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ABSTRACT

In recent years, schools have been investing heavily on information and communications technology (ICT) infrastructure to implement eLearning systems to enhance the quality of education in secondary schools in Tanzania. The majority of these systems are implemented using a traditional web-based eLearning approach on school premises which is costly and limits usage due to lack of scalability and flexibility. Consequently, many schools have started adopting cloud computing as a solution. However, this adaption depends on well-defined cloud eLearning architecture. This study proposed cloud architecture for implementing an eLearning system in secondary schools in Tanzania by adopting various layers proposed in previous studies. The effectiveness of this proposal was evaluated by comparing its performance with a similar traditional web-based eLearning system using the Moodle benchmark tool and Apache Jmeter. The study found that eLearning systems implemented in the cloud-based infrastructure had better performance metrics than web-based eLearning systems on school premises.

Keywords

Cloud computing, eLearning, Internet, Secondary schools

INTRODUCTION

In recent years, schools have been investing heavily on ICT infrastructure and human resources to implement various eLearning systems in order to enhance the quality of education in secondary schools in Tanzania. Studies have shown that eLearning solutions can support students with different learning styles (Mtebe and Twaakyondo, 2012) as they are normally presented in visual and/or auditory channels via multiple formats, such as graphics, video, and audio (Lin and Atkinson, 2011). With these benefits in mind, the government and partners have been equipping schools with ICT facilities and implementing various eLearning systems for sharing digital content to the majority of students countrywide. Towards the end of 2017, nearly 31% of government schools were equipped with computers with 20% of them being connected to the Internet (MoEST, 2017). Moreover, Halotel and Tigo mobile firms supported 400 and 700 schools, respectively, with computers connected to the Internet in selected regions in Tanzania (Kazoka, 2016; Tanzania TELECOMS, 2016).

Similarly, several eLearning systems have been implemented aiming at sharing digital content with students countrywide. For instance, the College of Information and Communication Technologies (CoICT) in collaboration with Halotel Tanzania developed the Halostudy system consisting of digital content for science and mathematics for Form 1 to Form IV and deployed it to 426 schools (Mwakisole, Kissaka, & Mtebe, 2018). The Brainshare firm developed audio-video digital content of English, mathematics, science, and social studies for secondary students (Raphael and Mtebe, 2017). Christian Social Services Commission (CSSC) developed an eLearning system consisting of digital content of all subjects for secondary schools in Tanzania (CSSC, 2014). Other initiatives that have developed various eLearning systems for sharing digital content include Shuledirect (Mtebe and Kissaka, 2015), 21-ICT Solutions, retooling project (Mtebe, Mbwilo, and Kissaka, 2016), Offline Personal Learning Environment for mathematics (Mselle and Kondo, 2013), and simulations and experiments (Msoka, Mtebe, Kissaka, and Kalinga, 2015).

Despite the continued adoption and implementation of several eLearning systems in secondary schools, several challenges still exist. The implementation of these systems require high initial cost on the ICT infrastructure and software applications as well as human resources to manage them (Chandran and Kempegowda, 2010; Dong, Zheng, Yang, Li, and Qiao, 2009; Laisheng and Zhengxia, 2011; Radenkovic, Despotovic-Zrakic, Bogdanovic, Vujin, and Barac, 2014). Schools require approximately US$25,000 to implement an eLearning system on premise for three years (Mtebe and Raisamo, 2014) in addition to the cost of developing digital content (Selviandro and Hasibuan, 2013). This cost is not affordable to many schools in Tanzania and beyond.

Moreover, many schools have been implementing these systems using a traditional web-based eLearning approach on school premises. As a result of this approach, these systems lack scalability, flexibility, and interoperability (Phankokkruad, 2012). In other words, several resources can only be deployed and assigned for specific tasks, so when receiving high workloads, the system must add and configure new resources of the same type, making the cost and resource management very expensive (Fernández, Peralta, Herrera, and Benítez, 2012). This is to say, the traditional web-based mode does not adequately provide efficient utilization of computing resources, resulting in under-utilized resources during the night and semester breaks.

Given these challenges, many schools have turned their attention to cloud computing as a solution for implementing eLearning systems. Cloud computing offers a dynamic provision of virtualized resources, elasticity, and pay-as-you-use service with the ability to dynamically provision and de-provision resources as needed (Aljenaa, Al-Anzi, and Alshayeji, 2011). By adopting cloud computing, schools will no longer be required to procure and host ICT infrastructure on their premises to implement eLearning systems. All ICT infrastructure, software, and eLearning services can be hosted in cloud provider servers. Students can access these services via the Internet. This approach enables schools to reduce costs associated with hardware purchase, software licensing, electric power, cooling, and salaries for information technology (IT) support staff (Carroll, van der Merwe, and Kotzé, 2011; Mokhtar, Ali, Al-Sharafi, and Aborujilah, 2013; Sultan, 2010).

Nonetheless, effective adoption of cloud computing into eLearning depends on well-defined cloud architecture taking into account challenges facing eLearning in a specific context (Mircea and Andreescu, 2011). It also depends on the computational needs and user requirements of a particular learning context (Mokhtar et al., 2013). In several studies, cloud architectures have been proposed to serve as a basis of implementing eLearning in various contexts, such as those in Masud and Huang (2012), Phankokkruad (2012), and Selviandro and Hasibuan (2013). However, far too little attention has been paid to developing cloud computing architecture for implementing eLearning systems for secondary schools in Tanzania.

This study proposed cloud architecture for implementing eLearning system in secondary schools in Tanzania by adopting various layers proposed in previous studies. Through this architecture, schools can leverage powerful computing resources which are provided as a service for hosting and running eLearning systems with minimum investment in terms of infrastructure and human resources. The study also compared the performance efficiency of the eLearning cloud-based solution with that of the traditional web-based eLearning approach. This study is expected to raise the awareness of possibilities to adopt cloud computing to reduce the cost associated with eLearning systems implementation, and in enhancing teaching and learning in secondary schools in sub-Saharan countries.

LITERATURE REVIEW

Cloud Computing

The National Institute of Standards and Technology (NIST) defines cloud computing 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” (Mell and Grance, 2011, p.2). It allows dynamically scalable computing resources, software, and applications to be provided to users as a service over the Internet. There are three cloud-based services: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). The IaaS model enables users to manage and configure the cloud servers similar to the ordinary physical servers. In an eLearning context, for instance, the model will enable schools to configure eLearning systems into the cloud servers and pay per usage instead of configuring and hosting within school premises. Some good examples of IaaS providers include Amazon Web Services, Windows Azure, Google Compute Engine, and Rackspace Open Cloud.

The PaaS model provides facilities to support software developers in designing, implementing, testing and deployment of web applications. In the context of eLearning, developers can develop eLearning solutions such as animations and simulations using already available tools in the cloud without requiring the purchase and installation of software applications on their own computers. Examples of tools provided by PaaS include MySQL server, Apache, Tomcat, and LAMP stack. The SaaS is a model that offers software or applications that run on the cloud which users access via the Internet (Mokhtar et al., 2013). The SaaS delivers applications that are hosted and run by the service provider and consumers pay per use. Examples of SaaS applications include Google Play Store, Microsoft Office 365, Dropbox, and Salesforce.

In addition to these services, cloud computing can be deployed into four different approaches: private cloud, public cloud, community cloud, and hybrid cloud. The private cloud is the cloud infrastructure dedicated exclusively to be used by a single organization (Mell and Grance, 2011). It enables providers and end users more control of cloud infrastructure, data, and processes being managed within the organization (Aljenaa et al., 2011). The public cloud is the model that provides cloud infrastructure to be used openly by the general public (Mell and Grance, 2011). Some of the public cloud service providers include Amazon, Microsoft, and Google. The community cloud shares infrastructure between several organizations from a specific community with common concerns such as security, compliance, and jurisdiction (Mell and Grance, 2011). Finally, the cloud computing can be deployed as a hybrid cloud composing of two or more clouds (private, community, or public) that remain unique entities but are bound together, offering the benefits of multiple deployment models (Mell and Grance, 2011).

Related Works

In the last few years, several organizations have been adopting cloud computing in order to reduce the cost associated with the eLearning implementation in various contexts. For instance, Phankokkruad (2012) proposed architecture with three layers: infrastructure layer, platform layer, and application layer. The infrastructure layer is used for virtualization technologies to ensure the stability and reliability of the eLearning infrastructure. The platform layer provides the learning resources as a service through the middleware. The application layer provides an interface for users to access eLearning resources. It also provides content production, content delivery, virtual laboratory, collaborative learning, assessment, and management features.

Masud and Huang (2012) proposed an architecture consisting of four layers: infrastructure layer, application layer, resource management layer, and software resource layer. The infrastructure and application layers are similar to those layers proposed by Phankokkruad (2012). The software resource layer offers a unified interface for eLearning developers. The resource management layer achieves loose coupling of software and hardware resources containing three levels of services (i.e., software as a service, platform as a service, and infrastructure as a service).

Similarly, Selviandro and Hasibuan (2013) proposed an architecture consisting of five layers: infrastructure layer, platform layer, application layer, access layer, and user layer. In this study, the first three layers are similar to layers proposed by Masud and Huang (2012) and Phankokkruad (2012). However, the authors added two new layers: access layer and user layer. The access layer manages access to cloud eLearning services which are available on the architecture, such as types of access devices and presentation models. The top layer is the user layer which consists of various educational institutions.

El-Seoud and colleagues (2013) proposed an architecture consisting of four layers: physical hardware layer, virtualization layer, education middleware layer, and application program interface layer. The physical hardware layer and virtualization layer are a split of the infrastructure layer proposed in previous studies. The education middleware layer forms a basic business platform of eLearning. The application program interface layer provides the necessary interface for hosting the service and the model's scalability.

Generally, several cloud-based architectures for eLearning have been proposed in the literature such as those in Chandran and Kempegowda (2010), Guoli and Wanjun (2010), and Xu, Wu, Daneshmand, and Liu (2015). The majority of proposed architectures differ in the services they provide to the particular eLearning context (Doelitzscher, Sulistio, Reich, Kuijs, and Wolf, 2011; Puthal, Sahoo, Mishra, and Swain, 2015). However, there are a limited number of studies that developed cloud-based architecture for the secondary school environment particularly in the Tanzanian context. Therefore, this study aimed to address the identified gap in the literature.

PROPOSED CLOUD-BASED ARCHITECTURE FOR ELEARNING

The proposed architecture has extended the existing cloud-based architectures, specifically those proposed by El-Seoud and colleagues (2013), Masud and Huang (2012), Phankokkruad (2012), and Selviandro and Hasibuan (2013). A summary of layers proposed by each study is shown in Table 1.

	Phankokkruad (2012)	Masud and Huang (2012)	El-Seoud et al (2013)	Selviandro and Hasibuan (2013)
1st Layer	Infrastructure layer	Infrastructure layer	Physical hardware layer	Infrastructure layer
2nd Layer	Platform layer	Software resource layer	Virtualization layer	Platform layer
3rd Layer	Application layer	Resource management layer	Education middleware layer	Application layer
4th Layer	x	Service layer	Application program interface layer	Access layer
5th Layer	x	Application layer	x	User layer

Table 1. Layers of Previous Cloud eLearning Architecture

The layers were carefully selected based on requirements of eLearning in secondary school education in Tanzania. The proposed cloud-based architecture for secondary schools has six layers. The description of each layer is explained next.

Infrastructure Layer

The infrastructure layer forms the foundation of the proposed cloud-based architecture whereby physical servers, storages, network components, and power supply are provided. The layer was adapted from Masud and Huang (2012), Phankokkruad (2012), and Selviandro and Hasibuan (2013). This layer aims to ensure the distribution of computing and storage workload for eLearning systems running on the cloud infrastructure. It will enable schools to rely on cloud service providers for computing and storage services to host and run their eLearning applications instead of procuring and implementing their own infrastructures.

Virtualization Layer

This layer was adapted from El-Seoud and colleagues (2013) and it enables sharing of computing resources which leads to increased resource utilization and cost savings. Through this layer, virtual servers and storages will be created and dynamically allocated to secondary schools and scaled up depending on the workload processing requirements of a given school. It is responsible for ensuring the portability and availability of cloud computing resources for eLearning applications in secondary schools. Schools will be provided with dynamically scaled-up cloud computing resources in real-time adjusting for peak loads placed on their eLearning applications.

Platform Layer

This layer provides cloud-based virtual machines pre-configured and installed with the operating system and other software required for development and hosting various eLearning applications for secondary schools. The layer was adapted from Phankokkruad (2012) and Selviandro and Hasibuan (2013). Through this layer, schools may request virtual machines for running and managing their own applications in the cloud.

Management Layer

The management layer is responsible for the overall cloud infrastructure management, which includes management of servers, hosting eLearning applications, network management, service management, performance monitoring, storage resource management, and usage management metering resources used by individual schools. The layer was adapted from Masud and Huang (2012) aiming at managing the whole architecture.

Application Layer

The application layer is responsible for providing eLearning services to secondary schools. The eLearning applications, such as learning management systems, will be setup and customized depending on the school's requirement. The customization may include front page design to incorporate the school's features to distinguish it from other schools. These systems will be provided as a service to secondary schools across the country. Through this layer, secondary schools will be able to access public educational resources from cloud providers such as Google, YouTube, and Microsoft that are integrated within a secured private cloud in the architecture.

Access Layer

The access layer defines devices to be used for accessing eLearning applications hosted in the hybrid cloud. Various applications will be adapted to different Internet-enabled devices, such as mobile phones and tablets, which are frequently used by secondary school students. This layer will provide an integration of eLearning services and mobile Internet provided by mobile companies in Tanzania through their special dedicated bundles to support education in the country.

Figures 1 and 2 depict the proposed cloud eLearning architecture for secondary schools in Tanzania.

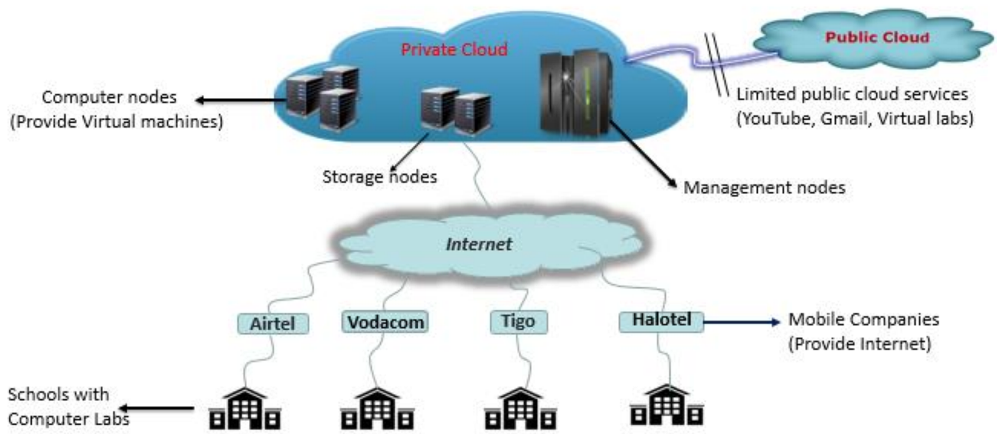

Figure 1. Conceptual View of the Proposed Cloud eLearning Architecture

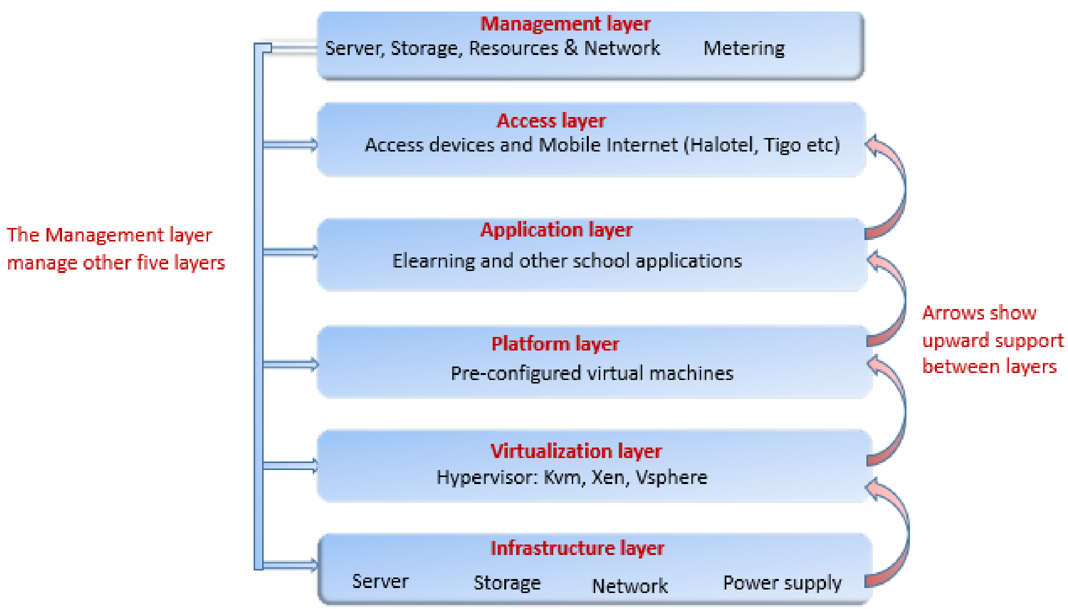

Figure 2. Layers of the Proposed Cloud eLearning Architecture

IMPLEMENTATION OF THE PROPOSED CLOUD BASED ARCHITECTURE

The proposed cloud eLearning architecture utilized Apache CloudStack version 4.9 as a cloud platform. The Apache CloudStack manages network, computing, and storage resources. It is widely used by a number of cloud service providers to offer private, public, and hybrid cloud services (Apache, 2018). The physical setup of the architecture is illustrated using Figure 3.

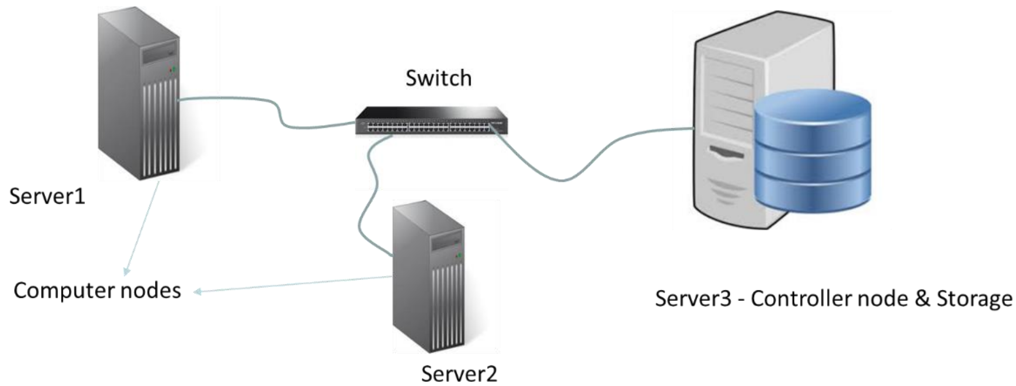

Figure 3. Implementation of the Proposed Cloud eLearning Architecture

The setup consists of two computing nodes (Server 1 and Server 2) which are used to run virtual machines with CentOS version 7.0 installed as host operating system on both servers. Kernel-based Virtual Machine (KVM) hypervisor for virtualization and Cloudstack-agent is installed on each server for administrative tasks. The Controller node (Server 3) is used for unified management of computing nodes, providing resource allocation and other services, such as Application Program Interface (API), Graphical User Interface (GUI), and database. The software installed is Cloudstack-Management and the database engine is MariaDB version 10.2. Figure 4 shows a typical setup done inside of one of the computing nodes.

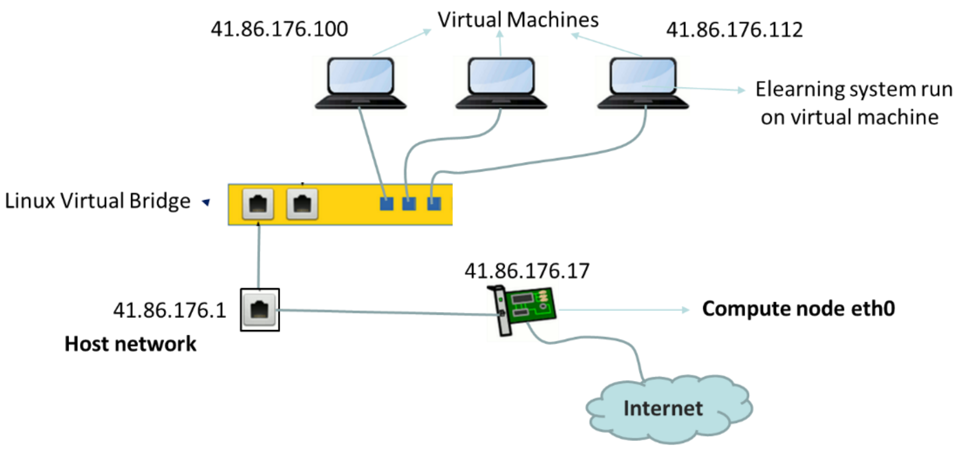

Figure 4. Setup Inside a Compute Node

ASSESSING EFFECTIVENESS OF THE PROPOSED ARCHITECTURE

In assessing the effectiveness of the proposed architecture, evaluation was done to compare the performance of the eLearning system hosted and run on the cloud server and the similar system hosted on a traditional web server. Both cloud and traditional web servers had the same specifications, installed with similar software, and placed in the same network environment. The eLearning system application used was the customized Moodle system. The performance of a cloud computing system was determined by the analysis of the parameters involved in performing an efficient and reliable service that meets requirements under stated conditions (Bautista, Abran, and April, 2012). In this study, the Moodle benchmark tool was used to assess the performance of the proposed cloud-based architecture.

This tool tests the quality of the Moodle system by assessing the server speed, processor speed, hard drive speed, database speed, and page loading. For these parameters, the tool uses the following benchmarks for testing: Moodle loading time, function called many times, reading files, creating files, reading course, writing course, complex request, time to connect with the guest account, and time to connect with a fake user account. The lower the score is the better performance of the system. Three consecutive tests were conducted per server, data were recorded, and their averages were calculated as shown in Table 2, Table 3, and Table 4.

Traditional web server				
Benchmark	**Test 1**	**Test 2**	**Test 3**	**Average (sec)**
Moodle loading time	0.004	0.022	0.005	0.010333
Function called many times	0.107	0.091	0.091	0.096333
Reading files	0.016	0.009	0.009	0.011333
Creating files	3.926	3.743	4.595	4.088
Reading course	0.097	0.098	0.087	0.094
Writing course	1.282	0.874	0.557	0.904333
Complex request	0.087	0.083	0.086	0.085333
Time to connect with the guest account	0.334	0.298	0.35	0.327333
Time to connect with a fake user account	0.496	0.364	0.457	0.439

Table 2. Testing Data for Traditional Web Server

Cloud Server				
Benchmark	**Test 1**	**Test 2**	**Test 3**	**Average (sec)**
Moodle loading time	0.007	0.012	0.007	0.008667
Function called many times	0.104	0.102	0.103	0.103
Reading files	0.037	0.038	0.034	0.036333
Creating files	1.657	1.704	1.664	1.675
Reading course	0.104	0.103	0.103	0.103333
Writing course	0.056	0.056	0.059	0.057
Complex request	0.09	0.093	0.09	0.091
Time to connect with the guest account	0.294	0.289	0.324	0.302333
Time to connect with a fake user account	0.309	0.233	0.254	0.265333

Table 3. Testing Data for Cloud Server

Benchmark	Traditional web server	Cloud server
Moodle loading time	0.010	0.009
Function called many times	0.096	0.103
Reading files	0.011	0.036
Creating files	4.088	1.675
Reading course	0.094	0.103
Writing course	0.904	0.057
Complex request	0.085	0.091
Time to connect with the guest account	0.327	0.302
Time to connect with a fake user account	0.439	0.265

Table 4. Average Testing Data for Two Servers

The average testing data in Table 4 was analyzed and the result of the performance test was compared for two servers, presented by using a graph (See Figure 5). As shown in Figure 5, the performance of the eLearning system implemented and hosted in the cloud infrastructure is higher compared to the traditional approach of implementing and hosting a similar system on the traditional web-based server located on the premises of a typical secondary school.

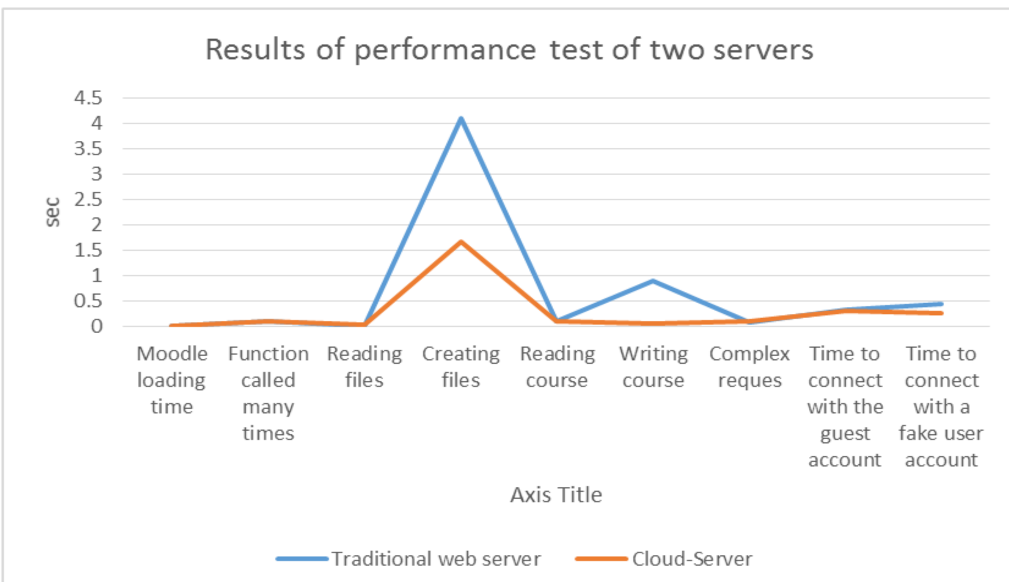

Figure 5. Results of Performance Comparison

DISCUSSION

The implementation of eLearning systems in secondary schools in Tanzania is becoming common. Many schools invest heavily on ICT infrastructure and human resources to implement these systems on their premises. The majority of schools use a web-based approach for implementing these systems, limiting its extensive use, as this model is not scalable and flexible. As a result, several IT services, such as servers and computers, are underutilized due to the structure of teaching semesters (Truong, Pham, Thoai, and Dustdar, 2012). On the other hand, these resources are on high demand towards the end of a semester following a dynamic rule of use (Fernández et al., 2012). Moreover, the web-based architecture of implementing eLearning systems is costly and few secondary schools in sub-Saharan Africa can afford to implement eLearning systems based on the web server approach.

Schools around the world have turned their attention toward cloud architecture for implementing scalable and affordable eLearning systems. Nonetheless, effective adoption of cloud computing into eLearning depends on well-defined cloud architecture taking into account existing challenges in a given context (Mircea and Andreescu, 2011). This study proposed cloud architecture for implementing eLearning systems in secondary schools in Tanzania by adopting various layers proposed in previous studies (i.e., El-Seoud et al., 2013; Masud and Huang, 2012; Phankokkruad, 2012; Selviandro and Hasibuan, 2013). The architecture consists of six layers (Infrastructure, Virtualization, Platform, Management, Application and Access) which are based on the context of secondary school education.

Through this architecture, schools can leverage powerful computing resources which are provided as services for hosting and running eLearning systems with minimum investment. With the cloud-based architecture in this study, the virtualization layer will enable the school to own virtual infrastructure, including its own network, leading to simplified management and giving additional flexibility in increasing computing resources when they are required while paying per usage. The flexibility and automation that comes with virtualization of the network allows both network administrators and application owners to respond more quickly to educational needs (Radenkovic et al., 2014).

The study also proposed the infrastructure layer, which ensures the distribution of computing and storage workload for eLearning systems running on the cloud infrastructure. With the majority of eLearning applications being developed with multimedia content such as audio, video and animations, this layer will enable schools to dynamically upload this content into the cloud servers without being worried about processing power and storage space (Pocatilu, Alecu, and Vetrici, 2010). Due to the limitation of server spaces in a web-based approach, it is not uncommon for schools to have some policies that limit users from storing certain amounts of disk space (Mtebe, 2013). The proposed cloud-based approach will eliminate this problem.

Finally, the proposed cloud-based architecture was compared for performance with the traditional web-based server approach. The Moodle benchmark tool was used to compare the performance of cloud-based architecture for eLearning with that of a web-based approach hosted on a school premise. The study found that the performance of an eLearning system in the cloud infrastructure was higher compared to the web-based counterpart located on the school premises. This finding collaborates with similar studies, such as those by Ahmed (2013), Hamidi and Rouhani (2018), and Radenkovic and colleagues (2014). The majority of these studies found the performance of cloud-based approaches are better than the traditional web-based server approach. This study therefore has demonstrated that in addition to cost saving, the adoption and use of cloud architecture provides higher performance compared to hosting eLearning services on the school premises.

CONCLUSION

With the improvement of ICT infrastructure and proliferation of mobile phones in sub-Saharan Africa, schools will continue implementing various eLearning systems. The current implementation of eLearning systems via the traditional web-based mode on schools' premises is not only costly, but also lacks scalability and flexibility of features. As a result, implemented eLearning systems are wasting their full usage potential in the majority of secondary schools in sub-Saharan Africa. This study proposed a cloud-based eLearning architecture for secondary schools in Tanzania through adopting layers from previous studies. The proposed cloud architecture was compared for performance with a traditional web server. The study found that in addition to cost savings, the performance of the eLearning system implemented and hosted in the cloud infrastructure was higher compared to the traditional approach of implementing and hosting a similar system on the web-server located inside the premise of a typical secondary school.

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