercise content. It gives the ability to monitor system's events.

During the exercise the learner modifies device's parameters, changes its values to meet the requirements set in the task's content. All this work is saved in router or switch configuration and exported on demand into a text file. The content of this file makes up a list of commands that need to be executed in order to obtain the given configuration.

The VNetLab has a modular and extensible architecture. Its implementation technology is restricted by the Moodle e-Learning platform technology it is embedded into. Networking trainings that are carried at AGH-UST are provided through Moodle platform, hence the necessity of integrating the VNetLab system with this platform. The next reason of choosing Moodle platform was the ability of utilizing built-in advanced tools as grade book, calendar, chat, glossary without which the VNetLab's functionality would become sparse and implementing them from scratch would be very costly. The Moodle platform is very flexible for further extensions and adding other modules to it is straightforward. The developer has a template with defined functions that has to be filled with proper code. These functions are called by the portal and serve as an interaction layer between the portal and the new module.

Recently, there exist many implementations of virtual laboratories. It is important to distinguish the simulations from experiments on real devices. VNetLab falls to the latter category. To analyze the proposed solution with the existing ones it is good to choose one from the same line. The Network Development Group (NDG) offers a similar product named NetLab. NetLab is offered in two versions:

Academy Edition – adjusted to Cisco CNAP trainings (CNAP). The main differences between VNetLab and NetLab are:

- lack of possibility of cycling the power on device (VNetLab),
- lack of versioning capabilities (VNetLab),
- lack of logging students' commands (VNetLab),
- lack of assessment phase (NetLab),
- the system only works with certain topologies, it is not possible to define new one (NetLab),
- it is difficult to integrate it with e-Learning platform (NetLab),
- to expensive license and necessity to buy dedicated hardware (NetLab).

The integration with e-Learning platform is one of the most important feature that distinguishes the proposed solution from the other. If e-Learning is to be successful in bringing technical training courses, it has to provide comprehensive solutions. The VNetLab is trying to fulfill this requirement, but still needs some improvements, as described in the following section.

4 SUMMARY

This paper has discussed the potential of virtual laboratories included in the program of technical trainings. The elaboration was done based on experiences from implementing Virtual Networking Laboratory at the AGH-UST. The gained experiences show that VLab environments are essential parts of training provisioning and increases learners retention and satisfaction. The learners engaged in performing tasks in a virtual laboratory develop their technology skills making them more valuable employees.

As shown, virtual laboratories must be embedded into e-Learning platforms to enhance the quality of education. The described architecture of VNetLab system is so general that with ease can be mapped to any kind of virtual laboratory, leaving for developers the implementation of core functionality of the specific area. Embedding the laboratory into other e-Learning platform should not impose difficulty as most of them have already defined modules that were used with the VNetLab system.

There are many improvements worth implementing that should be taken into consideration. The major one is the ability to allow more than one learner to undertake the exercise at the same moment. This would be achieved through creation of twin set of devices. Another feature includes module that automatically verifies correctness of learner's work without the supervision of the instructor. The module would include semantic aspects and explore reasoning and inference solutions. Hence, the necessity of introducing an ontology layer into the system.

Finally, it is worth to emphasize that this kind of innovative training is beneficial especially for those learners that are disciplined, motivated to learn, has a need for learning and self-directed, so for the one that the business seeks.

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