Cloudemy: Step into the Cloud

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***Abstract*—Cloud computing is often referred to as a general term for the delivery of hosted services over the Internet, providing users choices among less expensive computing services in terms of user-friendliness, accessibility, and reliability. Thanks to the rapid advancement of technology today, the growth of cloud computing has boomed. However, existing cloud computing platforms and services are too costly for educational institutions to use, and proper platforms that utilize the current services are scarce. In this paper, a prototype cloud service called Cloudemy is developed to provide an affordable cloud service to meet the education needs. Cloudemy utilizes the Openstack framework coupled with a customized attractive web panel for users to interact with the system. Cloudemy allows users to deploy their own servers and make use of the resources at an affordable price all according to their chosen plan and within the scope of teaching and learning. The main contribution of this research work is to provide educational support for students to engage in cloud computing through the use of tutorials and documentations within the cloud platform.**

***Index Terms*—Cloud Computing; Education; Infrastructure-as-a-Service; Openstack.**

I. INTRODUCTION

In IT education, hands-on practice is important for students to improve their problem-solving skills [1] and to gain practical experience. It encourages them not to memorize the steps for exams but rather to grow the skills to manage and develop a real system. Hence, the supervisors or the institutes themselves need to have enough resources to accommodate such needs. However, there are some limitations to implementing such practice. One of them is a resource limitation which has always become the key issue in most institutions. Therefore, the newly developed cloud computing platform may provide an alternative solution to this problem.

According to the National Institute of Science and Technology (NIST), cloud computing can be defined as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [2]. Cloud computing relies on sharing resources and provides primarily three levels of services which are Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS).

IaaS is said to be able to supply virtualized computing resources including servers, storage, and networking as a service over the Internet. Usually, the Cloud Service Provider (CSP) will host and maintain the Cloud virtualization, hardware server, storage, and networks while the consumers just need to maintain the applications, runtimes, integration SOA (Service Oriented Architecture), databases, and server software [3]. There are some characteristics and components of IaaS which allows for dynamic scaling, automates administrative tasks, provides desktop virtualization and internet connection, and has utility computing services and a billing model [4]. Not to mention, there are many types of IaaS providers, divided between proprietary or open source software, such as Amazon Web Service (AWS), Digital Ocean, Openstack, and Microsoft Azure.

However, there are some challenges in utilizing the current IaaS platform for educational purposes. These problems are described below in order to provide a background on the design issues that resulted in Cloudemy becoming a solution.

i. Commercial cloud service providers are too costly for educational institutions to use.
ii. No proper platform for learning and utilizing the current services.

In order to use the current IaaS provider, the consumers need to choose an affordable plan with a wide spectrum for prices, power, and storage capacity. However, the price can still be considered expensive for institutions when it is just for testing and learning purposes. Moreover, the system also does not provide proper guidelines for a beginner to engage in cloud computing. This is particularly true when it comes to the e-learning systems available today, tutorials and documentations for certain courses are prepared however, there is no proper platform to test and practice the knowledge gained.

Based on the problem mentioned above, we came up with the requirements of a cloud computing system for education. To save make it cost realistic, we are adopting the Openstack framework to deploy the IaaS platform for this system. We aimed to provide an affordable cloud service to meet the education needs.

The paper is organized as follows. Section 2 provides literature reviews of cloud computing for education. Section 3 presents a comparison of the existing IaaS platform and e-learning system with our proposed system. Section 4 lists the system scope definition. Section 5 provides the main system features while Section 6 describes the details of system implementation. Then in Section 7, we summarize the results of our implementation and conclude the paper in Section 8.

II. RELATED WORK

The idea of implementing cloud computing for education is not entirely new. Shahid, Mustafa, Chowdhury et al. [5] have proposed a system that utilizes their limited resources in the most efficient way and get rid of third party involvements. It was believed to provide a more secure environment since

the client can also configure his own security policy. They also conducted a comparative analysis of their proposed architecture with the existing system in terms of Data Portability, Economical Feasibility, Overseeing and Reporting, and Distance Learning Education and e-Learning Toolkits to prove their proposed system is better.

However, there are some challenges that need to be made aware to institutions in adapting cloud computing for education. The main concern is related to who controls the data, privacy, security, anonymity, telecommunications capacity, government surveillance, reliability, liability, availability, support, interoperability, and compliance among other [6]. José, Miguel, Eduardo et al. [7] suggested that data encryption should be implemented in order to prevent unauthorized access in the cloud so as to secure the data that is going in and out of the cloud environment. The firewalls also need to be taken care of because it stores the data location. Additionally, organizations may also adopt a private cloud model to ensure data security.

The idea of adopting cloud computing is a good approach to solve some challenges faced by institutions in terms of hardware and software problems such as cost, storage, and scalability [7]. Cloud Service Providers (CSP) usually apply a Pay-Per-Use policy which may reduce the cost spent for resources used. It also allows users to increase the storage dynamically and upscale or downscale the resources easily when required.

Additionally, the advantages of implementing cloud computing for education is also being discussed in many research literatures. In 2012, Abdullah, Ahmed and Emam [8] did a research on how cloud computing can benefit e-learning education in the Kingdom of Saudi Arabia (KSA). They discussed the cloud computing education environment and explored the advantages that institutions can get from implementing cloud computing in their education system. The same idea was discussed by Getso and Ahmed [9] in 2014 which in turn lead them to propose a system for administrative staff and educators which can work in any cloud deployment models like private, public, or hybrid clouds. Cloud computing is believed to be able to give advantages in terms of efficiency, reliability, portability, flexibility, and security [7]–[9].

III. System Review

By utilizing Openstack, Cloudemy is first and foremost an IaaS platform. As such, a comparative analysis between IaaS providers was done based on the following parameters:

i. Cost: fee for implementing and utilizing the IaaS platform.
ii. Migrations: methods for migrating the IaaS infrastructure to another cloud in order to accommodate the users' needs.
iii. Scalability: the resources ability to scale vertically (i.e. add/remove instance capacity) and horizontally (i.e. add/remove instances).
iv. Documentations and Supports: medium for users to engage with the IaaS platform.
v. Hypervisor Support: manages and orchestrates the hardware resources and provides a virtualization platform to the guest OS.
vi. Customer and Operations Access: medium for users to interact with the system.
vii. Storage Support: support for the virtualization and orchestration of the storage.
viii. Network Support: network management for shared network resources.
ix. APIs: set of functions which developers can perform requests and receive responses.

The following tables provide a concise look at the contrast between the systems that are similar in function to Openstack. Table 1 compares systems that act as IaaS providers in terms of non-technical aspects and Table 2 compares the technical aspects.

Table 1
Comparing Non-Technical Features

System	VMware	Openstack	oVirt
Cost	License and migration fees	Open Source (Free but may be charge for maintenance fee for enterprise support)	Open Source (Free but may be charge for maintenance fee for enterprise support)
Migration	VMware converter for P2V and others virtualization format	OpenStack any to any through built-in qemu tools	Vdsm Disk Images
Scalability	Max 32 physical nodes on VMware vCloud, though not recommended	No actual limitation (might be handy create different availability zones)	Max 4,096 logical CPUs/64TB per host and max 64 vCPU and 2TB vRAM per guest
Documentation and Support	VMware commercial telephone or web support	OpenStack active community and vendors support	oVirt active community and vendors support

Table 2
Comparing Technical Features

System	VMware	Openstack	oVirt
Hypervisor	ESXi (default hypervisor)	Support variants hypervisor and container (KVM, Xen VMware ESXi, Microsoft Hyper V, Citrix Xen, Docker, LXC)	KVM and Libvirt
Customer and Operations Access	Windows Clients, Web console, API	Open API, CLI, Horizon (Dashboard)	Web Client
Storage	VMFS over SAN and iSCSI	Default non-persistent images. Pluggable Cinder (block volumes, Cepth, several vendor SAN)	FC, NFS, iSCSI, and local Storage
Network	Traditional switching infrastructure, SDN with additional product	Traditional switching	Data center + cluster network (logical network definition) and vNIC profiles + vNICs (the network usage)

System	VMware	Openstack	oVirt
APIs	vCloud API	Open REST APIs, Horizon (Dashboard) and Openstack CLI	OVirt API, Open REST APIs and Web Client

IV. System Scope Definition

In this section, we provide the scope of our proposed system. We also describe the possible benefits that the system may offer. The scope of the system includes the following:

i. An IaaS provider's capability in order to provide and manage the server requested by the system.
ii. A login system to allow the administrators, supervisors, and students to enter the required data for authentication to access into the system.
iii. A server management system to control the creation of new server and to manage (edit or destroy) the existing servers.
iv. A course system that provides tutorials and documentations for users to engage with cloud computing.
v. An account management subsystem to control the creation of new sub-accounts and to manage (edit or delete) the existing sub-accounts.
vi. A profiling subsystem to edit and track general information about the user (username, email address, resources, etc.).

Cloudemy also provides capability for users to get in touch with the administrators for any inquiries or to report bugs. It provides a frequently asked questions (FAQs) page to give users more information regarding the system. Cloudemy has the following expected benefits:

i. Provides an affordable IaaS platform for institutions to provide for students and supervisors.
ii. Provides an IaaS platform that is modular, making it highly scalable.
iii. Provides step-by-step guidelines for beginners to engage with cloud computing.

V. System Features

Cloudemy includes many features that can be utilized by users to deploy servers and to help them in engage with cloud computing. The features of the system include the following:

i. User friendly interface for users to interact with the system. The user interface might differ depending on their type of role. For instance, some roles have a special pane for managing their sub-accounts.
ii. Deploying and managing servers with the option to customize their own resources. However, it is limited to the resources that have been allocated to them only.
iii. Online courses to support and help their cloud computing learning process. It is always available for use without time-oriented or progress-oriented features that will restrict its usage.
iv. Security features are incorporated into the system. We take into consideration an SQL (Structured Query Language) injection that might destroy the database. Moreover, all the passwords stored in the database are irreversibly hashed to prevent the data from being used if the database is hacked. SSH key pairs are also being used to authenticate the user before accessing the server.

VI. System Implementation Methodology

In this section, we decided on how the system will operate in terms of software, hardware and architecture. We will present the techniques and tools that were used to develop the system. We were adopting Extreme Programming (XP), a software development methodology to improve software quality and to stress on customer satisfaction. We divided the project into several iterations and make small release for each iteration to ensure the features are functioning well. Hence, the proposed system is developed using tools and architecture described as follows.

A. The Implementation Environment

The architecture of our IaaS system is developed using Openstack, an open source software, to take advantage of its modular technology besides reducing the development cost. For the web panel side, we are using W3.CSS alongside Bootstrap 3 framework to work on the frontend design and PHP 7 as the computational backend. W3.CSS and Bootstrap 3 has many inbuilt CSS helper classes which increase the speed of the development significantly. A brief description of the languages and tools are given in Table 3.

Table 3
Tools and Languages

Tools	Description
Openstack	An open source cloud computing software that provides Infrastructure-as-a-Service cloud deployment for public and private cloud [10].
W3.CSS	A responsive and modern CSS framework
phpMyAdmin	A free and open source tool to manage MySQL or MariaDB administration using a web browser.
Apache	The world's most used web server software.
MySQL	An open source relational database management system (RDBMS) based on Structured Query Language (SQL).
PHP7	Recursive acronym for PHP: Hypertext Preprocessor. It is an open source general-purpose scripting language. It is best suited for web development and can be embedded into HTML.
Bootstrap3	A free front-end framework for web development. It includes HTML and CSS based design templates.
HTML5	A markup language used for structuring and presenting content on the World Wide Web (WWW). It is the current version of the HTML standard.
CSS3	The latest version of the Cascading Style Sheets (CSS) language. It is used for describing the presentation of a document written in a markup language.

B. The Implementation Concept

For the implementation concept, we needed to design an architecture that is capable of virtual machine deployment and management. In this case, the Openstack framework is utilized, whereby modules and nodes are implemented. Figure 1 describes the Cloudemy high-level system description. The figure illustrates that the users can interact with the system using different kinds of devices over the Internet. On the system side, it interacts with the database for data exchange. The system needs to communicate with Openstack to retrieve the information needed through APIs. In the Openstack architecture, several modules were used. The modules included in the system are as follows:

i. Neutron (Network): manages networks and IP

addresses of the system.

ii. Nova (Compute): a cloud computing fabric controller designed to manage and automate pools of computer resources.
iii. Cinder (Block Storage): provides persistent block-level storage devices for instances.
iv. Horizon (Dashboard): provides a graphical interface for users to access, provision, and automate deployment of cloud-based resources.
v. Keystone (Authentication): provides a central directory of users mapped to the Openstack services they can access.
vi. Glance (Images): provides discovery, registration, and delivery services for disk and server images.
vii. Heat (Orchestration): orchestrates multiple composite cloud applications using templates.

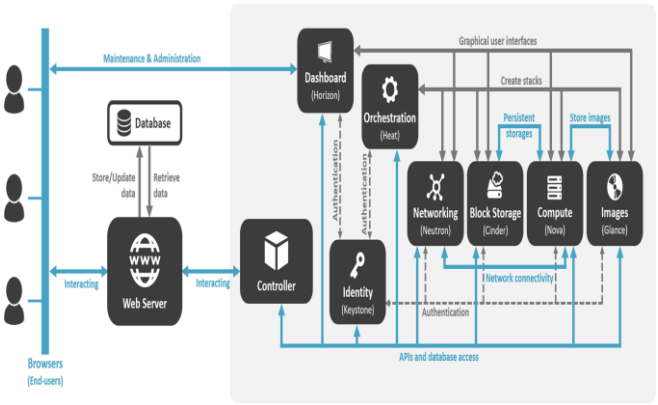

Figure 1: Cloudemy High Level System Architecture

As for the website, we decided to create an architecture design that separated the back-end logic from front-end presentation. Thus, we adopted the Model-View-Controller (MVC) approach that separates the system into three main logical components which are the model, the view and the controller. Each of these interconnected parts will handle different areas of development of the system. The MVC pattern is described as Figure 2.

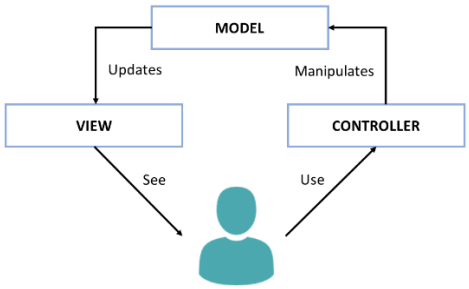

Figure 2: Interaction within MVC pattern

The Model component correlates with all the data-related logic that the user works with. It is the central component of the pattern which expresses the application's behavior. On the other hand, the View component is used for all the User Interface logic of the system. It contains all interface specific functions and enables the presentation of content and processing logic [11][11]. The third part, the Controller model, will accept inputs and convert them to commands for the Model or View. Usually, in web applications, the Controller will update the View by using data from the Model based on user inputs.

MVC is believed to support parallel development that results in a rapid development process. By using this approach, we are able to do pair programming where one of us works on the view and the other works on the controller to create the business logic of the system. MVC also supports multiple views for a model and any modification does not affect the entire model.

VII. System Results

By using the tools and architecture as mention before, an educational IaaS system with strong set of features was developed for the Cloudemy prototype. Cloudemy consists of 5 main pages which are Login, Dashboard, My Profile, Manage Users, and F.A.Q. As a reference, some samples of user interfaces for the system are included as in Figure 3 and 4. It should be noted that the target users consist of three categories which are administrators, supervisors, and students. A brief description of system functionality will be discussed in this section.

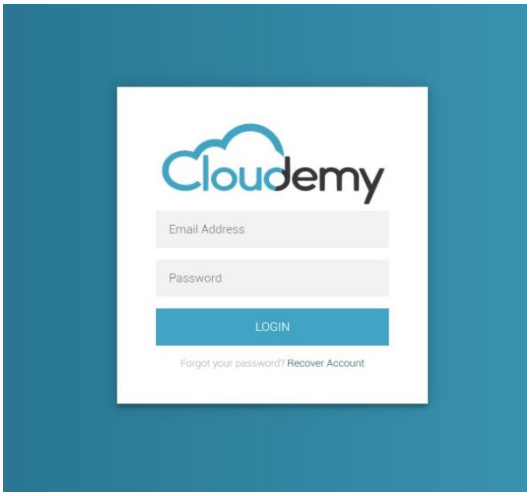

Figure 3: Login Page

Figure 4: Dashboard Page

The first step before accessing into the system is that users need to fill in required information at the Login page. Some security features are implemented in this system to protect from illegal attacks. For instance, the latest version of MySQLi and PHP were used and the passwords are irreversibly hashed. Double validation of form input is also being executed at the front-end and back-end part of the

system to prevent any SQL injection attacks. In addition, during the login phase, only three attempts are allowed in a session. If the user fails to be authenticated after the third attempt, he or she will need to wait for 2 minutes before trying again.

At the Dashboard page, there are two distinct views which are Cloudemy Courses and Server Details. Cloudemy Courses contains tutorials for students to engage cloud computing while Server Details is for hands-on practices. Users can deploy new servers and manage them in this section. By placing these two views side by side it might help users interact with Cloudemy easier without the need to change pages constantly during their practices. On the other hand, My Profile page allows users to manage their account details such as username, email address, password, SSH keys, and others. In case there are any inquiries, users can view F.A.Q page to get more information. The questions that are provided were collected from the participants during usability testing.

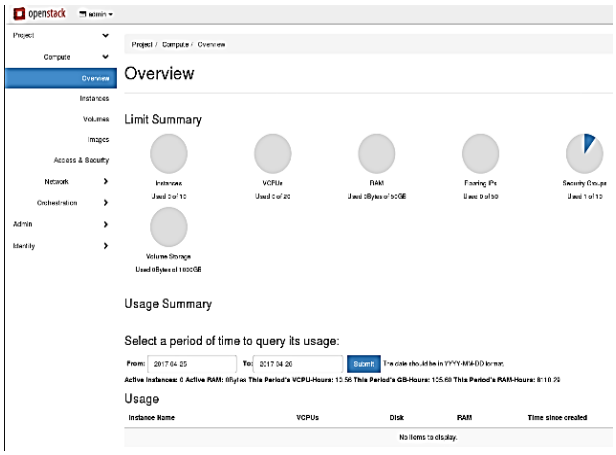

Figure 5: Openstack Dashboard

Manage Users page is only for administrators and supervisors to manage their sub-accounts. Administrators can create accounts for supervisors while supervisors can create new accounts for their students. In this page, administrators and supervisors can view and manage their allocated resources accordingly. Besides having full access in the web panel, administrators can also fully utilize the Openstack dashboard to manage all of the resources. Openstack dashboard is a user friendly and simple back-end panel that might help administrators in managing the system. The Openstack dashboard is shown in Figure 5.

VIII. CONCLUSION

Considering budget restriction and resources limitation in academic institutions to utilize cloud computing in IT activities, Cloudemy provides a good foundation in learning and implementing cloud solutions. Some rigorous testing has been conducted to prove its reliability and usability. Evaluation of the system under different scenarios and conditions also gives a clear indication of its worth. However, there are some recommendations for future enhancements that might be helpful.

From a developers' perspective, there are few areas that can be improved further. The Openstack software could be upgraded to its latest version for the improved monitoring module (Ceilometer) added to the Openstack architecture. Since this system will be used for commercial purposes later, the data collected from the Ceilometer may be used to provide customer billing, resource tracking, and alarming capabilities across all Openstack core components. Moreover, a custom courses feature might need to be considered for future enhancement in order to allow supervisors to create new courses that fit their own areas. Thus, with respect to student activities, a course enrollment feature may need to be developed for them to keep track of their own progress.

Overall it may be said that Cloudemy strives to assist institutions in providing an affordable cloud platform for educational needs. It is designed to be simple and easy to use.

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