Teaching/Researching Practically Oriented ICT Security Topics using Green Mobility Solutions within a Virtual Campus

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ABSTRACT

"Hacker attacks the German government", January 2015 – "Hacking of Government Computers …", July 2015. These shocking headlines have almost become "routine" nowadays. ICT security has become a global, cross-vertical, deep concern for government agencies, companies and individuals. It has reached a dimension which definitely necessitates joint international efforts, supported by combined know-how and expertise. Consequently, the demand for skilled network security professionals is set to accelerate dramatically. The Open Distributed European Virtual Campus on ICT Security Project (DECAMP) presented here pioneers the creation and implementation of a new model for an innovative network blended-learning online courses aimed to equip students and researchers with new key competences among others also with practical hands-on labs. It is being carried out by an international strategic partnership between the specially selected Computer Sciences departments of six European High Education Institutions (HEI) and three associated partners. In addition to the concept and architecture of the project, the paper presents the solutions adopted to integrate the virtual lab platforms into Moodle learning system as well as some key aspects of managing such a strategic partnership. The DECAMP Project is supported by the EU under the "Erasmus+ Strategic Partnerships" grant 2014-1-DE01-KA203-000695.

Keywords: ICT Security, Virtual campus, Green mobility, Integrating Virtual Laboratories in Moodle.

1. INTRODUCTION

The aims of this international strategic partnership for developing and implementing teaching/researching practically oriented ICT security topics using "green mobility" solutions are as follows:
1) contributing to rectifying the underrepresented field of practically oriented ICT security in university curricula in response to huge industry demand;
2) amplifying partner HEIs teaching and technical resources through offering online courses not taught at their home university, which reduces the costs in replicating courses and labs at the partner HEIs;
3) enhancing the relevance of the learning and researching offer in ICT security, improve students' ICT security skills and promoting cross-border collaboration by virtual "green mobility";
4) fostering each DECAMP partner's internationalization strategy.

These aims have resulted in the following objectives which are currently being developed:
1) creating innovative practically-oriented blended-learning online network security courses for international collaborative learning and researching;
2) creating innovative hands-on remote labs based on virtual and real equipment;
3) developing a scalable online campus platform by integrating heterogeneous virtual lab environments and e-learning platforms for distributed courses in one "virtual campus".
DECAMP online courses encompass IT security aspects in network management and computer networks (Germany), eHealth systems (Romania), wireless networking (Italy), applied forensics (UK), WEB application (Finland), cloud networking (Spain).

Target Groups (TGs) of the project are: a)TGs inside the DECAMP organization: the ICT students, researchers, teachers, instructors of the partner universities; b) TGs outside the DECAMP organization: ICT students of the EU partner universities of the DECAMP partners offering ICT degrees, ICT students of universities offering ICT degrees in each partner HEI country, non-traditional learners 25+ working in ICT jobs of companies associated with the HEIs partners.

Assessment Criteria for the designed, implemented and delivered courses will be based on Finnish quality criteria since Finland has a worldwide reputation in education and for being extremely practically oriented. Specifically the project will uses the "Quality Criteria for Materials at the Portals of Virtual Institutions of Higher Education" and the "Quality Evaluation Tool" [5] developed by Finnish Online University of Applied Sciences. Assessment/Quality criteria categories for the course materials are:
1) use: accessibility, transparency and interaction, ease and smoothness of use, structure and communicativeness;
2) content: suitability, comprehensiveness, reliability and topicality of online material;
3) production: quality of production plan, compliance with standards, data confidentiality and integrity;
4) usefulness: benefits to users and competitiveness.
Quality Assessment for all online courses will be applied during the course development and fully carried out after each course rollout and consistent update.
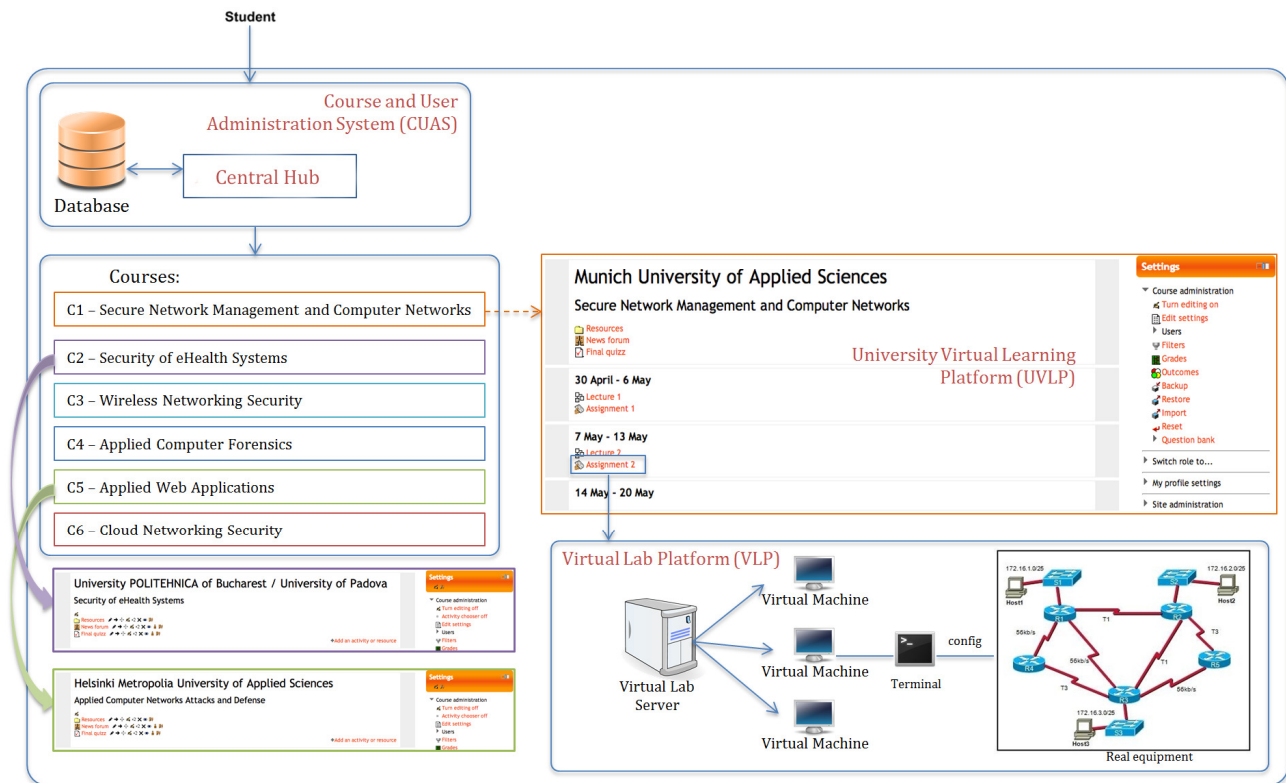
Fig.1. Architecture of Open Distributed European Virtual Campus on ICT Security (DECAMP)

2. DECAMP PROJECT CONCEPT

Relevant publications show that e-learning and e-researching is in a strong uptrend. The literature presents the experience made in introducing online teaching and research elements based on virtual labs using virtual servers. [1], [2]. However, the majority of these online teaching components are available only to students and researchers enrolled at the respective university. Lectures are not combined with other pedagogical elements, such as instructor-evaluated hands-on lab assignments or hands-on collaborative research projects.

DECAMP pioneers the creation and implementation of a new model for an open technology campus.

One of its most prominent features and, as literature reveals, one which is quite possibly unique worldwide, consists of hands-on remote virtual labs containing virtual machines and real equipment. Virtual labs enable students to gain hands-on experience of security attacks and security prevention scenarios. Normally, these are scenarios that cannot be practiced in real lab environments because of the risk to local networks.

Further major innovative elements in comparison with other similar implementations worldwide consist of the following:
1) The virtual labs are open to Bachelor/Master/PhD final projects as well as for R&D.
2) Cross-international exchange of professional ICT network security expertise: Master and PhD students can select ICT security courses free-of-charge not offered by their home university.

3) DECAMP course modules can also be inserted into the curricula of the partner universities' PhD courses which support PhD students to complete their PhD program requirements.
Open interfaces enable other European universities to complement their course offerings. DECAMP could therefore easily attract other EU universities to add ICT security courses to the DECAMP core courses. This is how DECAMP will contribute to boosting the process of internationalizing education. All course materials are free and open to all European students, teachers and ICT employees of companies. Student-centered, learner-paced pedagogical strategies are based on new methods, such as collaborative international projects, video conferences with case studies by company experts. Each DECAMP partner will fully recognize the ECTS credits gained by the students passing the exams of any of the DECAMP courses.

Last but not least, cost savings are achieved because the participating universities do not individually have to create and maintain more than one lab and yet have scale-up access to five more labs.

3. IMPLEMENTATION ARCHITECTURE

DECAMP distributed platform consists of following components (see Fig. 1):
1) Course User Admission and Information System (CUAS) comprising the authentication and registration system of EU students and teaching staff;
2) University Virtual Learning Platform (UVLP) at each partner comprising course materials and link to the Virtual Lab Platforms (VLP);
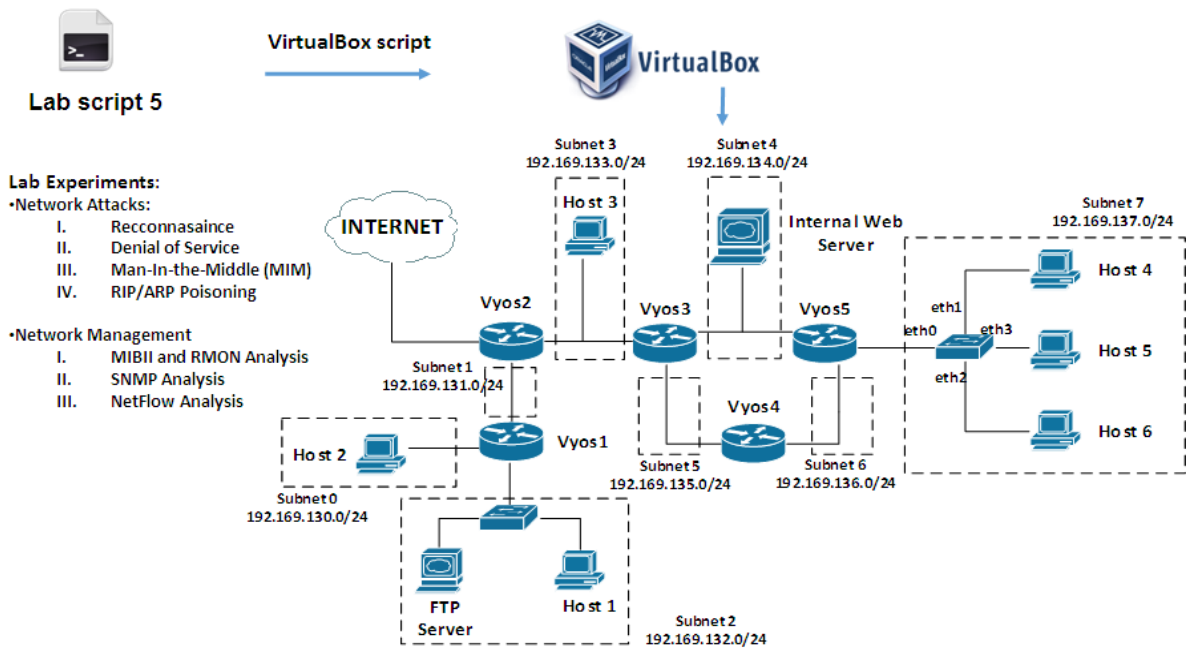
Fig.2. Example of a complex network configuration included in a VM cluster

3) VLP and Virtual Real Equipment Platform at each partner including the soft- and hardware support of all types of remote labs offered in the courses.

The first step in the DECAMP deployment was to design, implement and test the CUAS module. Some existing solutions presented in the literature were analyzed [3], [4]. The main challenge in the case of DECAMP consists of the difference in user enrollment and authentication procedures. Each partner university has a customized local solution of registration and verifying the access to their local resources of their own users.

For the DECAMP platform, two types of authentication solutions are possible: a central or a distributed solution. The solution adopted is based on a distributed access control to the distributed resources of the platform. It implicitly involves all local types of access control already in existence at each partner. Taking into consideration that all the partner universities use Moodle as their main UVLP, the distributed solution is based on the use of Moodle plug-ins. It supports the authentication and the course enrollment procedures applied locally at each partner university according to the rules they have already implemented (i.e.: Shibboleth, LDAP).

It nonetheless allows optimized and secure access to the distributed platform materials and labs.

A prototype system was developed and installed to validate the distributed solution [12]. After authentication at the home university the student can register and follow the course at another partner university. The student can access all the materials available, as well as the labs assigned to the corresponding course. The labs are based on virtualized components or/and real equipment. All components belonging to various labs are already installed on the lab platform of the corresponding course.

The lab experiments can be reserved any time for a two or longer hour period on 24/7 basis. During that time the user has exclusive access to all the virtual or/and real components corresponding to the particular lab experiment. The reservation can be repeated as many times as needed. One example of such a lab, used to have hands-on experimenting network management, various attacks to security of LAN components and protocols as well as experimenting with Software Defined Networks (SDN) and attacks to their security are depicted in Fig. 2 and Fig.3.

At the same time, the solution offers more flexibility to advanced students or researchers in using complex environments for their experiments, also outside the ones required by the course. Once such network lab environment base is installed, lab users can concentrate on real learning or on research objectives instead of wasting their time and attention to secondary aspects, such as software download and installation, configuration, troubleshooting, etc.

4. INTEGRATING VIRTUAL LAB PLATFORMS IN MOODLE

The lab experiments are grouped in virtual clusters based on a large virtual machine. Each virtual cluster contains a number of virtual network components (router, switches, hosts, firewalls, intrusion prevention system, network management systems, analyzers, etc.) which build a complex network. Each individual lab experiment does not require all the components of a cluster. However, to keep the reservation process simple, as well to ensure the usability of the lab environment carrying out the same experiments at the same time, we decided to create more identical clusters which are to be used for different types of experiments. The solution allows regular students to move always within a known network environment. During the
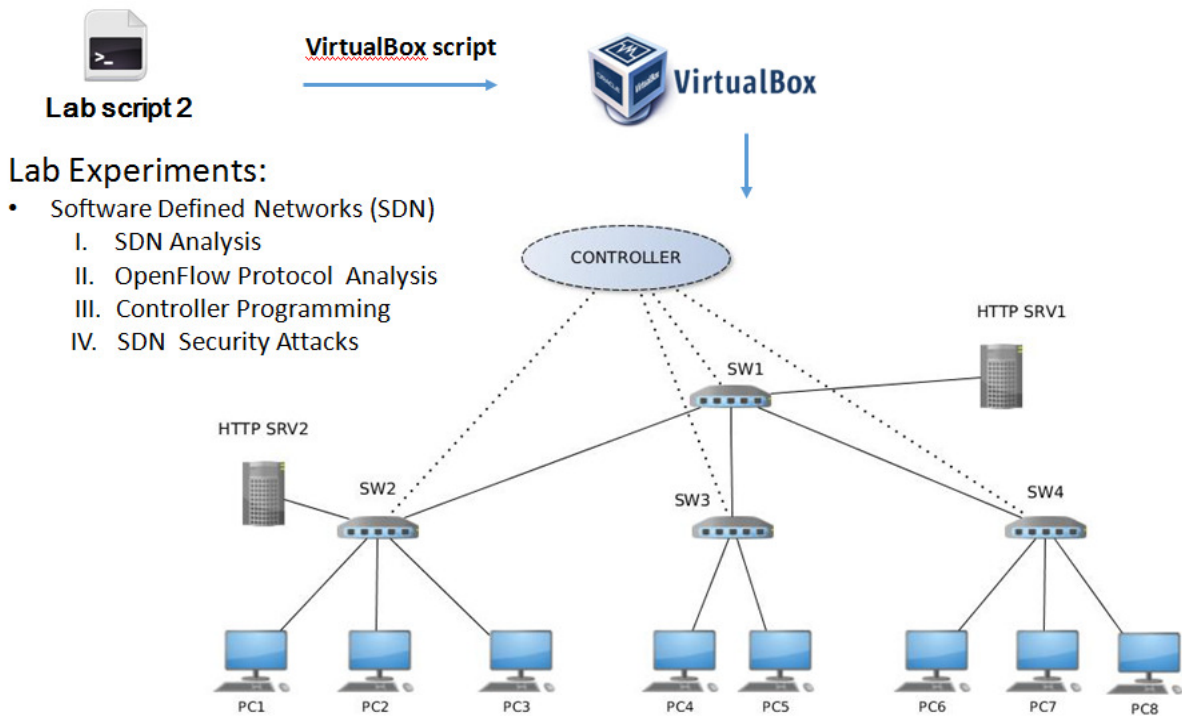
Fig.3. Network configuration for SDN lab experiments

process of designing and implementing the integration of VLPs in Moodle we consider two main solutions:

A) Integration via Moodle`s module: "External Tool Resource: Learning Tools Interoperability (LTI)"

LTI module [6], [9] is a plug-in used to provide access from Moodle's courses to activities offered by other remote systems, i.e.: Web server or Hypervisor platforms (see Fig.4). The LTI link is dynamically generated and therefore unique for each user. It can contain a security mechanism that prevents unauthorized access to the Lab Management Application (LMA) implemented as a web application on a server. LTI supports the feature to supply student e-mail and name as attributes to allow reservations in advance.
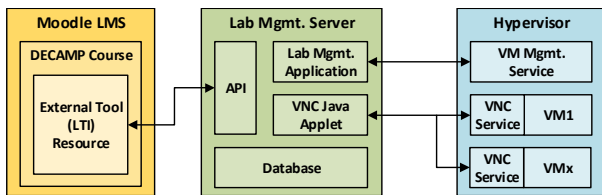

Fig.4. Embedding the Virtual Lab Platform into Moodle system using LTI plug-in interface

Moodle Learning Management System (LMS) hosts a DECAMP Course which in addition to course materials has also an LMA embedded as External Tool. Lab Management Server hosts LMA, VNC Java Applet and a Database. LMA manages VM reservation system, control VMs through VM Management API of Hypervisor and provide VNC Java Applet with connection parameters to the users.

The VM clusters (VM..VMx) are preconfigured and stored at Hypervisor (see Fig.4). There are many VM clusters containing various or identical configurations (see Fig. 2 and Fig.3). LMA controls VM`s running on hypervisor by sending some API requests to the hypervisor management service, i.e.: connect users to the required VM, VM start/stop, reserve the usage of a VM for a period of time, keep track of the users working with the VMs. LMA provides VNC java applet and connection parameters, so that students are able to connect to the VNC service and get the desktop of the reserved VM.

Figure 5 depicts a scenario of connecting a user of a DECAMP course to a lab experiment running on a VM within the Hypervisor platform. In order to be connected to a VM containing the requested lab environment, the user needs to be enrolled in a DECAMP Course and have an account on Moodle LMS [11].

By clicking on External Tool Resource the user gets the URL of the LMA and a unique Token [10]. With this URL and Token, the user will be identified by the LMA and he/she can reserve a VM for a specific period of time. LMA configures and starts an unused VM. The user will get a web page with embedded VNC Java Applet and connection parameters (IP address, port, login, password and other VNC settings). Accepting the execution of Java Applet, the VNC connection will be established. After elapsing the set previous predefined time period, the VM will be stopped and the user will be disconnected.

B) Integration using "OpenStack" (OS) technology [7]

OS is an Infrastructure as a Service (IaaS) open-source project that offers a collection of software tools for building and managing large-scale virtualization environments. Basically, OS lets users deploy and manage VMs through a GUI very similar to how Amazon's EC2 and S3 services work. OS has been already successfully used for various educational
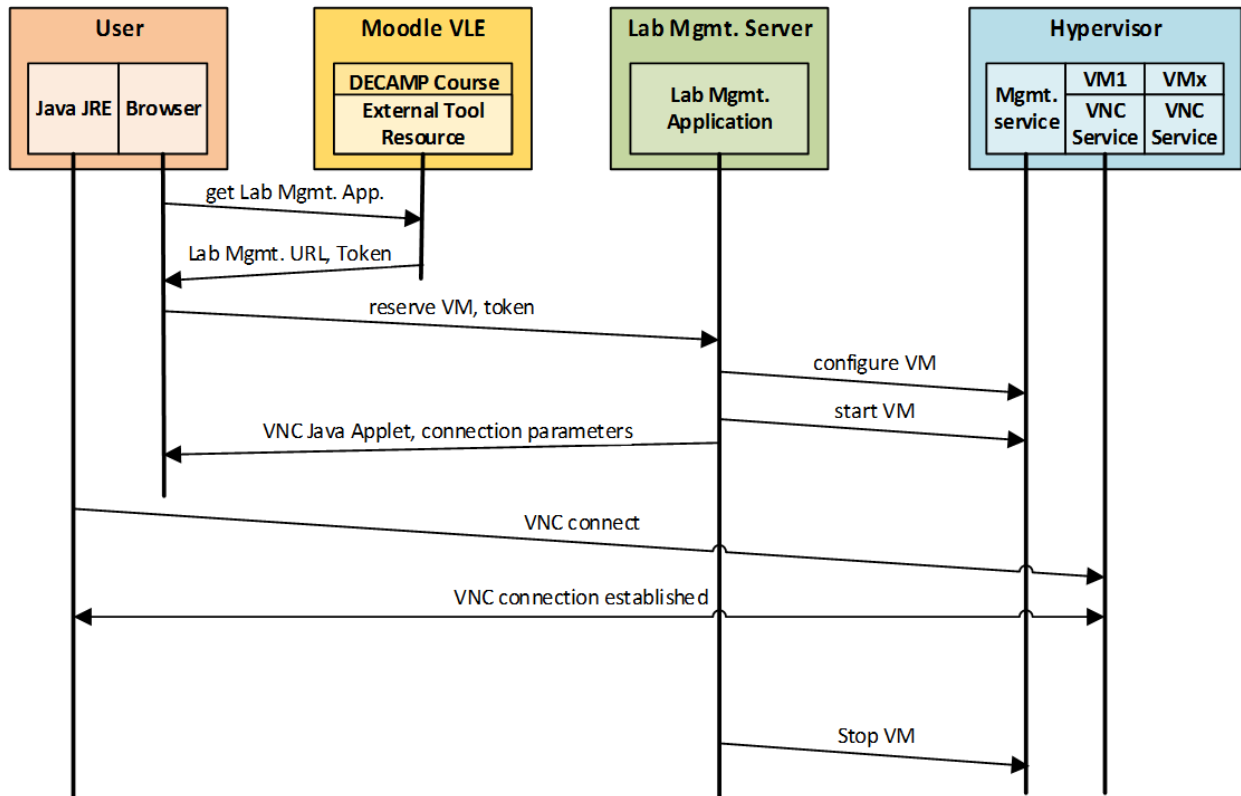
Fig.5. DECAMP User connectivity to VLP: a simplified case scenario

platforms, i.e.: Cisco's powerful simulation platform "Virtual Internet Routing Lab" (VIRL) [8]. Do to scalability and extensibility OS is divided into seven individual service components that communicate with each other through a set of APIs (see Fig.6).

As mentioned above the VLPs represents mainly a set of IT components which are implemented using open source software on virtual machines. OS builds the interface between the user of the lab and the VM clusters. Several approaches to embedding VLPs into the Moodle courses using OS have been investigated. The result was in the favor of the solution to store lab environments based on preconfigured VM image representing a network configuration and a set of virtual components. The students can easily deploy these preconfigured clusters by accessing the OS graphical interface.

Based on that OS support, we are in the process of developing and implementing a plug-in which allows the students to deploy preconfigured clusters directly from Moodle courses. Fig. 6 depicts a simulated scenario: student "Popescu" from Bucharest University enrolled in the "Secure Network Management and Computer Networks" course offered by the Munich University accesses the materials available for that course. Among those materials there are also Lab experiments that the student can access by clicking "Lab activities". The plug-in will then create and deploy a private VM cluster for the student "Popescu" and will display the connection details when the VM is ready running within the Hypervisor. The student can easily access the VM with a remote connection client tool, i.e.: SSH, RDC, PuTTY and start working on the lab tasks inside the VM. With a simple click, the procedure allows to reach the VLP platform for carrying out any type of lab experiments.
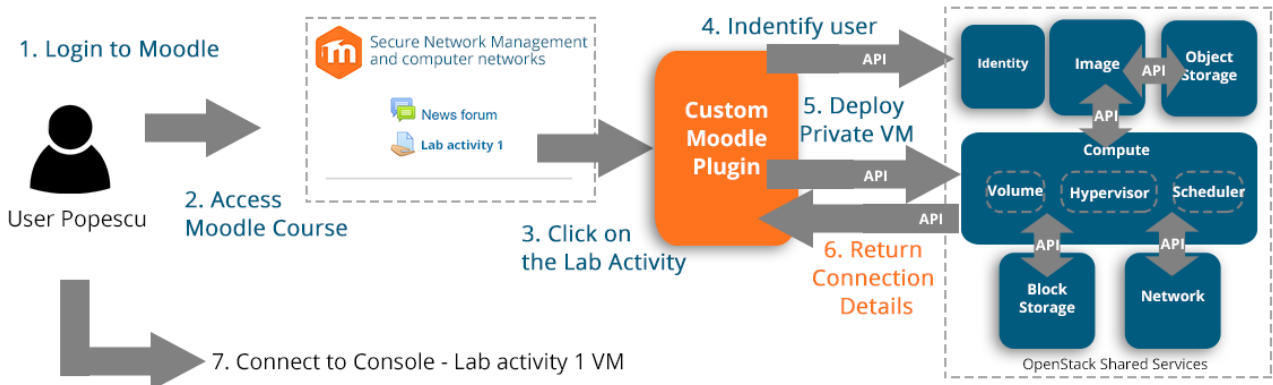

Fig.6. Access of students, authenticated by Moodle, to the OpenStack-based VLP

5. INTEGRATING EDUCATION WITH PRACTICAL PROBLEM SOLVING

The Project implies a close international collaboration not only with academia but also with companies specialized in ICT security consulting and/or solving practical problems concerning ICT security.

These companies can cooperate with the course developers in preparing case studies based on real-life, practical cases and lab environments. This has been enabled through building a link to the companies through Bachelor/Master/PhD students working in close connection with them on their theses, i.e. master thesis on "Software Defined Networks Security" in cooperation with the company Siemens AG in Munich. Accordingly, the results of their work can flow into the lab contents, course assignments and collaborative projects, as well as into case studies. In analyzing and solving practical problems, they prove the usefulness and applicability of the lab platforms created.

This ensures a win-win advantage between academia and real practice. The academic approach to real-life cases, for instance, may lead to finding solutions to practical problems. And vice versa: academia will be in a better position to orient research and education towards real-life application and practically oriented cases.

6. PROJECT MANAGEMENT KEY ASPECTS

The project management so far, demonstrated that several procedures in addition to the initial planed ones could be very useful and solve many practical problems efficiently, i.e.:

1) Plan and carry out additional mini working meetings to check the solutions proposed by a partner and carry out tests for jointly proving the validity of the solution. These mini working meetings with reduced number of participants for testing and implementing Moodle connectivity and plug-ins were hosted at various partners and took place in addition to the transnational meetings planed within the Project.

2) Setup a Moodle platform at our DECAMP Server at the Bucharest university to include all the course materials from all developers for being reviewed by the partners. This procedure assures that the envisaged assessment criteria of the courses will be checked during the development period and not only at the end of the development phase.

3) Enforce dissemination activities to complement project development phases, i.e.: announcements about the coming DECAMP platform at local journals, university newsletters, university and DECAMP web sites, student information via posters, word-of-mouth during classes , university social media and preparation of film trailers for transporting the students per video to the partner universities. All these dissemination activities are also intended to attract students from various partner universities to participate in the courses during the pilot sessions starting in fall 2016.

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