



An Implementation Of A Software Defined Network Based Virtual Laboratory

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Abstract—The cost of adequately equipping laboratories with required laboratory equipment has been found to be prohibitively expensive. This has made teaching of practical oriented courses very challenging in educational institutions. Virtualization is a technology that can create the impression of having dedicated hardware resources in place of physical laboratory equipment thereby reducing this prohibitive cost. In this paper, the development of a virtual laboratory using software defined networking approach is presented. The developed system was tested using a network penetration testing laboratory session. The results derived show that the virtual laboratory has the potential of enhancing learning in practical oriented courses because of the ease of conducting practical sessions and the elimination of procurement cost of laboratory equipments.

Keywords—virtual laboratory, SDN virtual laboratory, software based virtual laboratory

I. INTRODUCTION

Virtualization has been used for many years as a solution in many cooperate settings to ease the daily activities and provide security to equipment [1]. It involves the creating perception of having dedicated systems resources whereas, resources are being shared [2], [3], [4]. This has brought great benefits to the large variation of usage involving both industry and academia.

In academics, virtualization has helped to reduce the prohibitive cost of setting up a laboratory for teaching practical courses. Heretofore, laboratory equipment have to be purchased and set up for use in the laboratory. Apart from the linear increment in cost as the number of students increase, there is also the issue of space where the equipment will be placed. Furthermore, students need to be physically present in the laboratory to use the equipment. With the use of virtualization, these overheads and more can be eliminated.

An upcoming technology in virtualization known as Software Defined Networking promises greater flexibility [1]. With this, the layer one functionality of the network can be transformed to be purely software based. The network tasks are further divided into two; data and control plane. The control plane decides how a given packet should be handled while the data plane forwards the packet to a specified destination.

In this paper, the development of a virtual laboratory using a software defined networking (SDN) approach is presented.

This work was implemented using a cyber security practical session. However, it should be noted that the developed laboratory can be applied in a variegated range of disciplines. The paper is further structured as follows: In section II detailed review of related work is presented. The description of the employed methodology is presented in Section III. The results and discussion is presented in Section IV while Section V concludes the work.

II. RELATED WORKS

The use of virtualization in the development of virtual laboratories has gained large acceptance in academia due to the high cost of procuring laboratory equipment. A large amount of work has been done in the development of a virtual laboratory for educational purposes. Based on these works, virtual laboratories can be classified into two namely: - Centralized and Decentralized structured virtual laboratories.

In the case of the centralized structure, the nodes have a central server where all remote connections are made in order to access the laboratory. In [5], a centralized virtual laboratory known as VNLab was developed to evaluate virtual laboratory based on virtualization technologies. Students could access the central server by establishing a remote connection. An Integrated physical and virtual laboratory was developed in [6] to teach basic computer networking concepts. VMWare was used at the core of the virtualization environment.

In Decentralized structure, the nodes operate with no dependence on a central server. This creates a whole range of advantages to the virtual laboratory development. The use of decentralized structure is a trend among education and professional fields [7]. This is obviously because of the great advantages derived for their usage which include reusability and flexibility of making changes. A framework for implementing a decentralized virtualization solution for computer laboratory was proposed in [8]. In [9], some free virtualization tools were used to develop a virtual laboratory for educational purposes.

Heretofore, virtualization for educational purposes has been focused mainly on Information Technology (IT) based courses and subjects. Some of the subjects include computer networking and cyber security. Advanced computer network

[10] and VoIP [11] concepts were also taught using virtual network laboratory. A cyber security based virtual laboratory was developed in [7] with the Game Based Learning (GBL) technique employed to encourage learning among students. An intrusion detection system (IDS) virtual laboratory was developed in [12]. The system was made modular so that changes can be made for other courses without affecting the main operation of the virtual machine. In this study, an attempt was made to extend the earlier approaches by using the software defined networking (SDN) based approach.

III. SYSTEM DESIGN

Software defined networking being an upcoming concept involves the abstraction of the network functionalities. The implication of this is that the network becomes more efficient and flexible in maintenance. This section expounds on the methods used in developing the SDN based virtual laboratory.

A. System Architecture

The layered model show in Fig. 1 was employed in the development of the virtual laboratory.

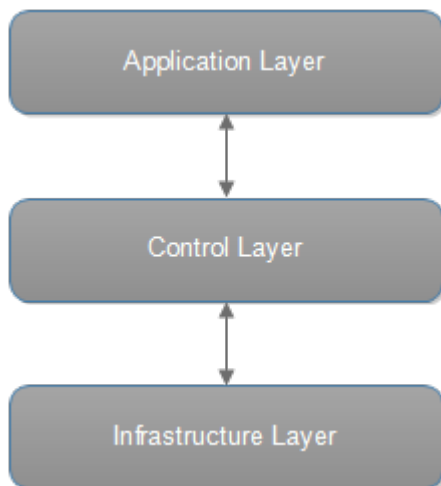


Fig. 1. SDN model adopted in the design

Control layer defines how the network handles a given packet. Infrastructure layer involves the use of a physical or virtual network device. Application layer involves the kinds of high layer functionality expected on the network. It involves the virtualization of a designed network.

In order to develop the system, two tools; VMWare and GNS3; were employed. The application layer resides on the VMWare while the control and infrastructure layers reside on the GNS3 platform. The network is set up on the GNS3 emulator and it is used to interface the application on the VMware platform.

A personal computer running windows 7 was used as the Host Computer (HC). On the HC, VMware workstation 11 was installed to be used to create Virtual Machines for the developed Virtual Laboratory. The overview of the developed system is further depicted in Fig. 2

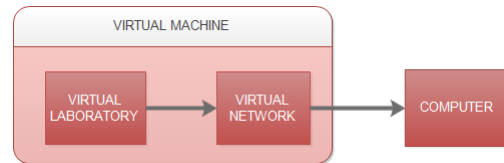


Fig. 2. Block Diagram of Developed System

1) *VIRTUAL LABORATORY*: This block represents the various laboratory practical sessions taken in the laboratory. For the purpose of this research, a network penetration laboratory session is implemented in the laboratory. This block will reside on the VMWare platform. Course Instructor simply modifies this to accommodate the required laboratory session.

2) *VIRTUAL NETWORK*: This block enables remote connection between the user and the laboratory. Various modules of the laboratory are connected together using this block. A user is further required to remotely log into laboratory to be granted access. GNS3 network emulator is used to implement this functionality in the design.

3) *COMPUTER*: It is from this unit that the user connects to the laboratory. A secured login encryption is enabled using SSH to eliminate possible eavesdropping on the provided password.

B. Use Case Diagram

From Fig. 3, the instructor can set up all the virtual machines for the SDN. The administrator is responsible for creating virtual machines when needed, installing new software or services on the virtual machine for the purpose of laboratory practical.

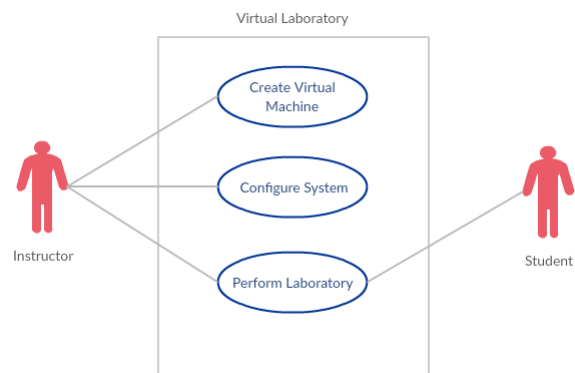


Fig. 3. Use Case Diagram of proposed system

The students of the system can perform the set laboratory tasks. A remote connection is required to access the laboratory platform. Once login has been established, users can now carry out various penetration tests on the VM instance that has been created.

IV. RESULTS

This section shows the results and output from the developed Software Defined Network (SDN). The screen-shot of the designed system is shown in Fig 4.

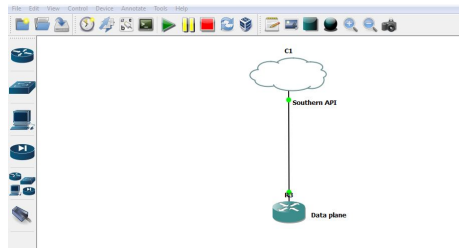


Fig. 4. Developed system on GNS3

The system was tested by implementing a Penetration Testing Lab. The details of the tests conducted are presented as follows.

- 1) Scanning of the networks.
- 2) Test for SQL injection vulnerability on webserver.
- 3) Perform SQL injection on the web server

A. Scanning

Zenmap, a GUI scanning tool is used to scan the internal and external networks which are 10.10.10.1/24 and 192.168.10.1/24 respectively. The results of the scanning are shown in Fig. 5

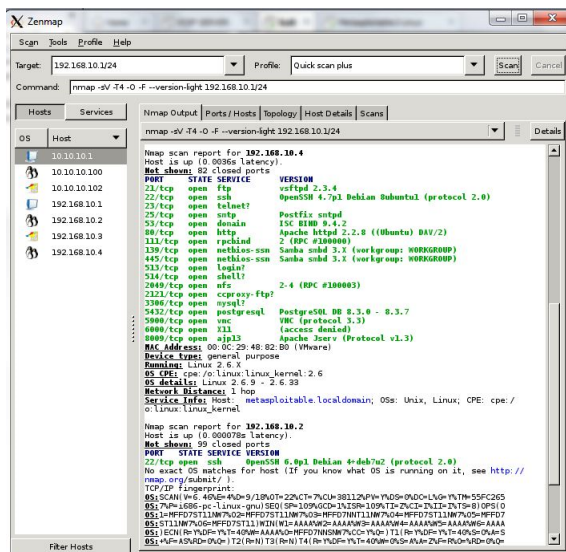


Fig. 5. Result of Network Scanning

B. Testing for SQL Injection

A single quote (') or 'or 1 = 1' was submitted to the webserver to test for SQL injection vulnerability. An error being generated afterwards indicates the presence of such vulnerability as shown in Fig. 6

C. Exploiting SQL Injection

Burpsuite proxy is used to intercept the request and the request is sent to SQLMAP, a database exploitation tool. To run burpsuite, "burpsuite &" command is sent to the shell. On default, burpsuite intercepts the request sent to the database and it is saved in a file. All request information saved in

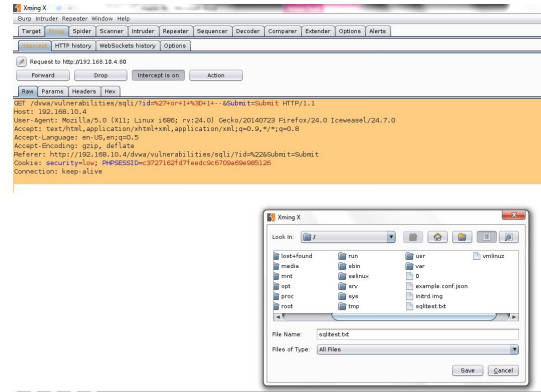


Fig. 7. Exploiting SQL Injection

sqlite3.txt will be used by sqlmap to exploit the database. The process of exploitation is shown in Fig. 7.

V. CONCLUSION

A virtual laboratory was designed, implemented and tested using virtualization and SDN technologies. It was designed using GNS3 and VMware workstation. Network penetration test was conducted to determine the efficiency of the developed system. It can be concluded from the results that the virtual laboratory has the potential of enhancing learning in practical oriented courses because of the ease of conducting practical sessions and the elimination of procurement cost of laboratory equipments.

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Fig. 6. Result from SQL Injection Test

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