Design and Assessment of an Experimental SDN-Enabled Private Cloud using Openstack

Adib Habbal[1], Suhaidi Hassan[1], Belaid Mohammed Addokali[1], Nabil Benamar[2]
[1]*InterNetWorks Research Laboratory,*
School of Computing, Universiti Utara Malaysia,
06010 UUM Sintok, Kedah, Malaysia.
[2]*Moulay Ismail University of Meknes, Morocco.*
adib@uum.edu.my

***Abstract*—Nowadays, educational and research institutions, especially universities, have considered their focus on cloud computing rather than using conventional prospects to take the most benefits of the services offered to support current trends in teaching and learning strategies. To build these networks in a cost effective way, open source cloud computing platforms are used. One of the powerful tools is Openstack, which allows users to create virtual networks and manage virtual machines within distributed learning environments. In this article, we describe our project on designing and evaluating a private cloud within a university environment using Openstack. To this end, we conduct a survey to measure the students' attitude towards the use of private clouds in which students and experts serve as samples. We design a virtual lab consisting of a number of virtual machines operated by a selected sample. We evaluate the proposed solution by adopting Technology Acceptance Model (TAM) methodology. The results obtained from this study show that the students' acceptance in using the private cloud in performing their tasks is encouraging albeit their anxiety on security issues and their lack of experience.**

***Index Terms*—Distributed Learning Environments; Cloud Computing; Technology Acceptance Model; Openstack.**

I. INTRODUCTION

The Rapid development in information technologies (IT) and the continuous change of educational needs, along with the significant growth in the volume of data and information exchange, has created various challenges in managing university's network. Because of these challenges, educational institutions have limitation on the ability to manage and control the information effectively in their own networks. Further, the conventional forms of IT services in universities may pose a strong barrier on the way of modern educational process. Among the factors that affect technology migration are the cost of hardware, software and operational cost of human resources that may be unaffordable to the university [1]. Services virtualization and cloud computing approaches have been popular options for the universities to achieve the highest returns of its technology investments, protect and manage their information effectively and efficiently and, at the same time lowering their operating cost.

Cloud computing offers a great opportunity and benefit for universities's residents (i.e., students, researchers, and faculty members). It provides access to applications, services and computer resources from any place with Internet connection. Also, it permits to share resources, including data storage space, networking facilities, and computing processing power. Moreover, Cloud computing allows users to use the software and hardware which are provided by the network or the Internet at remote locations such as on-line inventory system, social networking, mail services, and e-commerce applications [2]. Generally, educational and research institutions are using dedicated computer resources and servers for their students or staff, which are permanently or temporarily based on the fluctuation of the numbers of users. This leads to frequent change of the servers and computer resources, which is impractical and constitutes inefficient exploitation of the resources [3].

This paper describes the private cloud network we build for the purpose of the current study. The main aim of this work is to design and implement a private cloud within a university research laboratory based on OpenStack. The second goal is to explore and determine the extent of benefits that can be obtained from the developed private cloud. The remaining of the paper is organized as follows: The next section presents the background and the related works on Openstack and software-defined networking. Section 3 describes the design and implementation of an SDN-enabled private cloud. Section 4 describes the assessment and performance evaluation of the implementation, while Section5 presents the analysis of the results. Finally, Section 6 concludes the paper and suggests further research works.

II. BACKGROUND AND RELATED WORKS

Virtualization in its simplest signification is the ability to create a virtual version of something. In the context of computer sciences, virtualization is the capability of creating multiple instances of different operating systems, applications, and other resources and run it in one server. This server can act as one or more servers virtually [5]. Software that runs on those servers is separated from underlying hardware. Indeed, a thin layer of software called hypervisor controls the virtual machines created in that specific server. The hypervisor lies between hardware and the operating system and can run one or more virtualized operating systems concurrently [6], as shown in Figure 1.

Figure 1: Virtualized Server Architecture

Creating cloud computing without virtualization is more complicated, costly and provides less services and features. Some researchers [7] proposed creating cloud networks without virtualization by removing the hypervisor and assigning each operating system to one core in the CPU. However, such a solution imposes more complexity on cloud networks setup and configurations. Therefore, one should build the cloud on a virtualized infrastructure by creating virtual servers on the top of the existing network.

A. Openstack

Openstack is an open-source platform for building software-defined cloud computing environment that provides infrastructure as a service, network as a service and storage as a service. The goal of Openstack project is to support cloud services and to provide a smoother control for the cloud to those who wants to build their private clouds in their own data centers. Openstack consists of several components, as shown in Figure 2, Dashboard ("Horizon") provides a web front end to the other OpenStack services, Compute ("Nova") stores and retrieves virtual disks ("images") and associated metadata in Image ("Glance"),Network ("Neutron") provides virtual networking for Compute, Block Storage("Cinder") provides storage volumes for Compute, Image ("Glance") can store the actual virtual disk files in the Object Store("Swift"), and all the services authenticate with Identity ("Keystone").

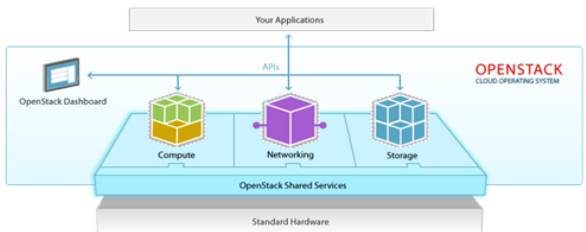

Figure 2: Openstack Software Diagram [4]

B. Software Define Networking

Software Defined Networking (SDN) is a new approach to computer networking [8]. SDN allows network providers and administrators to integrate physical parts of a network with virtual environments. The benefit of this integration is to unlock the capabilities that were never realized before. SDN has direct impact in scalability, flexibility and simplicity in small or large network environments [9]. The rapid growth of SDN and its wide adoption in enterprises has driven the leading IT and networking companies to invest in the market.

The network layer architecture has control plane and forwarding plane (data plane). The control plane controls how to prepare paths and the proper way to send packets over the network while the forwarding plane parses packets, manages, and deals with user traffic. The key point in SDN is decoupling control plane and forwarding plane, centralize the control plane and provide (API's) to control the planes programmatically. The programmable control plane can divide one network into more virtual networks; each network has its own policy [10].

There are many previous works that have studied cloud computing, virtualization and Openstack implementation, both in the educational and general contexts. In a project implemented by a group of students at Gjovik University College in Norway [11] aiming to build a framework for virtual labs using Openstack, it was found that Openstack is a proper solution for implementing private clouds. The main intention of this project was to build a virtual lab for students, so the teachers can assign virtual machines for students for doing their assignments. Doelitzscher et al. [12] of Hochschule Furtwangen University deployeda private cloud called CloudIA targeted students and staff to provide virtual computers to run e-learning applications, and out-side users for collaboration purposes

III. Design and Implementation of SDN-Enable

This project aims to design and develop a private cloud using Openstack to resolve some of the main challenges being introduced earlier in educational networks as well as to support the implementation of new strategies in teaching and learning activities. The proposed design of this private cloud is divided into two networks named external network and management network. In the External Network, all the nodes are connected to the campus network to let users connect to the dashboard (Horizon) which is used to control the private cloud and provide access to the virtual machines (VM). In addition, all servers can download package updates and security updates via this network. Meanwhile, the Management Network is responsible to manage the private cloud and run the virtual machines. Furthermore, it has been used to guarantee the direct connection between the service nodes away from the external network. This approach avoids consuming network bandwidth if the external network is used or both user access and data management. Figure 3 shows the proposed network topology.

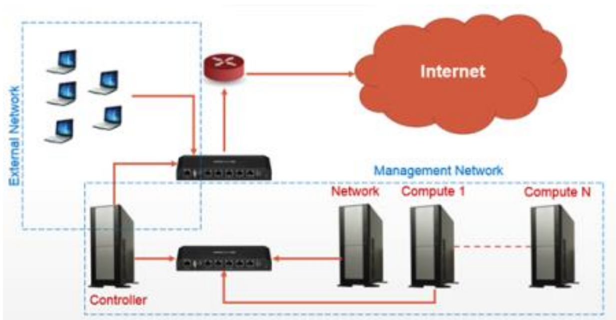

Figure 3: Openstack Physical Network Topology

To implement the proposed network design, three different servers have been used called controller node, compute node, and network node. The controller node server is connected to the external network and the management network to provide the management and authentication. Users and nodes cannot access or run any service without permission from the controller node. The Compute node server is connected to the management network, it is used to manage and host the virtual machines. The Network node server is used to provide connection and bridging between virtual machines and the external network.

Each server must have two Ethernet cards. Ethernet card (eth0) is used to connect the server to the external network while the second ethernet card (eth1) is used to connect the server to the management network. The operating system installed on these servers is Ubuntu 12.04 server edition, because this distribution is fully supporting Openstack-Havana release. Table 1 shows the specifications of these three servers being used to install Open stack services:

Table 1
Server Specification

	Controller Node	Compute Node	Network Node
Brand	HP	HP	DELL
CPU	I5	I7	2.2 GHz Quad Core
RAM	4 GB	8 GB	2 GB
Hard Disk	500 GB	1 TB	80 GB

IV. PERFORMANCE EVALUATION

In this study, the evaluation was divided into two phases. The first phase is about evaluating the ease of use, usefulness, security, functionality and behavioral intention. The second phase is to evaluate the Openstack in terms of installation, configuration and compatibility, and finally network performance during operation.

In our evaluation process, we adopt the Technology Acceptance Model (TAM), which was introduced by Davis in 1986 [13]. It is a widespread model in determining information technology acceptance. It specifies the relationships between system design features, perceived ease of use, perceived usefulness, attitude toward using, and actual usage behavior as shown in Figure 4.

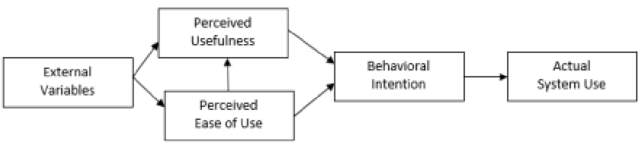

Figure 4: Technology Acceptance Model

Since perceived ease of use and perceived usefulness are not enough to reflect the user's intention to adopt private clouds, additional factors are needed to predict the acceptance of private clouds. Legr is [14] suggested that while TAM is a useful model, it should be integrated into a broader model which would include variables related to both human and social change processes, and to the adoption of the innovation model. One of those factors is the perceived security. This metric is determined by user's subjective evaluation of the service [15]. It is defined as the subjective probability with which consumers (students and experts in the current study) believe that their information will not be viewed, stored, or manipulated during data transmission by unauthorized persons [16]. In addition, the functionality is used to measure students' perception on the function and effectiveness of the system used.

In this work, we use a survey for collecting data about the evaluation of the proposed system from all students and experts. The questionnaire is structured to get reasonable opinions towards the cloud computing phenomena from various respondents, who were required to express their opinion on a Likert scale ranging from 1 to 5 (i.e., strongly disagree to strongly agree).

Before responding and filling the questionnaire by students and experts, the respondents sit for a simple training course to use the Openstack, to create virtual machines and virtual network. For this test, we create a virtual lab (Vir-Lab) to provide a simple course by provisioning ten virtual machines of Linux operating system (Fedora release 20).

The sample includes 50 information technology students divided into groups, and 10 experts in one group. Final respondents were 39 students (29 males, 10 females) and 10 experts participated in this evaluation phase. Seven students did not respond and 3respondents were rejected.

On the other hand and in order to monitor the performance of the Vir-Lab and the status of each server in the cloud, a scalable distributed monitoring system named Ganglia was used to check several system performance metrics such as disk usage, utilization of memory, CPU load, and network traffic

V. RESULT AND DATA ANALYSIS

Descriptive statistics was used due to its convenient and simplicity to analyze the collected data. These statistics took the forms of percentage, mean and frequency distribution. The findings are presented by using tables, graphs, Cronbach's alpha, mean, frequencies and percentages. Table 2 and 3 show the demographic profile of the respondents. Table 4 shows the Cronbach's alpha test to determine the internal consistency and reliability of the results delivered in this study. The commonly used value for Cronbach's alpha is 0.70 for the lower limit of acceptability. Values more than 0.7 indicates that each of these particular items is measured correctly and reliably. All factors in Table 5 have obtained Cronbach's alpha value of more than 0.7, which is a sign of acceptable reliability. Particularly, perceived usefulness, perceived ease of use, and functionality have obtained Cronbach's alpha value of more than 0.8 which is considered very good [17].

Table 2
Respondents by Age

Age	Frequency	%
18-22	8	21%
23-27	16	41%
28-32	11	28%
33-37	4	10%

Table 3
Respondents by Level of Studies

Level	Frequency	%
BSc	12	31%
MSc	21	54%
PhD	6	15%

Table 4
Reliability Analysis Using Cronbach's alpha

Factor	Cronbach's alpha
Perceived Usefulness	.862
Perceived Ease of Use	.876
Perceived Security	.743
Behavioral Intention	.741
Functionality	.806

Perceived usefulness: People tend to use or not to use the information system, which depends on the extent to which the user believes that using the technology enhances the work performance [13]. In this study, perceived usefulness is used to determine the extent of the student's (and the expert) believe whether 285 he can improve his study by performing the tasks more quickly. In the descriptive statistics for perceived usefulness shown in Table 5, most of answers were distributed between agree and strongly agree, this indicates that there is a tendency to acceptance and usefulness. The scores of mean and standard deviation support that elicitation. The highest score is (mean = 4.64, Sd = ~0.49) and the lowest score is (mean = 4.46, Sd = ~0.60).

Perceived ease of use: even if the perceived usefulness is high, sometimes, users are not satisfied when making efforts to use the system [13]. Therefore, the study also focused on perceived ease of use. Table 6 shows the descriptive statistics for perceived ease of use. Like perceived usefulness, most of the answers are distributed between "agree" and "strongly agree", with little "natural" and "disagree". Although, there is no effect caused these two last answers. Results has shown that the value of mean and standard deviation, is above 4, (highest mean = 4.48, Sd = ~0.51) (lowest mean = 4.25, Sd = ~0.63).

Perceived Security: Users that are using systems in networks and Internet must pay attention to the security risks, because usefulness and ease of use are not enough to say that the system is reliable and satisfactory. Most of users worry about the security in network systems inside the university campus, which is very clear in Table 7. The answers are scattered between disagree and strongly agree, which reflects the awareness of the students in terms of system security. The mean is decreased compared to usefulness and ease of use (highest mean = 3.87, Sd = ~0.98) (lowest mean = 3.28, Sd = ~ 1).

Behavioral Intention: Many studies stated that the behavioral intention is positively affected by usefulness and ease of use. Table 8 shows the Descriptive statistics for Behavioral Intention. Agree and strongly agree gain most of the answers. The highest mean and standard deviation is (mean = 4.51, Sd =~0.56) while the lowest is (mean = 4.33, Sd = ~0.53).

Functionality: use to test the user's perception towards the functionality and effectiveness of the system. Table 9 shows the Descriptive statistics for Functionality feature. All scores of mean are above 4 which means that there are satisfaction in the functionality and effectiveness of the system. (Highest mean = 4.51, Sd = ~0.60) (Lowest mean = 4.10, Sd = ~ 0.68).

Experts' perspective is different from students' perspective. Indeed, we find that experts are focusing on the aspects of security and performance factor more than other factors. The analysis of experts' answers in questionnaire shows clearly that they are focusing on security and functionality. Internal consistency and reliability are also high as shown in Table 10. All values are more than 0.70. The respondents' answers indicate that there is a convergence in the answers of experts and students.

VI. Conclusion

The purpose of this work is to design and implement a private cloud environment using Openstack to explore the benefits it can offer in an educational distributed learning environment. In order to achieve the goals of this research, we identified the influencing factors that affect the students' attitude and behavior towards the private clouds, based on TAM. These factors are perceived usefulness, perceived ease of use, perceived security, behavioral intention and functionality. The results obtained from this research show that the students' intention to use private cloud in performing their tasks is positive. In terms of security, there were some anxiety towards the use of private clouds due to the lack of experience. The results obtained from experts give more motivation to implement private clouds in university.

Table 10
Reliability Analysis Using Cronpach's alpha

Factor	Cronbach's alpha
Perceived Usefulness	.875
Perceived Ease of Use	.828
Perceived Security	.812
Behavioral Intention	.745
Functionality	.797

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Table 5
Descriptive Statistics for Perceived Usefulness

Item	N	Mean	Std. Deviation	Min	Max	Likert Scale				
						S. Disagree	Disagree	Neutral	Agree	S. Agree
PU1	39	4.5128	.55592	3.00	5.00	0	0	1	17	21
PU2	39	4.4615	.60027	3.00	5.00	0	0	2	17	20
PU3	39	4.5128	.55592	3.00	5.00	0	0	1	17	21
PU4	39	4.6410	.48597	4.00	5.00	0	0	0	14	15
PU5	39	4.4872	.50637	4.00	5.00	0	0	0	20	19

Table 6
Descriptive Statistics for Perceived Ease of Use

Item	N	Mean	Std. Deviation	Min	Max	Likert Scale				
						S. Disagree	Disagree	Neutral	Agree	S. Agree
PE1U	39	4.4872	.50637	4.00	5.00	0	0	0	20	19
PEU2	39	4.3846	.54364	3.00	5.00	0	0	1	22	16
PEU3	39	4.4615	.60027	3.00	5.00	0	0	2	17	20
PEU4	39	4.2564	.63734	2.00	5.00	0	1	1	24	13
PEU5	39	4.2821	.75911	2.00	5.00	0	2	1	20	18

Table 7
Descriptive Statistics for Perceived Security

Item	N	Mean	Std. Deviation	Min	Max	Likert Scale				
						S. Disagree	Disagree	Neutral	Agree	S. Agree
PS1	39	3.2821	.99865	2.00	5.00	0	11	10	14	4
PS2	39	3.8718	.97817	2.00	5.00	0	4	9	14	12
PS3	39	3.7692	.90209	2.00	5.00	0	3	12	15	9

Table 8
Descriptive Statistics for Behavioral Intention

Item	N	Mean	Std. Deviation	Min	Max	Likert Scale				
						S. Disagree	Disagree	Neutral	Agree	S. Agree
BI1	39	4.3333	.52981	3.00	5.00	0	2	23	23	14
BI2	39	4.4615	.55470	3.00	5.00	0	4	17	17	18
BI3	39	4.5128	.55592	3.00	5.00	0	4	16	16	19

Table 9
Descriptive Statistics for Functionality

Item	N	Mean	Std. Deviation	Min	Max	Likert Scale				
						S. Disagree	Disagree	Neutral	Agree	S. Agree
FN1	39	4.4103	.54858	3.00	5.00	0	0	3	21	15
FN2	39	4.1282	.73196	3.00	5.00	0	0	9	18	12
FN3	39	4.3333	.57735	3.00	5.00	0	0	4	19	16
FN4	39	4.5128	.60139	3.00	5.00	0	0	4	17	18
FN5	39	4.1026	. .68036	3.00	5.00	0	0	8	20	11