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Simternet - Complex Internet Exercise on a Virtual ICT Learning Environment

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Abstract

Information and communications technology systems are increasingly important to the modern society. Understanding the complex systems, which powers our everyday lives, is an important competence for future experts, since everything is getting connected from the simple household devices to the complex industrial systems. In this paper, a high-level concept for a complex learning environment is presented, which aims to simulate the Internet and offer a realistic environment where ICT (Information and Communications Technology) systems can be further studied. A model of Internet was used as a centre point to interconnect virtualized cases together and a simple, scalable virtualization platform was developed to meet the demands. This study was conducted to assess the performance and scalability of the solution, and test the system user experience and usability issues when under heavy workload. The results indicate that the system is capable of simulating several thousand different devices, and serve as a basis for further development.

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Keywords: Simternet; virtual laboratory; case study; computer science education

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1. Introduction

Teaching ICT systems as a domain has changed as rapidly as the area of expertise itself during the past decade. Traditionally laboratory exercises have been executed using hardware based systems, which needing physical wiring work and hardware configurations [1]. The competences in this area are still important, but using hardware to teach the fundamentals of telecommunications has several limitations. For example, complex exercises need lots of equipment, which is expensive to acquire and maintain [2].

The advances in virtualization technologies have changed the way ICT systems can be taught [3]. Today even networking devices such as routers and switches can be run as virtual machines, which opens up many new possibilities for teaching complex ICT systems. However, building an independent laboratory exercises from different areas of study doesn't still represent the whole complex picture of how systems interoperate and connect to each other. For example, what actually happens, and how complex the mechanisms are when corporate users access online resources, can still be difficult to understand in a large scale.

This paper outlines an environment where the different areas of study are combined together to form a network of virtual laboratories. Each of the laboratories represents student work from one area of the degree program, eventually combining into a virtual corporate network with an access to the simulated model internet, 'Simternet'. The long term goal is to integrate this model to the whole curriculum, during which students gain experience of putting different areas of expertise together, forming a complex interconnected environment as close to the real world counterparts as possible. In this study, our focus is on answering to the following research questions:

How can we improve the performance of the laboratory system to better support simulated Internet, "Simternet"?
How capable is our current version of the Virtual Laboratory Simternet, and what are its main limitations?

Rest of the paper is structured as follows: In Section 2, prior studies related or similar to our work are discussed. In Section 3, the research method and approach on the development of the construct is introduced, and the results of this study are presented in the Section 4. Section 5 discusses the implications and observations made on this study, and Section 6 discloses the paper with the conclusions.

2. Related Research

Virtual laboratories have been proven to be very effective learning environments for studying ICT topics [4,5]. Latest advancements in virtualization have led to numerous implementations for different purposes, such as better support in collaboration, which can be run for extended periods aiding learning and fostering student interest towards the subject. Virtualization can also isolate laboratory environment from campus network, which enables the possibilities to execute potentially harmful cybersecurity experiments in isolated environment and give students full access privileges to the systems. [6].

There are commercial as well as open source virtual laboratory systems, which are available for integration into the existing learning environments [7,8]. Most of these solutions aims to solve a single educational or modelling problem, and are not designed for quick deployment. Studies also show that these solutions require additional skills for students to be able to use the system itself [5]. In addition to these limitations, the cost of running hundreds of commercial software instances may also become unacceptable and affect the ability to use them for extended periods of time in the complex educational networks.

Virtual laboratory environments have gained popularity especially in cybersecurity training, where isolation from the host environments and the user computers are of high importance [9]. Studying malware, vulnerable systems and penetration testing requires the use of potentially harmful software. Projects such as ReSeLa [10] are targeting towards cybersecurity training environments, with these types of objectives in mind. ReSeLa shares also focus on usability as well as creating predefined virtual machine templates and network topologies which are one of the key components in this study.

Virtualization is the enabling technology in each of these solutions; Virtualization is needed to isolate laboratory modules from each others and the university network, as well as to run virtual laboratory components inside the module. Two main solutions exist to the problem: Full Virtualization (Hypervisor) and container virtualization. Full virtualization is based on emulated hardware, which is presented to the virtual machine. Example full hypervisor solutions are VMWare ESXi [11] and KVM [12]. Alternatively, container virtualization is a technology which shares