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GUIDELINES FOR WEB SERVER OVERLOAD MANAGEMENT FOR E-LEARNING SYSTEMS: A CASE OF HIGHER INSTITUTIONS OF LEARNING IN UGANDA

BY

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DECLARATION

I, Ejang Edina Nighty do hereby declare that this dissertation is original and has not been published and/or submitted to any other University before.

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APPROVAL

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DEDICATION

I dedicate this work to Holy God who has brought me this far.

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ACRONYMS

MoES	Ministry of Education and Sports
UNCHE	Uganda National Council of Higher Education
SQL	Structured Query Language
MUELE	Makerere University E-Learning Environment
MUBSEP	Makerere University Business School. Makerere University Business School E-Learning Platform
KELMS	Kyambogo University E-Learning Management System
TCP	Transmission Control Protocol
RAM	Random Access Memory
HTTP	Hypertext Transfer Protocol
CPU	Central Processing Unit
URL	Uniform Resource Locator.
ICT	Information and Communications Technology
LMS	Learning Management System
HTML	Hypertext Markup Language
IP	Internet Protocol
ISP	Internet Service Provider
DICTs	Directorate of Information and Communication Technology Support
OS	Operating System
IIS	Internet Information Services
IMAP/POP3	Internet Message Access Protocol / Post Office Protocol Version 3
HLD	Hardware Load Balancing Device

ECLB	Exhaustive Criterion Based Load Balancing
CH	Cluster Heads
CM	Cluster Manager
DHT	Dynamic Hash Table
DB	Databases
MAC	Media Access Address
DSR	Design Science Research
IT	Information Technology
GUELE	Gulu University E-Learning Environment
The BEE	Lira University E-Learning Environment
HDD	Hard Disc Drive
SSD	Solid State Drive
RENU	Research and Education Network Uganda
IODeL	Institute of Open Distance and E-Learning
NIC	Network Interface Cards
FTP	File Transfer Protocol
DBMS	Database Management System
SMTP	Simple Mail Transfer Protocols
MVCC	Multiversion Concurrency Control
ACID	Atomicity, Consistency, Isolation, and Durability
SOPs	Standard Operating Procedures
GIS	Geographic Information System
UUID	Universally Unique Identifiers

ABSTRACT

Globally, e-learning has been adopted as an alternative learning method due to the outbreak of the COVID-19 pandemic in a bid to curb the spread of the virus. In Uganda, the Ministry of Education and Sports (MoES) together with Uganda National Council of Higher Education (UNCHE) issued a directive for all education institutions to adopt e-learning to enable continuity of learning. Because of this directive, customized e-learning systems used by the different institutions of higher learning in Uganda became a better alternative of learning which led to massive uptake of e-learning. E-learning systems are therefore faced with web server overload due to concurrency access especially during peak time leading to poor performance. This affected students in many ways for instance, postponing of examinations, quizzes, tests among others which led to a shift to other platforms such as zoom, Microsoft teams, google classroom among others due to frustration with the poor performance in terms of slow response time. The aim of the research study was to develop guidelines to improve on the performance of e-learning systems that are used in higher institutions of learning in Uganda.

The study adapted the design science research methodology with mixed research methods. The first objective was achieved by conducting interviews which led to the discovery of web server overload causes for the e-learning systems. The second objective was also achieved by conducting interviews with the purposively selected participants which led to the determination of web server overload management strategies deployed by the institutions. These strategies contributed to the development of web server overload management guidelines which was the third objective. The developed web server overload management guidelines were later validated based on the Likert scale to ascertain their relevance and anticipated outcome or implications on the e-learning systems when implemented.

The study developed web server overload management guidelines that can be adopted to improve on the performance of the e-learning systems used at higher institution of learning in Uganda. These guidelines include: the use of least connection load balancing method; configuring a backup or secondary load balancer; hosting e-learning systems on dedicated web servers; upgrading of the database server from MySQL to PostgreSQL Database Management System; clustering of PostgreSQL database into “read only” and “read and write” databases; optimization of the databases through indexing and caching of information using Redis in-memory software. These guidelines can be used in other systems that face web server overload coupled with high concurrency access during peak time.

CHAPTER ONE

1.0. Introduction

Presently, COVID-19 pandemic has forced educational institutions such as universities to rapidly shift to distance and online learning (Almaiah et al., 2020). Millions of e-learning systems and other websites are expected to be up and running 24/7 to support continuous learning. Many schools and institutional administrators were forced to look for alternative means to deliver educational services to their students. E-learning became the most appropriate alternative which was back then considered a supplement to traditional learning. However, the increasing number of students, services, education contents and resources as well as the way of adapting the e-learning system have become problematic (Khedr & Idrees, 2017). This has posed much strain on the available e-learning systems resources which are unable to handle all the million requests from both the students and the lecturers. It has also put a test on the available e-learning systems and unmasked their weaknesses such as slow speed and performance degradation due to the limited resources thus hurting the functionality of the entire system. Bateson (2020) reported that North Carolina Union County Public school's NCEdCloud online learning system which was mainly utilized by teachers to post grades, information, and assignments crashed due to overload as many students tried to access it. The author further explained that notifications about system crash as a result of system overload when many students tried to login at the same time were sent out to parents who were having trouble assisting their children to attend the online classes. Another Online learning system crash was reported by Lanning (2020) from Hillsborough Country school that a flood of web traffic for online services led to a crash of the system when more than 220,000 teachers and students were logging into the district's new eLearning App Canvas. Kokkinidis (2020) explained that the Greek authorities counteracted the incident by regulating their internet usage when the state school e-learning system crashed after just one hour. In Uganda for instance, Krupar (2012) reported that Makerere University E-learning Environment (MUELE) also faced the unpleasant system crash experience when over 26,000 users traversed the site especially around final times. Agaba (2020) also reported that the Public Universities Joint Admissions Board crashed and this caused delays in the private student enrolment process. The users of the system which is hosted at Makerere University were left with no options but to re-upload the students' bio-data information afresh since the manual application forms were still available. The pain of the e-learning system crash was also inflicted on the students of Makerere University Business

School. According to URN (2021), Makerere University Business School E-learning Platform (MUBSEP) failed to handle the large number of online submissions by students during online examination sessions which led to the examination process being postponed.

Important to note is that the massive increase in access of online learning systems became more evident after the new lockdown measures which emphasized home schooling. This consequently put stress on the available resources of online platforms and continues to do so as many platforms are reported to have collapsed when students accessed them concurrently.

Castro (2016) argues that 53% of mobile users abandon websites that take longer than 3 seconds to load. In agreement with the above statement, Shabomwe (2021) reported that the majority of lecturers shifted from using e-learning systems to using other platforms like zoom and other cloud meeting applications. Web server overload has always been the major culprit to this shift, especially with popular websites. According to Queue.IT (2021), it is important to note that, not all user requests are equal as some requests are more complex or demanding than others and it is equally important to know the patterns of requests. Furthermore, as e-learning systems continue to grow in size, they certainly attract more users and therefore necessary web server resources must be in place to accommodate the growing number of users otherwise, performance decline will be noted in terms of speed, quality of service, productivity, throughput as other educators flock to the system. Other consequences of web server overload may include, users receiving partial content, seeing error codes on their screens like 500 (Internal Server Error), 502 (Bad Gateway Error), 503 (Service Unavailable Error) as well as experiencing substantial request delays. Vitkare (2019) explained that web-based system performance is vital and needs to load in the least time possible regardless of the number of users be it 1, 5, 15, or even 500.

System performance is the volume of useful work a computer system can accomplish (Castanheira, n.d). This can be estimated in terms of accuracy, efficiency and speed of task execution, short response time for a given task among others. According to Cast (n.d), minimal response time, high throughput, low resource utilization, high availability, short data transmission time, efficiency and scalability among others are some of the characteristics that are noticed when a system is performing well.

Therefore, this study focused on investigating causes of web server overload, the different web server overload management strategies used in various institutions of higher learning in Uganda and also investigating the e-learning systems infrastructure, policies, technical staffing, network

and cloud service providers at the higher institutions of learning and recommended suitable web server overload management strategies that can be adopted to improve the performance of e-learning systems used at institutions of higher learning in Uganda.

1.1. Background

As part of the new education trend, Agaba (2020) explained that Makerere University adopted the Makerere University E-Learning Environment (MUELE) which is a Moodle-based Learning Management System backed by some of the best ICT infrastructures. Samilu (2021) explained that e-learning systems enable lecturers and instructors to upload learning materials and also add interactive activities by using discussion forums, uploading assignments and quizzes among others. The author further explained that the interactive features are meant for students to engage in and enhance their learning. Agaba (2020) further explained that the system had 791 designed, interactive, activity-based courses by April 2020 and 157 more courses were added to the platform. MUELE however has faced several criticisms from both students and lecturers. Bahati (2021) reported that a finalist student at the Department of Journalism and Communication complained that the MUELE system is slow and cannot allow many users at a time. This was because of high traffic which greatly contributed to the web server overload as multiple requests are made to the server at the same time and the available resources cannot support many users. This affected students' productivity and also resulted in dissatisfaction with the slow MUELE system.

According to Hamiza et al (2020), Kyambogo university adopted Moodle LMS customized as Kyambogo University E-learning Management System (KELMS) which was implemented in 2016 with some courses facilitated by a few trained teaching and technical staff. Olema et al. (2020) noted several challenges with the Kyambogo University e-learning system which included; difficulty in accessing login details, difficulty in locating course units from the system panel, slow web browser response among others. Due to the aforementioned challenges, Shabomwe (2020) reported that the University resorted to using Google classrooms and other cloud meeting platforms to ensure continuity of online learning.

Bwire et al. (2020) clarified that the success of e-learning systems are hindered in several ways, for instance inadequate use of computers, low server capacity, poor network and internet services among others. With these challenges in existence, e-learning systems performance is compromised hence affecting students' and other users' productivity.

Additionally, the unceasing complaints about slow e-learning systems is obviously due to the increased number of traffic coming from the large students' population which overwhelm the available web server resources thus causing web server overload. Resonate (2019) noted that users start getting error codes, delivery of partial content, and delay in serving requests and transmission control protocol (TCP) denial as a result of the web server overload. This situation has mainly been experienced during quiz and assignment times where multiple requests are sent to the web server as students attempt online quizzes and assignments hence high traffic. Barber et al. (2015) in their study explained that when web servers become overloaded with requests, users experience slow response time which result to reduced concentration by users and eventually hampering learning performance and productivity.

It was thus important to investigate the main causes of web server overload and provide solutions to overcome these problems. Some of these problems could have contributed to the shift of the majority of lecturers from the current e-learning systems to other alternatives. For instance, in the COVID-19 era, Shabomwe (2021) reported that the majority of lecturers resorted to using other cloud meeting applications such as zoom and other applications as opposed to the slow MUELE system. Shabomwe (2020) also reported that Kyambogo University preferred to use Google Classrooms, Google Drive for sharing notes, and other cloud meeting platforms.

According to Resonate (2019), there is always a spike in system traffic as many users attempt to access the e-learning systems at the same time which causes the web server to be overloaded. In the case of higher institutions of learning, the web server becomes overloaded mostly during quiz time and while doing and submitting assignments which require submission at a timed deadline. These scenarios eventually flood the e-learning system since multiple concurrent requests are sent to the web server especially when students attempt online quizzes causing high traffic.

With the above being explained, web server downtime or crashing however is caused by several factors. According to ApacheBooster (2017), network problems which are sometimes slow, configuration error, software bugs that arise due to a flaw in the system or computer program leading to no output or unexpected output are some of the causes of server downtime. In further discussion, system overload was identified as another cause of server downtime or crashing as many users login to the e-learning systems yet the available server infrastructure is unable to handle the increased number of users and ultimately leading to crashing. In most cases, hardware

such as RAM, processors, hard disc capacity are looked at first when the server is not performing efficiently yet the available resources do not match the user demands.

Various techniques have however been explored to optimize the performance of web servers. In a study by Igder et al. (2016), Content distribution network (CDN) was explored to reduce the congestion on the network in order to reduce on the response time through caching frequently accessed contents thus offloading significant traffic. Tuaycharoen et al. (2016) also explored lazy loading mechanism which loads media on demand rather than loading all the contents of the page at once. With this mechanism, a web page can respond 50% faster than loading the entire web page on average, this has always made visitors perceive that the websites load faster, even if the actual load times are comparatively slow according to Google.

In another study by Sadikin et al (2019), implementation of load balancing as a mechanism to improve performance issues was explored. Shukla et al. (2020) in agreement explained that web servers partition incoming workload into smaller tasks such that they are assigned to computational resources for concurrent execution. Load balancing mechanism has predominantly been used in distributed systems and may not be applicable to learning institutions whose e-learning systems are hosted on a single web server and still other load-balancing techniques do not suit the higher institutions in Uganda that are resource-constrained.

Front-end optimization using image maps which associate multiple URLs with a single image to reduce the number of HTTP requests was another mechanism explored. The destination URL is chosen based on where the user clicks on the image (Report, 2015). Kyrnin (2020) criticized the use of image maps since they have usability issues as users find difficulty in figuring out which portion of the image redirects them to the content they are looking for. Higher institutions of learning, therefore, need to adopt web server overload management guidelines that can handle the surging traffic generated due to the increased usage the e-learning systems.

1.2. Problem statement

The performance of most web servers is affected by web traffic which leads to slow response because of overload. 83% of the countries are using online platforms to ensure continued learning (Rungta, 2022), and 98% of universities moved classes online (ThinkImpact, n.d). The online classes movement resulted to increased traffic over the Internet making web servers to face challenges to handle the large number of users (Shukla et al., 2020). The increased number of

online users involve several requests sent to the web server where the e-learning system is hosted causing overload. According to Resonate (2019), the available resources such as the RAM, CPU among others become exhausted and users start getting error code messages on their screens, delivery of partial or fragmented contents, delay in serving requests, and a total failure to respond to users' requests when the web server crash. These lead to setbacks in institutional activities such as postponing of online learning, rescheduling online examinations, assignments, and other activities required to be done online. More resources such as money and time will be required to buy additional components and also to restore the system respectively. Although scholars like Sadikin et al (2019) implemented load balancing mechanism, Igder et al. (2016) explored content distribution network (CDN), Report (2015) implemented front-end optimization using image maps to improve on the performance of the e-learning systems, not much was achieved.

This study therefore focused on investigating causes of web server overload, the different web server overload management strategies used in selected higher institutions of learning in Uganda and also investigating the e-learning systems infrastructure, policies, technical staffing, internet cloud service providers among others at the higher institutions of learning and developed guidelines for web server overload management that can be used at the higher institutions of learning. The guidelines intended to improve on the performance of e-learning systems at higher institutions of learning in Uganda.

1.3. General Objective

The aim of the research study was to develop guidelines for web server overload management in order to improve on the performance of e-learning systems used at higher institutions of learning in Uganda.

1.3.1. Specific Objectives

1. To investigate the causes of web server overload of e-learning systems at higher institutions of learning in Uganda.
2. To determine the strategies used to manage web server overload of e-learning systems and derive guidelines that can be used by higher institutions of learning in Uganda.
3. To develop guidelines for web server overload management that can be used to improve on the performance of e-learning systems in Uganda.

4. To validate the developed web server overload management guidelines that can be used to improve on the performance of e-learning systems in higher institutions of learning in Uganda

1.4. Research question

To solve the aforestated problem, answers to the following questions were required in the study.

1.4.1. Main research question

What guidelines can be developed for web server overload management to improve the performance of e-learning systems used at higher institutions of learning in Uganda?

1.4.2. Specific research questions

1. What are the causes of web server overload of e-learning systems at higher institutions of learning in Uganda?
2. What existing strategies are used to manage web server overload of e-learning systems used at higher institutions of learning in Uganda?
3. Which web server overload management guidelines can be developed to improve on the performance of e-learning systems used at higher institutions of learning in Uganda?
4. Can the developed web server overload management guidelines improve on the performance of e-learning systems used at higher institutions of learning in Uganda?

1.5. Significance of the study

The findings from the research study are significant in the following ways.

This research makes a significant contribution in the fulfillment of Ministry of Education and Sports' initiative "to enable students do their courses from wherever they are"

The developed guidelines boost the performance of the e-learning systems thereby attracting many e-learners as institutions shift from traditional teaching and learning to virtual learning.

The research contributes to institutions' move to decongesting the learning facility or environment as majority of them turn down applications due to the large number of students which presents the opportunity to occupy space through e-learning.

1.6. Justification for the study

Students and lecturers (instructors) are the key stakeholders and beneficiaries of the e-learning systems used at all the higher institutions learning in Uganda. These stakeholders require the e-

learning systems to be efficient, reliable and available 24/7 to accomplish the various tasks they perform. These tasks include but not limited to; doing online examinations, answering quiz, uploading assignments, conducting online assessment among other tasks. On the contrary, the aforementioned stakeholders have been frustrated by the e-learning systems used at their institutions of higher learning sparking protests. Shabomwe (2021) in agreement reported that many learners opposed the e-learning systems due to the pain of using slow e-learning systems coupled with inability to allow many users at the same time and unavailability of the system sometimes thus affecting their productivity. Castro (2016) defends the demonstrations carried out by the users of the e-learning systems as he argues that 53% of mobile users abandon websites that take longer than 3 seconds to load.

These study therefore developed guidelines to improve on the performance of the e-learning systems used at the higher institutions of learning in Uganda and also address problems like inability to handle many users at the same time, slow response time, unavailability of the system among other issues. These guidelines include; the use of least connection load balancing method; configuring a backup or secondary load balancer; hosting e-learning systems on dedicated web servers; upgrading of the database server from MySQL to PostgreSQL Database Management System; clustering of PostgreSQL database into "read only" and "read and write" databases; optimization of the databases through indexing and caching of information using Redis in-memory software. These guidelines were further validated by the systems and software developers who design and develop systems with high concurrency access to ascertain their relevance and applicability to the e-learning environment and the anticipated outcome in terms of performance when implemented. The scores obtained from the validation of the guidelines were high as most of the respondents agreed and strongly agreed using the 1-5 Likert scale.

1.7. Scope of the study.

This research covered the topic under study, the study area and the respondents who were selected to participate in the research study as listed below:

1.7.1. Topic scope

Higher institutions of learning, specifically the ICT department with professionals who had knowledge on web server operations and system developers from the target institutions, students pursuing software engineering, computer science and other related courses. Experts such as

systems administrators, network administrators, database administrators, system developers were also involved in the research study. The research focused on finding out the causes of web server overload and investigated the web server overload management strategies and guidelines used at higher institutions of learning to improve the performance of e-learning systems in Uganda.

1.7.2. Geographical Scope.

The study was conducted in five universities in Uganda namely; Makerere University, Makerere University Business School, Kyambogo University, Gulu University, and Lira University. The universities above were selected because they have e-learning systems that are used for online learning and they were in a position to provide relevant information needed to achieve the objectives of the study. Software and systems developers selected to validate the recommended web server overload management strategies and guidelines for the e-learning systems were all from Kampala districts because it was easy to coordinate with them.

1.8. Contribution of the study.

This study aimed at improving the performance of e-learning systems used at higher institutions of learning in Uganda. In order to achieve the aim of the study, the researcher set four objectives to guide the achievement of the study aim. The first objective was "*To investigate the causes of web server overload of e-learning systems at higher institutions of learning in Uganda*," where the researcher obtained increased number of concurrent users, insufficient network bandwidth and insufficient web server resources as the causes of web server overload of the e-learning systems. Objective one revealed the causes of web server overload for e-earning system.

Under objective two which was "*To determine the strategies used to manage web server overload of e-learning systems and derive guidelines that can be used by higher institutions of learning in Uganda*," the researcher interviewed the technical experts like the systems administrators, network administrators, database administrators, IT support staff among others and obtained the following strategies used to manage web server overload for the e-learning systems used at higher institutions of learning in Uganda; use of alternative platforms such as zoom meeting application, google classroom, upgrade of web server resources such as the RAM, network bandwidth, scheduling access to the e-learning systems by use of a timetable, single browser login was also emphasized by one of the institution, information caching was also another strategy used by one institution to

manage web server overload. Objective two led to the discovery of the various strategies used by higher institutions of learning to manage web server overload.

Objective three was "*To develop guidelines for web server overload management that can be used to improve on the performance of e-learning systems in Uganda*". These guidelines were derived from primary data collected from the field and literature from other related studies. These guidelines include; the use of least connection load balancing method; configuring a backup or secondary load balancer; hosting e-learning systems on dedicated web servers; upgrading of the database server from MySQL to PostgreSQL Database Management System; clustering of PostgreSQL database into "read only" and "read and write" databases; optimization of the databases through indexing and caching of information using Redis in-memory software. More about the guidelines are explained in chapter five.

To ensure relevancy, applicability and anticipated outcome of the developed guidelines to manage web server overload for the e-learning system used at the higher institutions of learning, expert opinions were sought through a validation exercise where, each guideline was validated based on relevancy, applicability and anticipated outcome criteria. Chapter 6 of this study presents detailed information about the validation exercise which was done in fulfillment of objective four of the study which was "*To validate the developed web server overload management guidelines that can be used to improve on the performance of e-learning systems in higher institutions of learning in Uganda*."

In summary, the study developed web server overload management guidelines that can be used to improve on the performance of the e-learning systems and also contributed to the knowledge base. These developed guidelines include; the use of least connection load balancing method; configuring a backup or secondary load balancer; hosting e-learning systems on dedicated web servers; upgrading of the database server from MySQL to PostgreSQL Database Management System; clustering of PostgreSQL database into "read only" and "read and write" databases; optimization of the databases through indexing and caching of information using Redis in-memory software.

CHAPTER TWO

Literature Review

2.0. Introduction

This chapter presents a literature review and discussion of the literature on e-learning systems used at higher institutions of learning, benefits of e-learning, challenges of e-learning, servers and types of web servers. This is followed by a critical review of strategies for web server overload management, a review of previous works in relation to web server overload management and ends with a summary of findings of existing web server overload management strategies and a conclusion.

2.1. Electronic Learning systems (E-learning)

E-learning is commonly referred to as the intentional use of networked information and communications technology in teaching and learning (GOYAL, 2012). According to Wright et al (2014), e-learning training, learning and delivering is carried out through a learning management system (LMS) which is a software application or web based technology used to plan, implement and assess specific training processes. Kasim & Khalid (2016) explained that e-learning contents are accessed through LMS which allows students to interact with learning tools via the different web browsers using any operating system, computer or mobile device. Also, Wright et al (2014) argues that different learning management systems such as Moodle, Blackboard, Sakai, Instructure Canvas among others are popularly used in education institutions. Turnbull et al. (2019) in agreement mentioned that Modular Object-Oriented Dynamic Learning Environment (Moodle) is the first open source platform which has widely been considered by higher institutions of learning. The authors further explained that Moodle platform has been highly adopted by institutions because of its user-friendliness, accessibility and flexibility. The majority of LMS consist of servers that perform the base functionality and user interfaces that are operated by instructors, students and administrators (Brush, 2019). Turnbull et al. (2019) further explained that LMS have different functions such as dissemination of knowledge, assessment of learning competency, recording of learners' achievement, support for online social communities, communication tools, and provision of system security. All these functions can be performed with the help of various tools in the learning management systems which include learning skills tools, communication tools and productivity tools as discussed below.

2.1.1. Learning skills tools

Learning skills tools according to Turnbull et al (2019) include; quizzes, online presentations and assignments tools which enable instructors to create activities and learning tools for students. The authors further elaborated that a quiz module has functions like a question database, a response facility, a marking scheme and means of facilitating students' performance. Online presentation tool facilitates presentations to be uploaded to the LMS and also has the capability of linking files from websites like YouTube. Lecturers can also upload assignments to the LMS and students can do them online, edit or send assignments any time until the date of submission using the assignments tool.

2.1.2. Communication tools

According to Kasim & Khalid (2016) explanations, communications tools enable interaction between lecturers and students and students themselves. The authors emphasized that announcements are the most commonly used tool for communication and for presenting any information regarding the course including the latest news and upcoming activities to all the students. Furthermore, discussions among other communication tools are used by both students and lecturers to post and reply to messages and also read comments from other users.

2.1.3. Productivity tools

Productivity tools include; document management systems, calendars, surveys among others. Document management systems allow lecturers and students to upload and download files from any computer which is connected to the internet (Kasim & Khalid, 2016). In their discussion, they revealed that other management tools in LMS collect information on how much students access the LMS and on students' performance. Moreover, some LMS such as Moodle among others were praised for allowing students to see reports of their overall performance such as grades for each assignment, quiz, and examination. (2019) however revealed that e-learning problems and challenges are increasing and becoming more complex due to the growing number of students. Some of the problems and challenges are discussed as below.

2.2. Challenges of e-learning systems

Several distinguished researchers have stated that technology related barriers hinder the successful operation of e-learning platforms. These among others include a technology illiterate user group, inadequate infrastructure, high costs of access, unreliable and poor quality internet connections,

unreliable electricity services, shortage of skilled personnel to manage the resources and maintain the new e-learning platforms. Islam et al (2015) also explained that technological problems may arise due to development issues like bugs, the speed, errors, functions and features not working correctly or not working according to what academics require. These problems are critical in academics and also critical in the success of e-learning technologies. Therefore, it is paramount that they should operate correctly otherwise, e-learning technologies will always remain the major barrier to the success of e-learning. The increased demand for e-learning services also come with more requirements for higher capacities of e-learning systems infrastructure. Another challenge of e-learning is the performance issue identified by Sadikin et al (2019) where increased access of the e-learning systems by users result in web server resource straining as it tries to provide quality performance. This is evident at peak hours when several systems become inaccessible and the learning processes are halted. According to Khedr (2017a), continuous increase in e-learning access reveals many problems including server resource limitations which consequently result in continuous upgrade in order to extend their functionality. Additionally, the continuous increase in e-learning access by students and lecturers leads to high load on the web server where the e-learning system is hosted and in a worst case scenario, the web server may break down consequently resulting to e-learning system inaccessibility. According to Rajarajeswari (2013), web servers are forced to line up requests that are made by users when there is a high volume of requests and this consequently result in additional time to process and respond to the requests leading to long waiting time or the server jamming completely.

The number of virtual learners is increasing day to day. Obviously, as the number of persons using the network increase, then serious management problems by the web server are expected to rise. As discussed by Rajarajeswari (2013), web servers struggle to line up requests sent by users over different network at the same time which require more time to process the requests. Consequently, web servers jam to respond to user requests due to overload and users are required to wait for a longer time in order to get responses from such web servers.

In agreement with the above argument, Sadikin et.al., (2019) also stressed that as user demands grow, the requirement for higher capability and capacity of e-learning infrastructures are also increasing day by day leading to exploration of many methods and architectures to overcome infrastructure capabilities and performance issues. Due to the increased demands of the users and increased number of users with e-learning becoming a mandatory method of teaching, challenges

are inevitable and they must be addressed. Sadikin et.al., (2019), explained that, the main challenge to be addressed is how to maintain continuity and availability of e-learning services while the number of users double at the same time. The authors further elaborated that, with e-learning system being faced with high user access demands, it suffers in providing quality performance.

Triggered by the challenges above, many authors have published various methods to minimize the challenges. Khedr & Amira (2017) discusses the adaptation of Load Balancing technique in cloud computing environment where they used the "Random Allocation Load balancing" technique for the Load Balancing scenario. Another Load Balancing scenario was presented by Mihăescu (n.d) where the author discussed the architecture of Load Balancing applied to a distribution system in which the architecture distributes functionalities of the e-learning into several web servers. The servers are checked to ensure that they have fully synchronized content thus; each server is able to respond to any of the possible requests.

2.3. Benefits of e-learning

The uptake of e-learning by the learning institutions has registered several benefits and because of these benefits, its considered the best method of education. According to Arkorful & Abaidoo (2015), e-learning has provided several benefits and advantages derived from the adoption of e-learning technologies into schools. Some of the benefits are discussed as below;

1. Flexibility when it comes to the issues of time and place are taken into consideration. Every student is given the luxury to choose the place and time that suits him or her. According to Al-adwan & Smedley (2012), the adoption of e-learning provides the institutions as well as their students time and place flexibility for delivery or receipt of learning information.
2. In a discussion by Sandhya & Benarjee (2020), e-learning provides opportunities for relations among learners by the use of discussion forums. Through this forums, barriers that may have potentials of hindering participation such as fear of talking to other learners are minimized. Furthermore, it motivates students to interact with others as well as exchange and respect for different points of views. E-learning also enables ease of communication which improves the relationships among participants thereby sustaining learning. Wagner et al (2008) pointed out that e-learning provides extra views for interaction among students and teachers during content delivery.
3. Sandhya & Benarjee (2020) mentioned that e-learning is cost effective in the sense that there is no need for the students or learners to travel. Cost effectiveness is realized in the

maximum number of learners who do not require physical buildings to acquire educational services.

4. In addition, Arkorful & Abaidoo (2015) explained that e-learning helps to compensate for scarcities of academic staff such as instructors or teachers or facilitators, lab technicians and other human resources that may be required.
5. And lastly, the use of e-learning allows self-pacing. For instance, the asynchronous way permits each learner to study at his or her own pace whether slow or quick (Arkorful & Abaidoo, 2015).

For e-learning systems to be successful, different technologies must be put together in order for the benefits explained above to be realized by the learners and the lecturers and other institutional stakeholders. These technologies can be classified into hardware such as physical computers, servers, networking devices and other supporting devices while the software such as the operating systems, database systems, networking software and other supporting software which are deployed together to ensure seamless operation of the e-learning systems. Some of these technologies are discussed as below.

2.4. Server and web server

Many statements have been recorded defining a server and web server and this study acknowledged some of these definitions and applied them in this study as below;

A server is a collection of programmes that listen to client requests that are transmitted via the communication network (Kimbonguila et al., 2019). A server is a computer designed to process requests and deliver data to another computer over the internet or a local network (Mitchell, 2021). On the other hand, a web server is a particular type of server that delivers services or content to client computers (Kimbonguila et al., 2019). Another scholar defined a web server as a software or hardware (or both together) used for storage and delivery of contents to a web browser (Birznieks, 2021). The author further described that storage, processing and delivery of the web pages when requested by the clients are the most prominent and technical key features and purpose of a web server. A client in this case is a browser like Microsoft Edge, Google Chrome, Opera Mini, Safari, Firefox among others. According to Jader et al. (2019), clients' requests that are sent over the World Wide Web are generally processed by the web server over Hypertext Transfer Protocol (HTTP) and the web pages are mostly delivered as HTML (Hypertext Markup Language) documents. For the above processes to be possible, web servers must always be connected to the

internet and each of them assigned unique addresses for communication to happen. Sanchi (2019) in agreement with the above statement argued that websites must be hosted on web servers such that they are visible and accessible by users. This is made possible by assigning them unique web addresses and domain names or the internet protocol address (IP). Furthermore, communication made through the websites are through HTTP (Hypertext Transfer Protocol) in order to access the internet and also to display the web pages of the websites to the users. The author also explained that, the moment the web server is down, users will not have access to the websites since the pages will not load and also, if a wrong domain name is entered, the website will not load. Hosting companies therefore provide and manage multiple domains on a single server by using the concept of shared hosting; however, other companies prefer to buy their own servers for security purposes. A case in point are some higher institutions of learning in Uganda for instance Makerere university whose servers are managed by the Directorate of Information and Communication Technology Support (DICTs) within the institution. In conclusion, it is the choice of website designers, system developers and technical staff in institutions to choose best web servers though this also depends on a number of factors. Johnson (2018) mentioned some of these factors such as; server reliability in terms of uptime and security, availability of site backups in case of cyber-attacks and other risk execution, registration and maintenance costs among others. The next paragraph discusses some of the web servers commonly used.

According to Sanchi (2019), Apache HTTP server which is one of the most widely used web server worldwide due to its advantage of supporting almost all the operating systems such as Windows, Linux, Apple Mac OS, Unix and others. The author further explained that 60% of the web server machines worldwide are reported to be running on the Apache web server since it is openly sourced with a lot of online support available in case of any problem or error and users can modify it to fit their requirements. Another web server is the Internet Information Services (IIS) which is part of the Microsoft® Windows® Server 2003 family and attempts to provide an integrated, reliable, scalable, secure, and manageable web server (Kornecki et al., 2005). The author however clarified that Internet Information Services (IIS) is not openly sourced like Apache web server which makes the process of customization and modification a little complicated. Lighttpd is another web server which is a secure, fast, and flexible open source web server software optimized for high performance environments (McDonald, 2021). According to the author, it has a low memory footprint which promotes efficient management of hardware and it runs natively on Linux/Unix systems and can also run in Windows environments. In an explanation by DreamHost Knowledge

Base (n.d.), Nginx web server is a free and open source web server which includes IMAP/POP3 proxy server also known for its high performance, stability, simple configuration and low resource usage. In conclusion, it must be noted that however powerful your web server maybe, it is likely to be overwhelmed by requests at one point and strategies and guidelines to manage and balance these requests must be at hand to avoid interruptions by the web servers going down. The next section discusses web server overload issues and the possible strategies explored by other researchers to handle them.

2.5. Overview of system overload

When choosing a web server, the ability to handle system load must be considered or planned for in case the need arises in future. Web server overload management strategies and guidelines become significant in managing the surge in requests across all the servers in instances where they become overloaded due to increase in demand for web services. According to Mayur & Chaudhary (2019) load balancing strategy supports web server overload management by dividing and distributing web requests across all the functional web servers to ensure faster and lesser interruptions of user requests. How to implement such a strategy remains a question that must be answered? This research study provided answers to web server overload management strategies and guidelines by exploring available methods pushed forward by other researchers as discussed in the next section.

2.6. Load Balancing Algorithms

Load balancing is a mechanism in which a single machine divides up the amount of work into two or more computer systems that allow the users to perform their tasks faster and each computer involved is expected to complete its job in a similar amount of time (Mayur & Chaudhary, 2019). Several servers are used during the load balancing process and connection among these servers are usually performed by scripting them using different programming algorithms to efficiently assign workloads. The workload is allocated and balanced by the load balancers between two or more servers. According to AVI Networks (n.d), the strategy eliminates collisions in the activity and enforces automatic resource allocation to ensure minimum delays in response time. In circumstances that require service continuity even when traffic is heavy, a load balancer is strongly recommended. There are two types of load balancers which are software load balancer and hardware load balancer. The software load balancer is simply installed on standard x86 servers or virtual machines to distribute network traffic to obtain minimum response time and peak

performance by preventing overload while the hardware load balancer also known as hardware load balancing device (HLD) is a device with a specialized operating system that distributes web application traffic across a cluster of web and application servers. The distribution of traffic is accomplished through customized set of rules such that the web servers are not overwhelmed with network traffic. The next section discusses works by other distinguished scholars in line with web server load management.

2.7. Review of previous server overload management strategies.

Several literatures were scrutinized to conceptualize the processes of web server overload management under different environments. The literature findings on web server overload management were as below;

2.7.1. K-Means clustering algorithm using Exhaustive Criterion based Load Balancing (ECLB) algorithm

In a study conducted by Rajarajeswari (2013), load balancing was applied using K-Means clustering algorithm for building clusters of nodes and then applied the Exhaustive Criterion based Load Balancing (ECLB) technique which targeted the ability to handle high requests rate in grid computing to optimize infrastructure. The algorithm consisted of cluster heads (CH) responsible for collecting details of the clusters attached to it such as speed, capacity among others which were then forwarded to the cluster manager (CM) responsible for maintaining a database for all the clusters. The information forwarded to the cluster manager (CM) was helpful in distributing work load to clusters attached to the cluster heads (CH) using the Exhaustive Criterion Load Balancing algorithm (ECLB) and cluster heads (CH) were required to update the capacity of each cluster periodically. Work load was distributed based on; the capacity, computational speed and the processing time for each cluster. When user requests were made, the cluster manager (CM) located a single cluster to accomplish the tasks then assigned it to the corresponding cluster heads (CH) based on processing time and the file size. If the tasks cannot be handled by a single cluster, then the tasks were shared among the clusters by the cluster manager (CM). Upon successful completion of tasks execution, the clusters report to the responsible cluster heads (CH) and users can then get the responses. The researcher for this study identified some limitations with this load balancing algorithm. In case of a failure of the cluster heads (CH), clusters are left idle and user requests are not provided. Furthermore, a fault in the cluster manage (CM) renders the whole algorithm meaningless as the cluster heads (CH) and the clusters become dormant. The proposed

approach however, was also measured in a simulator system to prove its success rather than in a real environmental setup to determine its performance measures. Furthermore, the proposed approach required minimized transfer of tasks to reduce required network cost. The algorithm on the other hand had the ability to handle failures and recoveries among clusters and also the ability to run large scale applications that perform execution and computation across multiple computer systems as opposed to one central computer system.

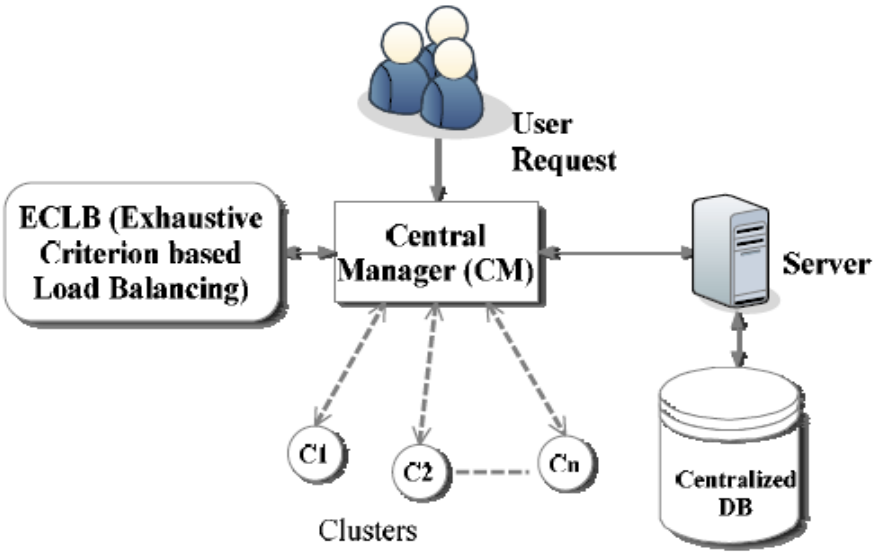


Figure 2. 1. K-Means clustering algorithm using Exhaustive Criterion based Load Balancing (ECLB) algorithm

2.7.2. Load Balancing a using peer-to-peer network.

In another study by Dominic & Francis (2012), load balancing using peers in an e-learning environment was demonstrated with the clients on the network. The clients were categorized into three different class clusters each having different file types of the learning objects like presentation, videos, audios, pictures, animations and others. The address table was used to hold the names of each file in the class cluster such that requests for the files were received corresponding to the cluster identified by reading the address from the address table. Each file in the cluster had a dynamic Hash table (DHT) which held the address of the linked list of which the linked list also held the file names downloaded to the server, linked list, and a binary tree. The nodes in the linked list held a file name, address, and the binary tree which held the IP address of the active clients and its current CPU processing status. The role of the binary tree was to identify

the leased CPU used by client to transfer the file to the requestor and the binary tree structure was used to reduce the search time for the leased used client. This algorithm however is applicable only when the learners access the learning objects which are stored in the repository. This would achieve reduced server response rate by directing a client to respond to the requestor with the file it has already downloaded from the server. The limitation of the proposed approach was that it focused only on one of the services which is the files download while more services are proposed in the e-learning system such as coursework or assignment uploads, navigation of students' degrees, and streaming of some files online. These services were not considered in this approach yet they seriously affect the network traffic. The location of the files also affected the system performance as well since files were fetched from a remote peer which consumed more bandwidth, and resulted in a long retrieving latency (Bhuyan & Xu, n.d).

2.7.3. Load balancing implementation on Moodle LMS

In a study carried out by Sakikin et al (2019), Moodle load balancing configuration was implemented on four application servers and two databases (DB) servers. Software or library tools such as HAProxy, Keepalived and Galera were used in its configuration. HAProxy was used to manage the high availability and proxying of the Moodle web server application while keepalived software was used to check the health of the failover server pools used to dynamically and adaptively maintain and manage load balanced according to their health and the synchronization between the Database clusters (DB) was performed by Galera. The performance of the load balancing was enforced by implementing a robot system which monitored the system in real time for user access status. The robot system was also meant to send notifications to the authorized personnel about the access uptime. This load balancing configuration however relied solely on the robot system for performance of the e-learning system monitoring and a failure in the robot system would make the load balancing configuration meaningless. The implementation and configuration of the load balancer together with the robot system is also complex and requires much knowledge to configure and maintain.

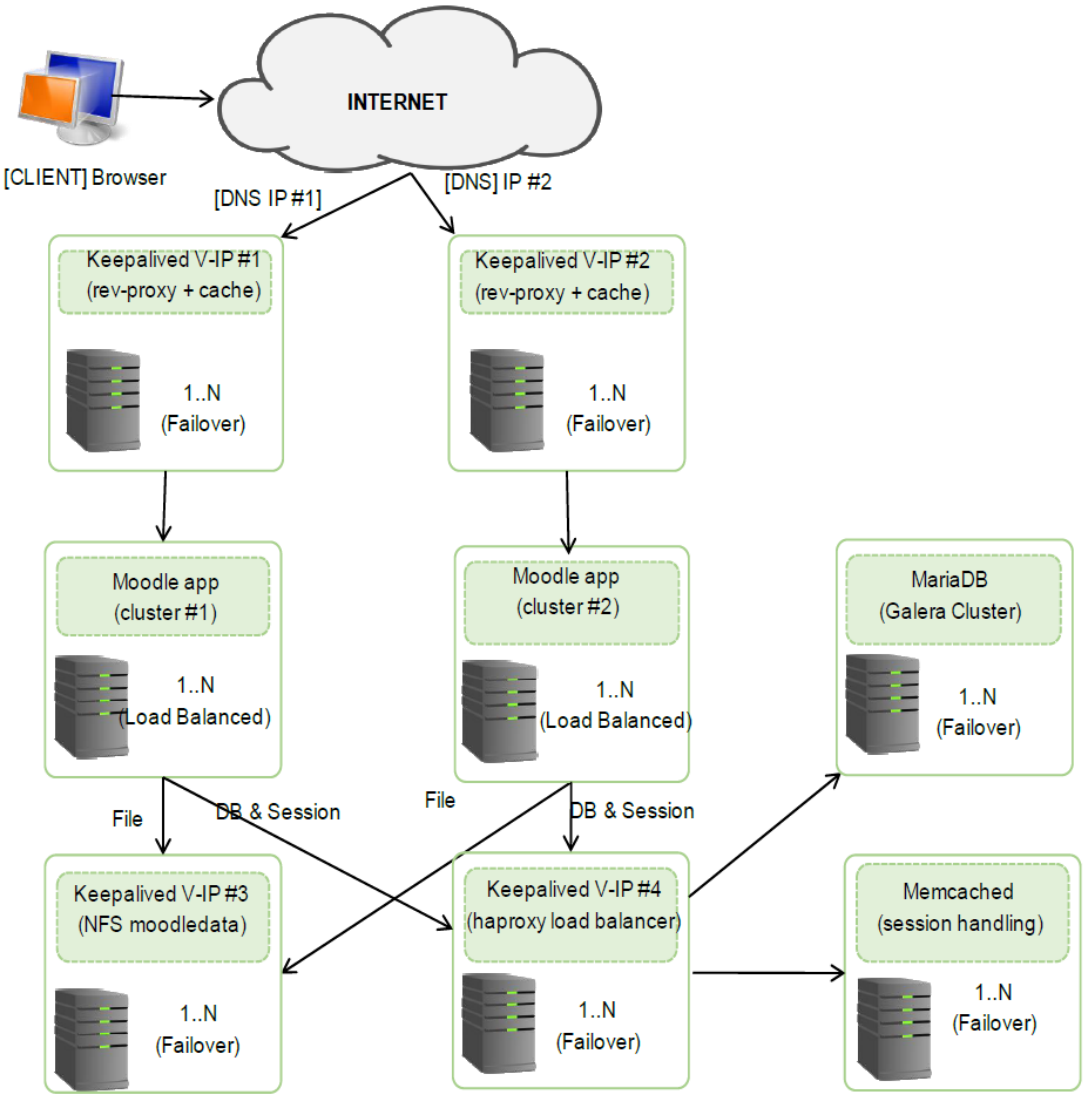


Figure 2. 2. The Moodle LBC configuration

2.7.4. Random Allocation Load balancing with task scheduling

In order to improve e-learning system performance, Khedr & Idrees (2017) proposed a static load balancing strategy using Random Allocation Load balancing technique to enhance the educational process carried out on the e-learning system. It was tested on an enhanced educational system in a 20 minutes' exam for 1200 students which led to high traffic in the system during the specified time period. The system was again applied to 6000 students in a limited determined time period for different courses, the system had a very serious situation in decreasing performance according to the strong need of service availability to all users (students). Due to the drawbacks of Random Allocation Load balancing technique, another load balancing technique, task scheduling was

applied to ensure more stability and for finding the best system performance and throughput. The combined technique however also had drawbacks for instance, higher complexity in the implementation of task scheduling load balancing algorithm and high power consumption. The application of the combined approach did not achieve much as the test result showed that random allocation had more stable latency than task scheduling yet higher bandwidth usage was required to utilize the network resources in order to provide the required services.

2.7.5. A framework for Load balancing and Load distribution among clusters

Sharma & Saxena (2011) study explored a framework to solve load balancing problems in heterogeneous environment. The composition of the framework included a server controller that was responsible for cluster building based on memory and CPU requirements, keeping records of the statuses of machines (clusters and servers) and distribution of load within and between clusters. Web servers were grouped into clusters and the server controller regulated the clusters. The cluster servers and controller server were responsible for load distribution and regulation of the central load balancing scheme with the clusters and among the clusters respectively. Review matrix was also used to maintain the load conditions of every cluster or web server respectively at a particular point in time. The clusters were used to decide the balanced or unbalanced state of the server and the server controller also determined whether the system was balanced or load sharing was required between and among clusters. The ability matrix contained information about the Media Access Address (MAC), CPU speed, primary and secondary memory details for each web server that belonged to a particular cluster and the server controller also kept details about the cluster. The load matrix maintained by the server controller and cluster server was used to keep track of load status with each cluster and was also responsible for keeping track of load position with each web server within the cluster. The framework was important in identifying the dead machines if no update was received from a particular machine by the cluster server. A fundamental merit of the proposed framework was its ability to trace dead machines and also the ability to divide and distribute web requests on the basis of processing power involved. The limitation of the proposed framework however was, in case of a failure of main server controller, the whole system would be brought to a halt since the server controller would not be able to pass the user requests to the cluster servers and among the clusters respectively. Furthermore, a failure of a cluster server would also render the web servers attached to it idle as they would not be able to receive and respond to requests.

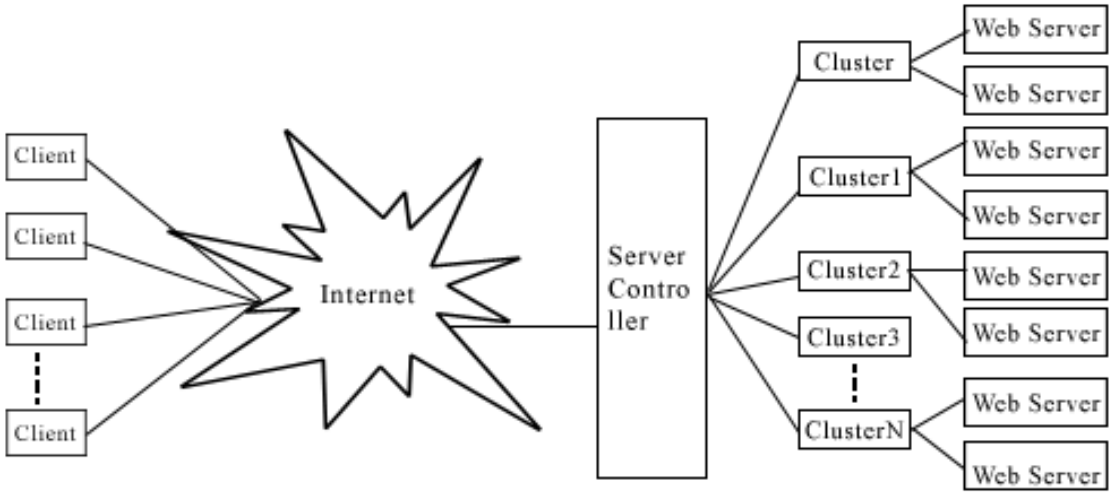


Figure 2. 3. System architecture where all the web servers are divided into clusters on the basis of their operational capabilities and Server Controller is responsible to manage Load balancing and Load distribution among these clusters.

Table 2. 1. Comparison of the reviewed previous related work.

Year and authors	Research papers	Server overload management strategies.	Limitation of the solution
Sakikin et al (2019)	Load balancing clustering on Moodle LMS to overcome performance issue of e-learning system.	Load balancing implementation on Moodle LMS	• Complexity in implementation since a robot system is required to monitor the performance of the system and notifications are sent to responsible persons about inaccessibility of the system • The structure also relied solely on the robot system for update, notifications and other activities and failure in the robot system would make the configuration meaningless.
Rajarajeswari (2013)	ECLB: A Novel Exhaustive Criterion Based Load Balancing Algorithm for E-Learning Platform by Data Grid Technologies	K-Means clustering algorithm using Exhaustive Criterion based Load Balancing (ECLB) algorithm	• Minimization of tasks transfers to minimize the required network costs. • A failure of Cluster manager (CM) would render the whole algorithm meaningless. • A failure of the cluster heads would also render the CM and the clusters dormant
Dominic & Francis (2012)	Load Balancing using Peers in an E-	Load Balancing using peer to peer network.	• Applicable to files already stored in the repository (already downloaded from the server).

	Learning Environment		• More time required to retrieve data from remote peers
Khedr & Idrees (2017)	Adapting Load Balancing Techniques for Improving the Performance of e-Learning Educational Process	Random Allocation Load balancing with task scheduling	• High complexity in implementation • High power consumption. • High bandwidth requirements
Sharma & Saxena (2011)	Reducing server response time	A framework for Load balancing and Load distribution among these clusters	• Failure of a server controller affects the whole operation of the web servers in the cluster. • Failure of a cluster also renders the web servers attached to it idle

2.8. Conclusion

With the penetration of technology, higher institutions of learning have taken up the full advantages that come with it. This is evident in the adoption of different forms of e-learning such as blended learning, synchronous learning, asynchronous learning and other forms of e-learning. A number of e-learning tools are currently employed to ensure successful e-learning and other factors such as the availability of the reliable network, the capacity of the web servers used to host the e-learning systems and the capacity of the web servers to handle multiple concurrent requests from the clients. There are however gaps with the reviewed strategies such as using robot system to monitor the performance of e-learning systems which is complex, task transfer minimization to minimize network cost which compromises throughput, high bandwidth and power consumption, and complexity of some of the strategies which may be constrained to the higher institutions of learning in Uganda. This study therefore investigated the web server overload management strategies and guidelines used by higher institutions of learning in Uganda to improve on the performance of their e-learning systems and thereafter recommended suitable web server overload management guidelines that can be used to improve on the performance of the e-learning systems used at higher institutions of learning in Uganda which are detailed in chapter five.

CHAPTER THREE

Research methodology

3.0. Introduction

This chapter presents discussions on different methodological research components and the flow of this chapter is guided as below;

Section 3.1 discusses the design science research approach, section 3.2 discusses the research strategy, section 3.3 discusses the research methods, section 3.4 discusses target population and sample size selection, section 3.5 discusses data analysis and section 3.6 discusses ethical clearance.

3.1. Design science research approach

According to vom Brocke et al (2020), DSR is a central research paradigm applied in engineering, architecture, business, economics, and other information technology-related disciplines used to create novel solutions to relevant design problems. They further explained that DSR has frameworks and conceptualizations deemed crucial in providing foundations on how to conduct research to scholarly standards. vom Brocke et al (2020), explained that DSR focuses on the development and performance of the designed artifact with a clear intention of improving its functional performance. It is because of these reasons that, the researcher adopted DSR methodology to accomplish the study objectives. The six phases of the DSR; problem identification and motivation, definition of objectives of the solution, design and development, demonstration, evaluation and lastly communication of the findings to the relevant stakeholders directed the research process. Each of the phases and how it was helpful in accomplishing the research study are discussed in **Table 3.1**

The phases in Design Science Research helped in addressing research questions stated in section 1.4.2 thereby achieving the research objectives of the study.

Table 3. 1. Design Science Research activities that were undertaken under each phase.

Design Science Research phases	**Research Questions**	**Activities carried out**
Phase 1: Problem identification and motivation phase	What are the causes of web server overload of e-learning systems at higher institutions of learning in Uganda?	Learning the issues in the problem domain which is web server overload for the e-learning systems was carried out. This phase involved data collection from purposively selected experts from Makerere University, Makerere University Business school, Kyambogo University, Gulu University and Lira university. These experts included; systems administrators, network administrators, IT support staff, database administrators and some students pursuing computer science and software engineering. Literature regarding web server overload management for e-learning systems and other systems that involved concurrent access were reviewed which included information from articles and journals concerning the aforementioned issues. Findings on the causes of web server overload are detailed in chapter four and this was helpful in answering research question 1 and eventually achieving objective 1 of the study.
Phase 2: Definition of	2. What existing strategies and guidelines are used to manage web server	Web server overload management strategies and guidelines used to improve on the performance of e-learning systems were obtained at this phase. These web server overload management strategies were derived from the primary data collected

objectives of the solution phase	overload of e-learning systems at higher institutions of learning in Uganda?	during field survey and existing data from other literature about web server overload management.
Phase 3: Design and Development phase	3. Which web server overload management guidelines can be developed and to improve on the performance of e-learning systems used at higher institutions of learning in Uganda?	Development of the recommended web server overload management guidelines were made based on; Web server overload management strategies and guidelines obtained from the data collected from the field and guidelines obtained from existing literature about web server overload management. Details on the developed web server overload management guidelines are discussed in Chapter five.
Phase 4: Demonstration phase Phase 5: Evaluation phase	4. Can the developed web server overload management strategies and guidelines improve on the performance of e-learning systems used at higher institutions of learning in Uganda?	Demonstration on the operation of the developed web server overload management guideline was done through illustration in Figure 5.2. Validation of the developed web server overload management guidelines was undertaken through disseminating questionnaires designed using google forms to experts who are systems and software developers to get feedback and also to get recommendations for future improvement of the e-learning systems' performance. Under communication, a scholarly contribution of web server overload management guidelines for the e-learning systems to the education sector was made. The developed web server overload management guidelines were presented to the target

Phase 6: Communication phase		stakeholders and feedback was sought from them which helped in ensuring that the artifact is appropriate. The result of the research study was also published through the master's thesis. The activities carried out at phase 6 enabled addressing research question 4 and thereby achieving objective 4 of the research study.

3.1.1. Contextualization of the design science approach components to illustrate how appropriate they are in the research study's purpose.

In this research study, Design Science Research Approach (DSR) was adapted.

The major objective of the study was to develop guidelines for web server overload management in order to improve on the performance of e-learning systems used at higher institutions of learning in Uganda. According to Hevner et al (2004), DSR has been used in the field of information systems because it supports the creation of artifacts or new knowledge and structures the research process in a logical way hence achieving the objectives. Several scholars have forwarded different approaches/processes to design science in a bid to advance the work of Hevner et al (2004). For the purposes of this research study, the design science research process or guidelines forwarded by Hevner et al (2004) was used because of their suitability for research in the field of information systems. The DSR has frameworks and conceptualizations deemed crucial in providing foundations on how to conduct research to scholarly standards. The authors further explained that DSR presents researchers with a conceptual framework for understanding, executing, and evaluating or validating their artifacts developed based on the Environment, Design, and Knowledge Base.

The Environment defines the problem space which in this research study was web server overload of e-learning systems at higher institutions of learning in Uganda. The environment is composed of the people who were the (technical staff at the higher institutions of learning. These included systems administrators, network administrators, database administrators, IT support staff and others, systems and software developers). Organization were the selected higher institutions of learning in Uganda which included; (Makerere university, Makerere University Business school, Kyambogo university, Lira University, Gulu University and a few software and system development companies which included Nsibuku Technology Ltd, Computer revolution, Systems developers from Innovation Village (Ntinda) and Uganda Revenue Authority). The technology of interest was the e-learning system used at the higher institutions of learning in Uganda. From the environment, the researcher obtained the causes of web server overload for the e-learning systems and the strategies used to manage the web server overload. The strategies used to manage web server overload helped the researcher to derive guidelines to develop web server overload management guidelines for the e-learning systems achieved in the design block. The knowledge

base provided prior research and results from reference frameworks, algorithms, techniques, research methods and instruments to beef up the development of the web server overload management guidelines in the design stage.

The adapted research approach is presented and explained in figure 3.2 below. The box on the left (Environment) of figure 3.2 represents the people, organizations and the technology of interest. The middle box (Design) of figure 3.2 represents two major phases in this research, that is the design phase and the validation phase of the designed artifact (developed web server overload management guidelines). The box on the right (Knowledge Base) of figure 3.2 shows the core existing algorithms, frameworks and other approaches that were adopted to carefully come up with the recommended web server overload management guidelines for the e-learning systems used at higher institutions of learning in Uganda which also contributes to the knowledge base.

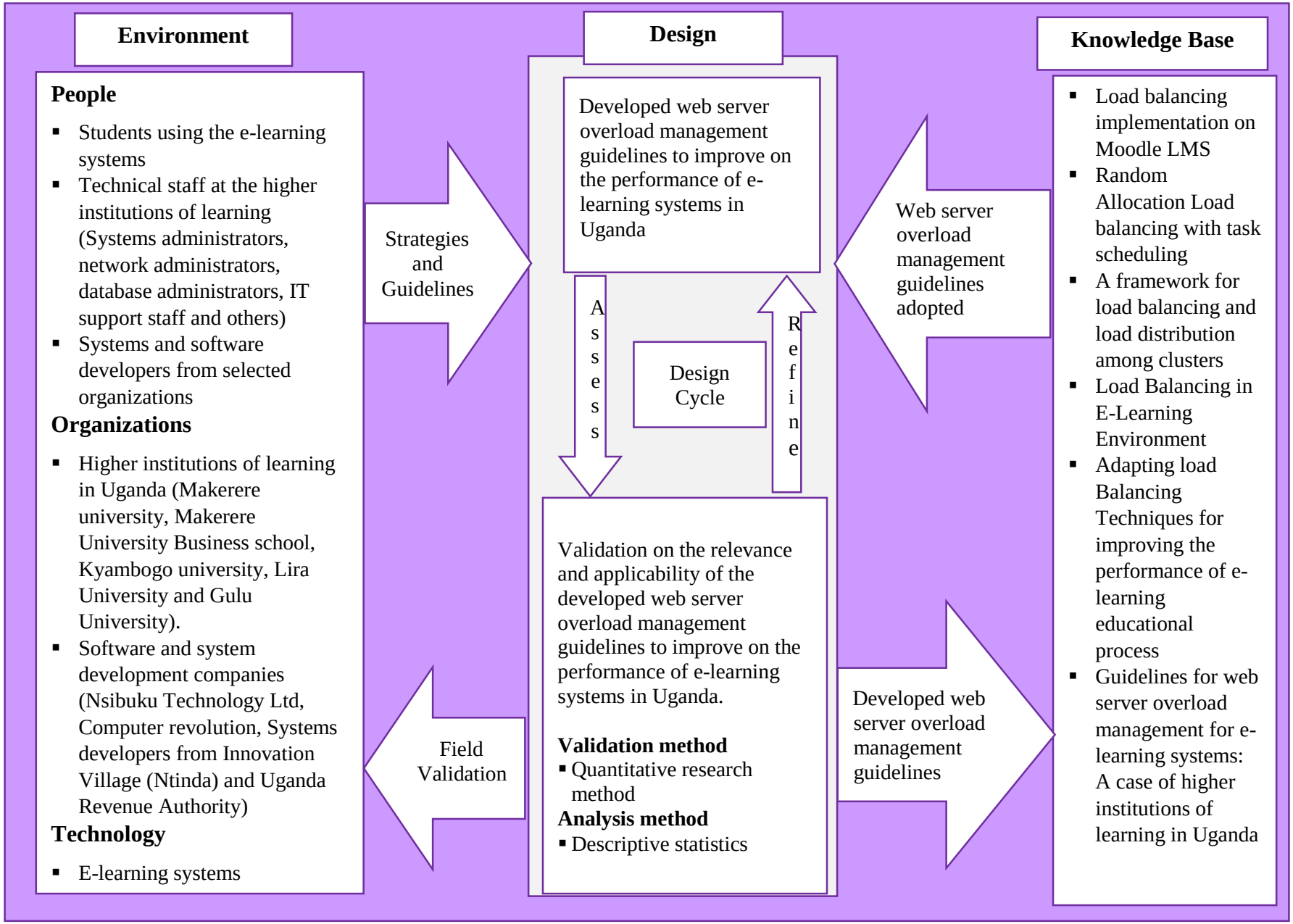


Figure 3. 1. Adopted Design Science Research Approach (based on Hevner, March, and Park (2004))

3.2. Research strategy

A research strategy is a step-by-step plan of action that gives direction to the researcher's thought process (Walia & Chetty 2020). These steps guide the researcher carrying out the research in a systematic manner and on schedule. The authors explained that research strategy's main purpose is to introduce the principal components of the study such as research topic, areas, major focus, research design and then the research methods and also, it helps a researcher to choose the right data collection and analysis procedure. The relevance of the strategy must therefore be considered when choosing it to conduct the research. According to Malhotra (2010), there are four research strategies which include; Inductive, Deductive, Retroductive and Abductive research strategies.

3.2.1. Selected research strategy and justification

Before choosing a research strategy to guide in a clear research direction, a comparison of the above mentioned strategies was made and an appropriate strategy to guide the research process was selected. Blaikie (2010) analyzed the four strategies and descriptions for each strategy was derived. Inductive research strategy involves moving from specific observations to broader generalizations and theories. The Inductive research strategy on the other hand commences with the gathering of data which is analyzed to come up with concrete explanations. Deductive strategy draws conclusions from already made logic from things already known. It commences with a theory, 'a hypothesis or a model' which the researcher tests by making observations (2010). Abductive research strategy involves drawing conclusions from preferring one hypothesis over others which explains facts when there is no basis in previous knowledge that could justify this preference or any checking done (2010). Retroductive research strategy involves coming up with models in order to explain observed consistencies. The recommended web server overload management strategies and guidelines envisioned to improve on the performance of the e-learning systems used at higher institutions of learning was based on inductive research strategy which involved data collection from the field and also using data from other literatures. Figure 3.3 below illustrates how inductive strategy's steps were helpful in achieving the objectives of the research study.

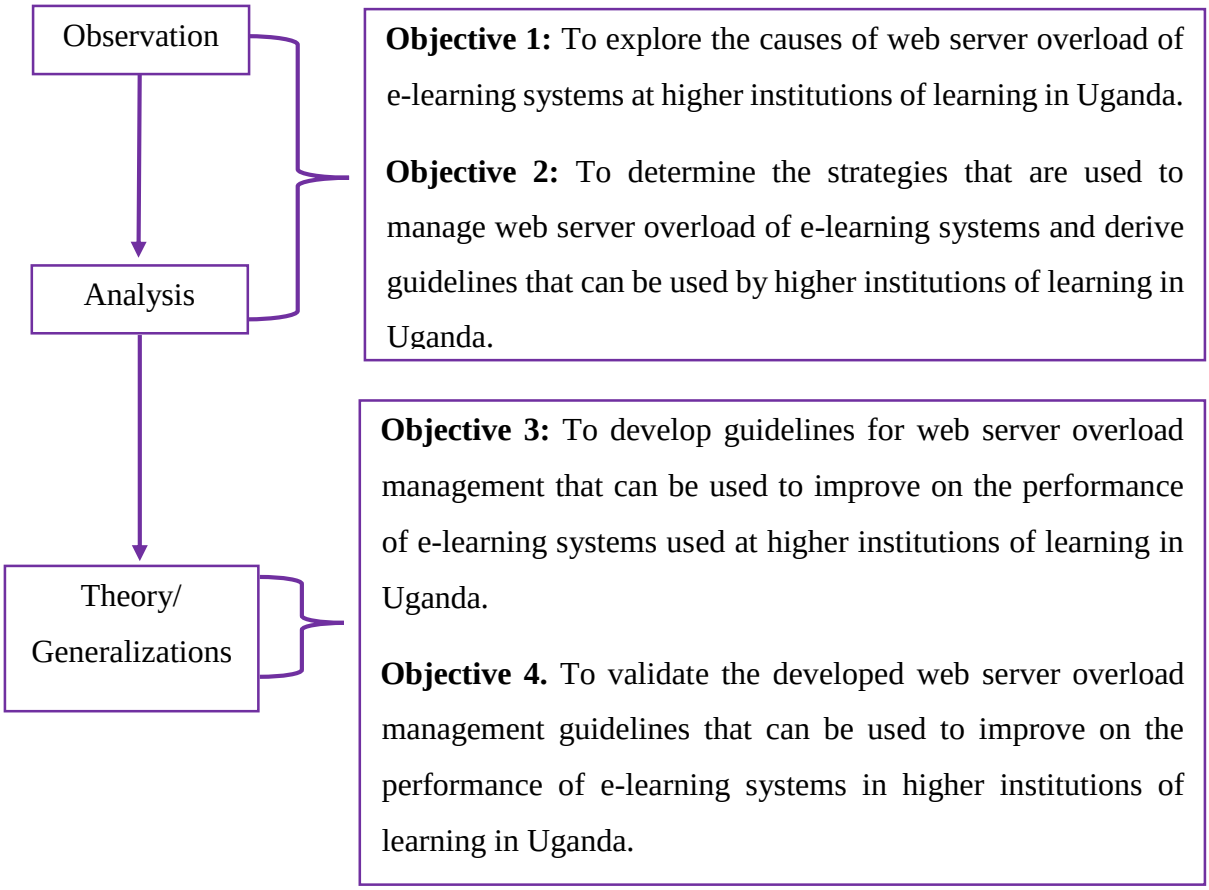


Figure 3. 2 Inductive reasoning (Based on Daniel Miessler, 2020)

3.3. Research methods

Research methods refer to the methods researchers use in performing research operations (Gounder, 2012). These methods can either be qualitative or quantitative or mixed. Typically, the quantitative research method responds to research questions requiring numerical data, qualitative research method responds to research questions requiring textural data, and mixed research methods respond to research questions requiring both numerical and textural data are selected (Creswell, 2003)

3.3.1. Method selection and justification.

A researcher ought to make comparisons between and among the different research methods in order to come up with appropriate method which is suited for the study and the choice of the method is heavily influenced by the research questions. The quantitative method is based on the scientific method and relies on statistical procedures for data analysis. Quantitative methods are

used to collect measurable data for the application of statistical processes which rely on experiments and surveys (Creswell, 2003). Qualitative methods on the other hand are used to analyze and evaluate non-numerical information and it is best suited to studies that involve relationships between individuals and their environments and motives that drive individual behavior and cause for action. The mixed methods approach employ both quantitative and qualitative data in the same study to collect data. Quantitative and qualitative methods are used to collect data which is then analyzed to provide a better understanding of research problems than using either approach alone in a single study. Mixed research methods combine elements of qualitative and quantitative research approaches (for example, use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding (Almalki, 2016). This research study used a mixed research method due to its benefits mentioned above to achieve the objectives of this research study.

Table 3. 2. Data collection instruments used.

Questionnaires:	**Interviews**	**Literature review**
According to Neuman (2003), a questionnaire is where a researcher prepares a set of questions for the participants to answer. In this research study, two sets of questionnaires were used. One set was used to collect data about the causes of web server overload of e-learning systems used at higher institutions of learning in Uganda. Another set was used to validate the developed web server overload management guidelines that can be adopted to improve on the performance of e-learning systems used at higher institutions of learning in Uganda.	Interview is an important data gathering technique involving verbal communication between the researcher and the participant (Fox, 2009). Interviews were used in determining web server overload management strategies for e-learning systems that are used at higher institutions of learning in Uganda and also recommendations on the possible guidelines that can be used to further improve on the performance of e-learning systems. Interview guide was developed and used to guide the interviews had with the technical staff from the selected institutions of learning.	Literature review involves analysis and evaluation of existing documentation about a given subject or topic (2003). Offermann et al. (2009) explained that unsolved problems could be mentioned in scientific publications as well as in practitioner reports which have the advantage of assuring practical relevance. Literature review was used in identifying the causes of web server overload for e-learning systems, understanding the strategies for web server overload management and the possible solutions to the causes of web server overload of the e-learning systems.

Table 3. 3. Methodology Matrix for data collection

Objectives	Research Questions	Methods	Data collection tools	Participants	Outputs
1. To explore the causes of web server overload of e-learning systems at higher institutions of learning in Uganda.	1. What are the causes of web server overload of e-learning systems at higher institutions of learning in Uganda?	▪ Qualitative ▪ Quantitative	▪ Interviews ▪ Questionnaires	▪ Systems administrators ▪ Network administrators ▪ Database administrators ▪ ICT support staff. ▪ Students pursuing (Computer science and software engineer)	The causes of web server overload of e-learning systems used at higher institutions of learning in Uganda
2. To determine the strategies that are used to manage web server overload of e-learning systems and derive guidelines that can be used by higher institutions of	2. What existing strategies are used to manage web server overload of e-learning systems at higher institutions of learning in Uganda?	▪ Qualitative	▪ Interviews	▪ Systems administrators ▪ Network administrators ▪ Database administrators ▪ ICT support staff.	Determination of web server overload management strategies used on e-learning systems at higher institutions of learning in Uganda.

learning in Uganda.					
3. To develop guidelines for web server overload management that can be used to improve on the performance of e-learning systems in Uganda.	3. Which web server overload management guidelines can be developed to improve on the performance of e-learning systems used at higher institutions of learning in Uganda.	▪ Qualitative	▪ Interviews ▪ Research papers, books and other records	▪ Experts ▪ Supervisor ▪ Researcher	Development web server overload management guidelines for the e-learning systems based on the recommended guidelines identified.
4. To validate the developed web server overload management guidelines that can be used to improve on the	4. Can the developed web server overload management guidelines improve on the performance of e-learning	▪ Qualitative	▪ Questionnaires	• Systems and software developers.	Enhanced web server overload management guidelines for the e-learning systems.

performance of e-learning systems used at higher institutions of learning in Uganda.	systems used at higher institutions of learning in Uganda?				

3.4. Target population and sample size selection

The target population is the specific, conceptually bounded group of potential participants to whom the researcher may have access that represents the nature of the population of interest (Casteel & Bridier, 2021). These may include individuals, institutions, groups, households among others. In this case, sample size selection was drawn from higher institutions of learning in Uganda with e-learning systems.

Sampling procedure: According to Collins & Onwuegbuzie (2007), sampling refers to the use of a subset of the population to represent the whole population. The types of sampling techniques which are probability sampling and non-probability sampling were discussed by the authors. Probability sampling is where every item in the population has a chance of being selected whereas non-probability sampling is where there is no random selection of items (2007). Probability sampling is commonly used in studies that involve issues of drawing statistical conclusions whereas non probability sampling is commonly used in exploratory studies (Saunders et al., 2019). This study used the non-probability sampling methods for qualitative research where sampling was purposively done and probability sampling for quantitative research. According to (2001), purposive sampling also known as judgmental, selective, or subjective sampling is a form of non-probability sampling where researchers rely on their own judgment when choosing members of the population to participate in their study. Samples are hand-picked for the research because the researcher has some knowledge about the samples who are in position to provide the most helpful and required data (Denscombe, 1999). In this study, systems administrators, database administrators, IT support staff, knowledgeable students among others were hand-picked for interviews who provided data which helped the researcher to derive answers to objectives 1, 2 and 3. To achieve objective 4 of the study, experts in web server configuration, systems and software developers for systems that attract high concurrency access were purposively selected to validate the guidelines developed in objective 3 for their relevance and anticipated outcome when implemented in the learning environment thus, answering research question 4 of the study. It is important to note that the researcher used purposive sampling because the samples selected would provide data relevant to the study and also in consideration of time, money, location, and their availability.

Sample size determination: The sample size is the number of individuals included in a research study to represent a population. It references the total number of respondents who are expected to

participate in a study (Singh, 2014). Given the time and financial constraints, it was not possible to consider all the higher institutions of learning in Uganda which have e-learning systems therefore, a sample survey was conducted as explained below. Five institutions of higher learning were purposively selected for the study. These included; Makerere University, Makerere University Business School, Kyambogo University, Gulu University and Lira University. Information from these institutions were obtained from the technical experts from DICTs (Directorate of Information and Communications Technologies) and the e-learning department. The technical experts included; systems administrators who are responsible for maintaining the systems, network administrators responsible for network operations within the institutions, database administrators, software and system developers, software engineering and computer science students who have extensive knowledge on web server configuration and e-learning system operation. The selection was purposive because the selected participants would provide the researcher with information relevant to this study's objectives for example describing the circumstance that would cause web server overload for the e-learning systems and strategies and mechanism to curb the web server overload for the e-learning systems among others. The information provided helped the researcher in achieving objective 1, objective 2, and objective 3.

Qualitative method

Under this method, interviews were used to collect data from the technical experts at the higher institutions of learning that helped to achieve objectives 1 and 2 of the research study. The researcher interviewed 4 systems administrators, 2 IT support staff, 1 lecturer, 1 student from computer science and 1 student from software engineering (web developer) from four institutions of higher learning to attain results for objective one. The results from the interview helped to meet the first and second specific objectives which involved investigating the causes of web server overload for the e-learning systems at higher institutions of learning and determining web server overload management strategies for the e-learning systems deployed by higher institutions of learning. Achievement of the two objectives contributed to the fulfillment of the third specific objective which involved recommendation of suitable web server overload management strategies and guidelines for the e-learning systems used at higher institutions of learning in Uganda.

Quantitative method

After the recommendation of the web server overload management strategies and guidelines for the e-learning systems, they were validated. Validation questionnaires were administered to twenty

participants (20) though only seventeen (17) participant participated in the study to validate their relevance and anticipated outcome or implications on the e-learning systems when implemented. Only 20 participants were considered because of availability factor since there are few existing experts with the required level of skills and knowledge.

According to Ahmad et al. (2019), quantitative research produces numerical data and hard facts that can be accurately and precisely measured. The study used quantitative research to get answers and opinions from the technical experts on the recommended web server overload management strategies and guidelines. This method was used since it was a viable method for validating the recommended web server overload mangement strategies and guidelines for the e-learning systems as it collected experts' opinions on the relevance of each strategy and guideline and the anticipated outcome or implications on the e-learning systems when implemented.

Detailed information on the recommended web server overload management strategies and guidelines to improve on the performance of the e-learning systems is in chapter five and validation of the recommended strategies and guidelines is more detailed in chapter six.

The breakdown of the respondents is highlighted in table 3.4 below. This facilitated in achieving objective four.

Below is a breakdown of the questionnaires distribution.

Table 3. 4. Showing breakdown of participants and types of systems developed and maintained.

Participants	**Systems**	**Numbers**
Systems / software developer	Financial system	5
Systems / software developer	Uganda Revenue Authority (URA) tax clearance systems	3
Systems / software developer	E-learning systems	2
Systems / software developer	E-commerce system	5
Systems administrator	E-learning systems	2
Total		**17**

3.5. Data Analysis

Both qualitative and quantitative data was collected.

Qualitative data analysis was done using content analysis. Content analysis enabled analyzing the contents of the interviews conducted in order to identify main themes that emerged from the responses given by the respondents. Quantitative data on the other hand was analyzed by use of google form graphs generated from the questionnaire responses for the validation phase and Microsoft excel 2016 to analyze data for the first and second objectives. Results and findings for this section are elaborated in chapter four and six.

3.6. Ethical Clearance

This study considered Lærd Dissertation (n.d.) related to ethical considerations in dissertations. The researcher undertook the below ethical considerations during the research.

Obtaining informed consent.

The researcher explained to the participants about the purpose of the research, the expected outcome of the research, what the research required from them and also assured them that their participation was voluntary.

Protecting anonymity and confidentiality

Protecting the anonymity and confidentiality of research participants was considered. Participants' names, addresses and contact details were kept private and only information provided by them were presented.

Avoiding deceptive practices

The researcher strived for honesty in all the communications by honestly reporting data and results. The information presented by the researcher was not fabricated or falsified. Honesty and transparency was also exhibited to the participants by explaining the purpose of the research, what was required from them and the anticipated outcome of the research.

CHAPTER FOUR

Presentation and Discussion of survey findings

4.0. Introduction

Chapter three described methodology used to answer the research questions for the study. It described how data for the study was gathered and analyzed to achieve the objectives of the study. This chapter now presents a detailed discussion of the findings obtained from the field in relation to the research questions outlined in chapter one. Quantitative data collected was analyzed using Microsoft Excel 2016 and qualitative data was analyzed using content analysis as discussed in chapter 3. The output of this chapter therefore addresses the research questions in chapter one and meets the specific objectives of this study which are;

- To investigate the causes of web server overload of e-learning systems at higher institutions of learning in Uganda.
- To determine the strategies that are used to manage web server overload of e-learning systems used in higher institutions of learning in Uganda.

Answers to research questions (3) and (4) and the corresponding findings for research objectives (3) and (4) are discussed in chapters five and six respectively. Figure 4.1 below shows the structure of chapter four.

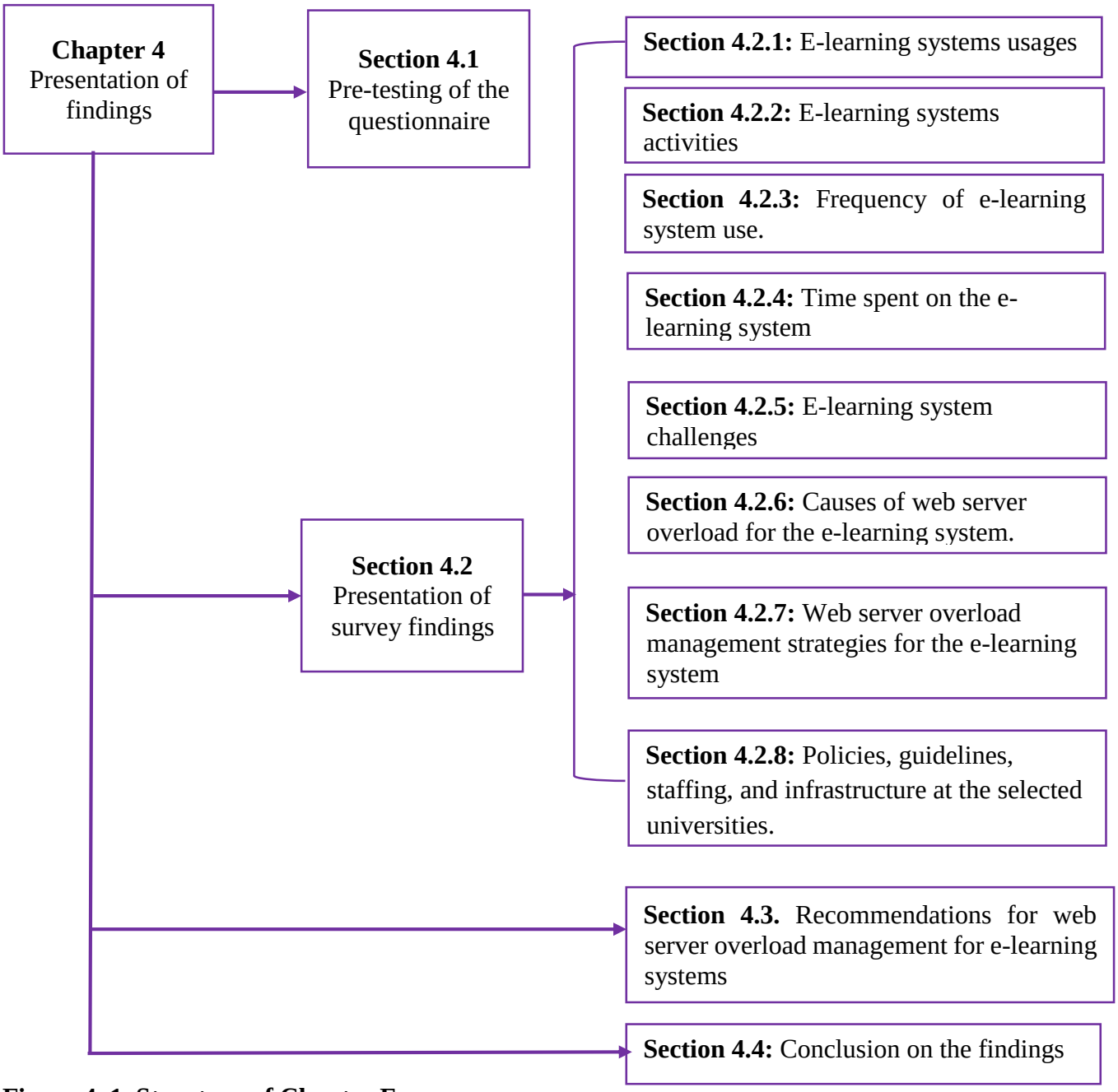


Figure 4. 1. Structure of Chapter Four

4.1 Pre-testing of the questionnaire.

A pilot study was undertaken before the actual study in which ten participants reviewed the questionnaire and interview guide and numerous changes were made to it. Some of these changes included; ordering of individual questions, restructuring of wordings and formatting of the questions. Out of the ten participants who reviewed the questionnaires and interview guide, five were technical people and five were students from some of the selected institutions of higher learning in Uganda. The purpose of the pre-test was to ensure that, there was consistency in the flow of the questions and also to ensure that the questionnaire and interview guide measured to the concept of the study.

4.2. Presentation of survey findings

This section presents the findings obtained from the analysis of data collected from one hundred twenty-one participants. Two data collection methods were used to collect data. Questionnaire (inform of google form) was designed and emailed to one hundred thirty students which captured questions concerning e-learning system usage. Twenty technical staff were purposively sampled for interview on technical questions and about management of the e-learning systems. Some questions applied to both the students and the technical staff and the responses obtained from those questions were merged and analyzed together. Out of the one hundred fifty participants both the students and the technical staff, a total of one hundred twenty-one respondents participated (one hundred twelve students and nine technical staff) which presented a response rate of (81%). Descriptive statistics were used to present and explain the findings obtained from the five selected institutions of higher learning in Uganda. The response rate is derived from the formula below;

Response Rate= (Questionnaires returned)/ (Questionnaires sent) *100

Response Rate = (121) / (150) *100

Response Rate = 81%

According to Fincham (2008), the goal of researchers should be attaining response rates approximating 60% which this study managed to score highly with 81%.

The discussion of section 4.2 and the other subsequent sections are as illustrated in figure 4.1 above.

4.2.1: E-learning systems usage

In this section, 34 respondents were from Makerere University Business School (MUBS), 29 were from Makerere University, 27 respondents were from Gulu university, 18 respondents were from Lira university and 13 respondents were from Kyambogo university. The E-learning systems used

by the respondents were Makerere University Business School E-learning Platform (MUBSEP), Makerere University E-Learning Environment (MUELE), Gulu University E-learning Environment (GUELE), Lira University E-learning Environment (The BEE) and Kyambogo University E-learning Management System (KELMS) respectively. Figure 4.2. shows the responses on e-learning system usage from the five selected institutions of higher learning in Uganda.

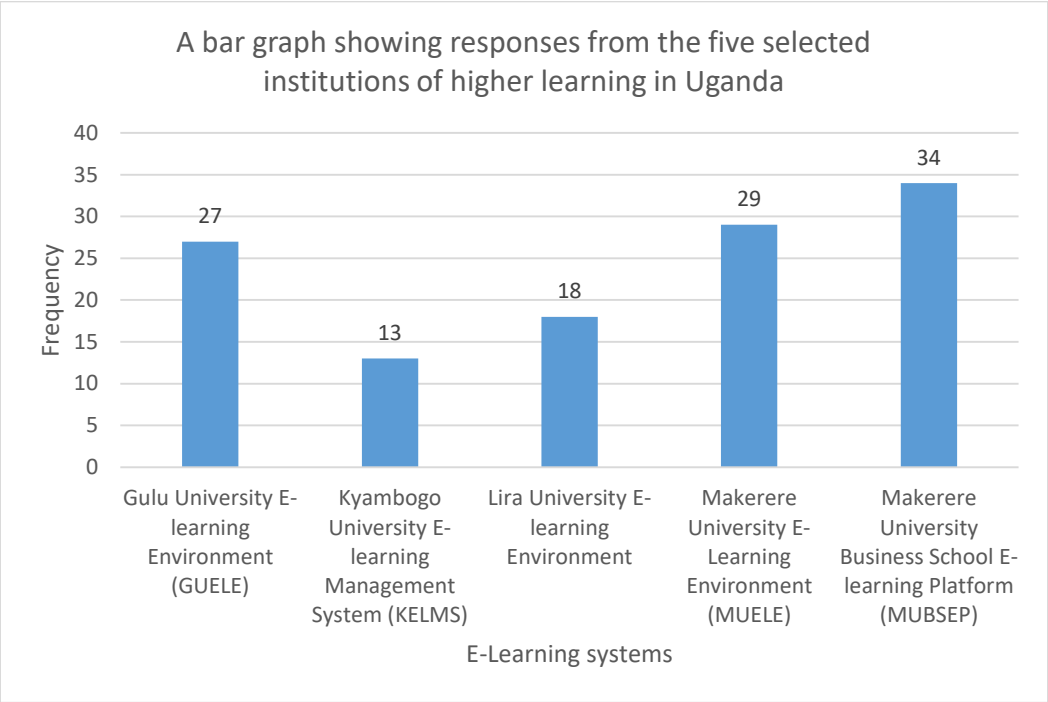


Figure 4. 2. E-learning systems usage (Source: Primary Data)

4.2.2: E-learning systems activities.

In this section, questions on the activities carried out while using the e-learning systems were asked because it was important to know the amount of resources required to handle network traffic while the e-learning systems are in use. From the analysis of the e-learning system activities, 71 respondents accessed it to download notes, 65 respondents accessed the e-learning systems to upload assignments and quizzes, 56 respondents accessed it to do online examinations and tests, 15 respondents accessed it to attend lectures and 15 respondents accessed the e-learning systems to interact with course mates through chats. Figure 4.3 shows the different activities performed on the e-learning systems.

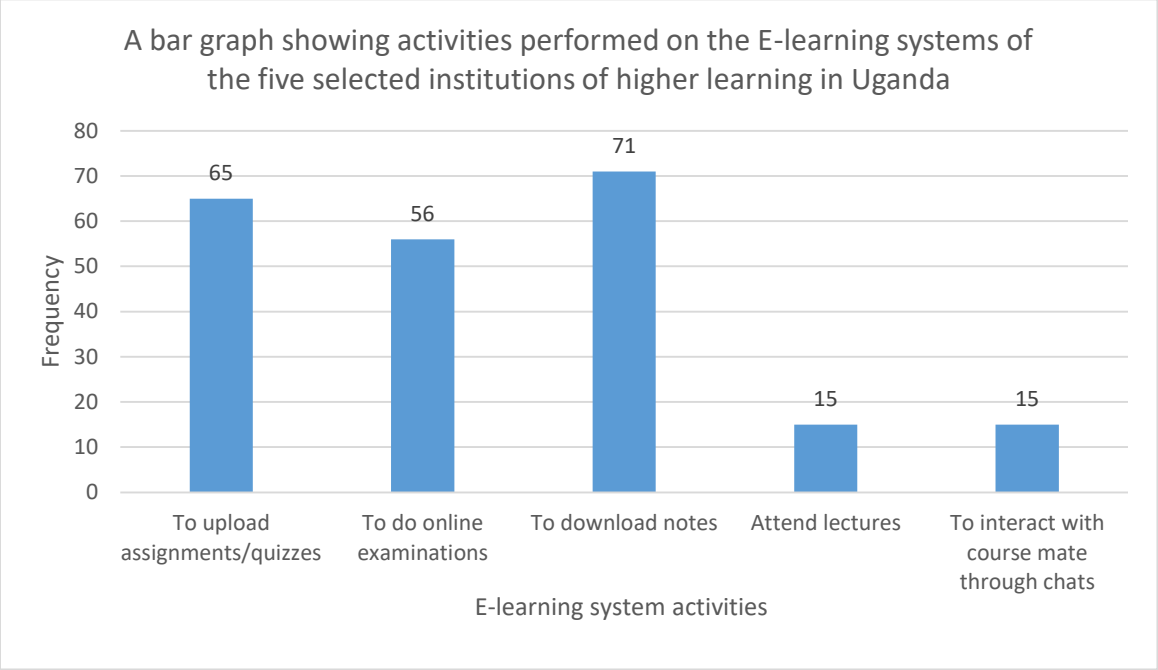


Figure 4. 3. E-learning systems activities (Source: Primary Data)

4.2.3: Frequency of E-learning system use.

The results presented in this section revealed that 35 respondents accessed the E-learning system every day, 23 respondents accessed it more than four times a week and 16 respondents accessed the e-learning systems once a month. The results further revealed that 10 respondents accessed the e-learning system once a week, 13 respondents accessed it twice a week and 10 respondents accessed the e-learning system thrice a week. Figure 4.4 illustrates the frequency of e-learning system usage from the five selected institutions of higher learning in Uganda.

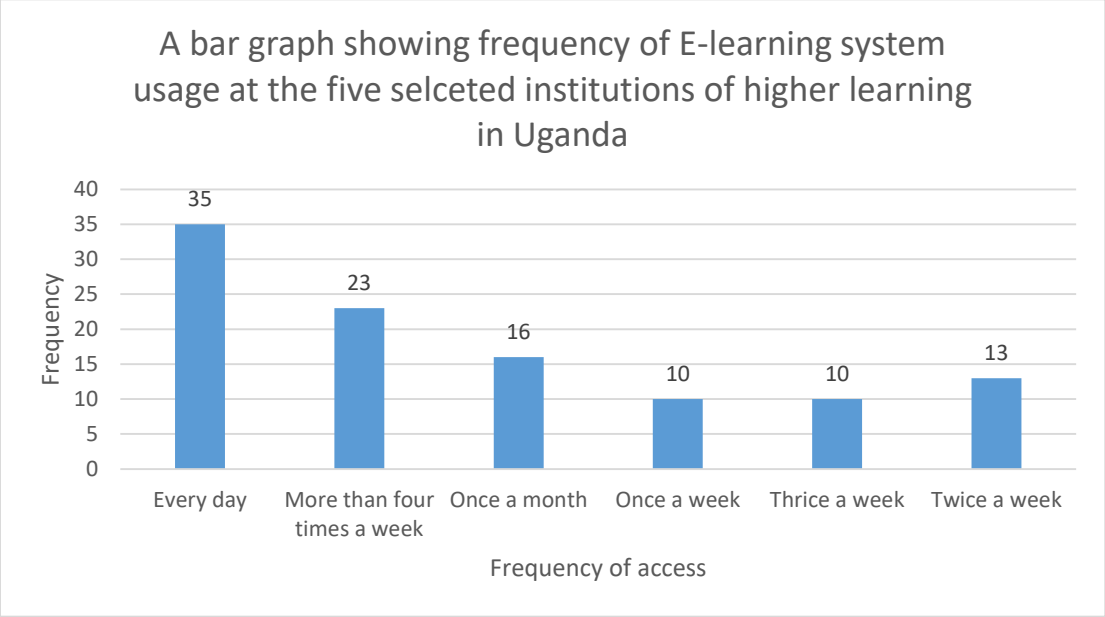


Figure 4. 4. Frequency of e-learning system use. (Source: Primary data)

4.2.4: Time spent on the e-learning system and user experience.

This section clearly presents the amount of time spent on the e-learning systems by respondents. This however, was based on the kind of activities being performed on the e-learning system. The results indicated that 39 respondents spent 1-2 hours on the e-learning system, 33 respondents spent less than 1 hour on the e-learning system and 29 respondents spend 3-4 hours on the e-learning system. Findings further revealed that 7 respondents spent 5-6 hours and 5 respondents spent 7-8 hours on the e-learning system. The illustration below shows the amount of time spent on the e-learning system from the five selected institutions of higher learning in Uganda.

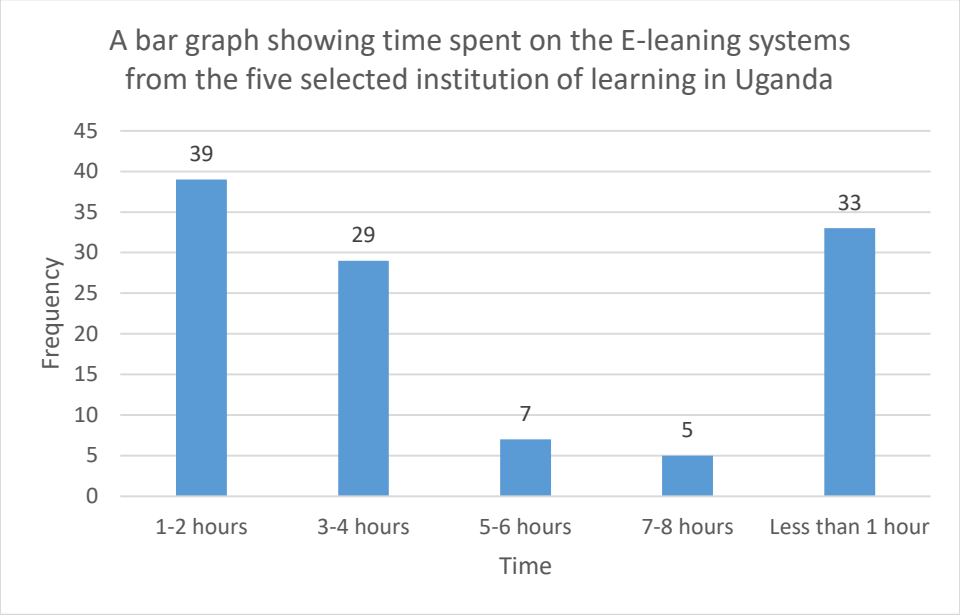


Figure 4. 5. Time spent on the e-learning system (Source: Primary Data)

4.2.5: E-learning system challenges

The challenges faced by respondents while accessing the e-learning systems from the five selected institutions of higher learning in Uganda are presented in this section. The challenges were both from the e-learning systems' side and from the respondents' side. This study however focused on the challenges from the e-learning systems' side. Out of the 114 respondents who used the e-learning systems from the five selected institutions of higher learning in Uganda, data collected revealed that 107 respondents faced challenges with the e-learning systems and only 7 respondents did not face any challenge with the e-learning systems. Out of the 107 respondents who faced challenges with the e-learning system, 71 respondents faced a challenge of slow speed of accessibility of the e-learning system, 58 respondents faced a challenge of lack of internet bundles and 50 respondents faced a challenge of e-learning system unavailability (system downtime). The findings further revealed that 15 respondents faced a challenge of difficulty to use the e-learning system and 14 respondents lacked computing devices to connect to the e-learning system. Figure 4.6 below illustrates the challenges faced while using the e-learning system from the five selected institutions of higher learning in Uganda.

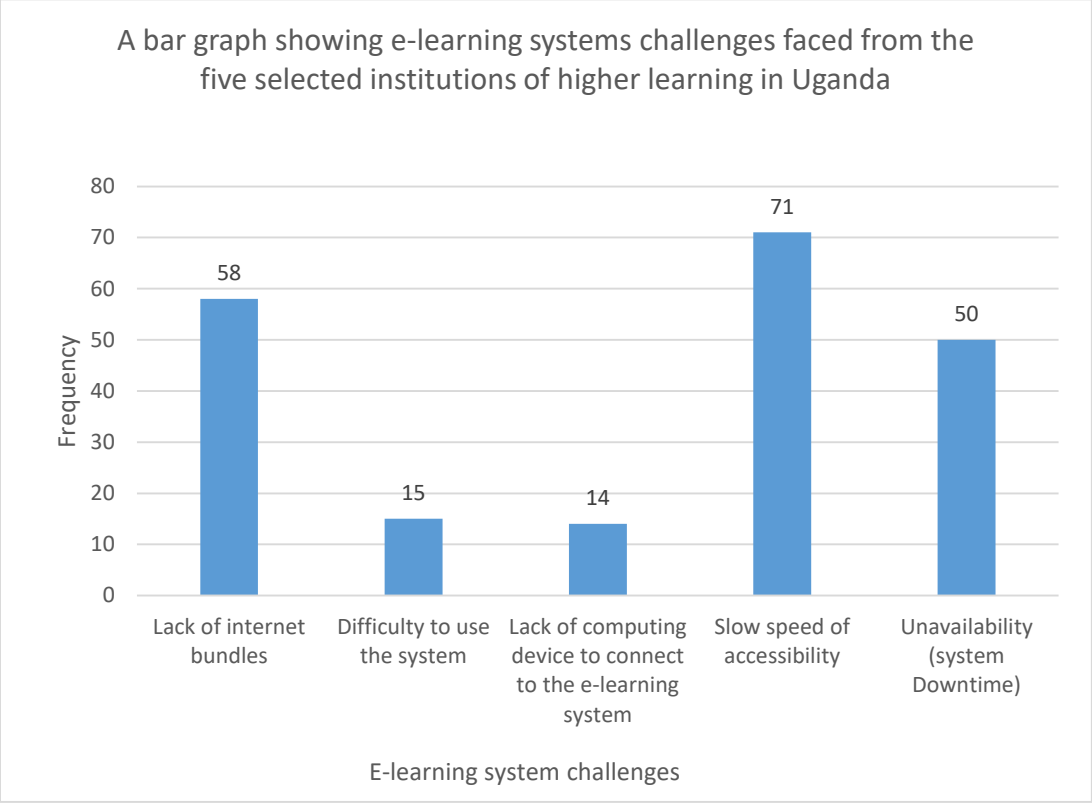


Figure 4. 6. E-learning system challenges (Source: Primary Data)

4.3.3: Causes of web server overload for the e-learning systems derived from the interview.

In order to achieve objective 1 of the research which was investigating the causes of web server overload for e-learning systems used at higher institutions of learning in Uganda, the researcher interviewed purposively selected participants from the five selected institutions of higher learning in Uganda guided by an interview guide for a systematic flow. Qualitative data obtained from the interviews were then analyzed using content analysis to derive the causes of web server overload of e-learning systems used and frequencies were generated for each cause of the web server overload mentioned by the respondents. The paragraphs below are the responses that were obtained from the participants from each institution annotated with letters A, B, C, D, and E for the purpose of confidentiality. The responses obtained were as follows;

From institution A, a systems administrator explained to the researcher that ‘’… The current bandwidth is not sufficient for the large volume of traffic generated by the users of the e-learning system, we are actually planning to upscale since there is increased traffic to…” The respondent elaborated more by saying; “… we were initially hosting our e-learning system on our own server

but the number of online users outweighed the capability of our server so we are now hosting our system with an external hosting company…"

From the above statements, the research was able to derive increased number of concurrent users, insufficient network bandwidth and insufficient web server resources as the causes of web server overload of the e-learning systems from institution A

While interviewing a systems administrator from institution B, the researcher obtained the following responses. "… we used to have one physical dedicated web server and one database server, but due to the complaints raised by the users, we decided to buy two additional servers to scale up the performance of the system, however, the performance has not yet reached our desired stage. We also intend to increase on our bandwidth with time…"

A software engineering student/ web developer from the same institution responded that "… I had a very reliable internet connection ready for the online quiz that our lecturer had communicated to us that we were having the next day, on the day for the quiz, I logged on to system some few minutes late when the other students had logged in and it took me almost 20 minutes just to access the system, the link to the quiz was not responding and it eventually opened in my last attempt when I had almost given up, when I finished the quiz, I could not submit it because the system was too slow, …"

A computer science student also from institution B narrated that "…I gave up on using the e-learning system, even when they said that the web server was upgraded, the moment all students log onto the system to attempt the quizzes, that's when you realize a snail is much faster than (system X) …"

Only two students were considered here because of their prior knowledge about web server configuration and the causes of web server overload. These students were chosen for the interview also because the work they do involve web server operations. The other students were not considered in determining the causes of web server overload because they were just users of the e-learning system and did not have much knowledge on web server operation and they did not also have the opportunity to configure web servers in real-time.

The researcher was able to derive increased number of concurrent users, insufficient web server resources, and insufficient network bandwidth as the causes of web server overload of the e-learning systems from institution B

A systems administrator from institution C enlightened the researcher that "…It's true that our students have complained about our e-learning system being slow. It was even catastrophic when students were given online exams. The system was very slow and we decided to postpone the exams since all the students could not use the e-learning system to do the online exams…"

A lecturer from institution C also narrated that "… Our web server could not handle the traffic generated by the online activities, we decided to upload the exams online for students to download, they wrote the answers on pieces of papers, scanned them and uploaded them to the e-learning system, this was to prevent complaints about the slow system by the students and others missing out…"

Still from institution C, an IT support staff explained that "… Before covid19, there were no many complaints on the performance of the e-learning system but when, we started online learning and all students were required to attend lectures online, we registered many complaints on the performance of the system and it unmasked the challenges with our system so we opted for other alternatives…"

The causes of web server overload for e-learning systems derived from institutions C were; increased number of concurrent users, and insufficient web server resources.

An IT support staff from institution D explained to the researcher that "…we used two modes of distance learning, which were; short term using google classroom and long term mode using e-learning system (xxx). However, we used the short term mostly since the e-learning system could not support the large number of students yet learners had to continue with the learning process …"

Another respondent who is a system administrator still from institution D explained that "…we took on e-learning seriously by utilizing our e-learning system (xxx) but its performance was not as we anticipated due to increased number of online users, we then upgraded our server by adding the RAM …", the respondent further elaborated, "…actually, our system was not so much used by students and even the teaching staff but when the government encouraged institutions to start online learning, we started having complaints from the students that they could not submit their assignments, the system was slow…"

With all the data provided, the researcher used content analysis and derived; increased number of concurrent users, insufficient web server resources, and insufficient network bandwidth as the causes of web server overload of the e-learning systems from institution D.

The researcher was unable to reach institution E due to time and unfavorable schedules

Qualitative data collected through interviews with the technical experts was analyzed using content analysis where the causes of web server overload were derived. The researcher interviewed 4 systems administrators, 2 IT support staff, 1 lecturer, 1 student from computer science and 1 student from software engineering (web developer). Out of the 9 respondents, all the 9 respondents revealed that increased number of concurrent users on the e-learning system was one of the causes of web server overload, 6 respondents revealed that insufficient web server resources such as RAM, HDD/SSD and others was another cause of the web server overload, 3 respondents also revealed that insufficient network bandwidth also contributed to web server overload for the e-learning system since it is not enough to accommodate the traffic to and from the server.

4.3.3: Web server overload management strategies for the E-learning system

Objective 2 of the research study was to determine the strategies used to manage web server overload of e-learning systems and derive guidelines that can be used by higher institutions of learning in Uganda. Interview with 4 technical staff from the four institutions of higher learning were conducted with the help of an interview guide to prevent deviation from the research objective. The respondents interviewed were primarily responsible for the e-learning systems who gave the researcher the reliable responses. The selected institutions of higher learning were annotated with letters A, B, C, D, and E for confidentiality purpose. Below are the strategies that were used by the selected higher institutions of learning.

From institution A, a system administrator explained that "… lecturers preferred to use zoom meeting app instead of the e-learning system since majority of students could not have access to it…." The participant further explained that "…the e-learning system was initially hosted internally but due server downtime occurrences, we have migrated to external hosting where by the hosting company takes care of all the hosting requirements…"

From the above strategies used to manage web server overload at learning institution A, the researcher derived two strategies, these were; use of alternative platforms and web server upgrade.

At institution B, a respondent who serves as a systems administrator and network administrator explained that "… the network bandwidth was up scaled from 1.6 Gbps to 2Gbps and its much better than before, however this is not yet sufficient to meet the demands of online users so we are planning to upscale it to…"

The respondent further elaborated that "… we used to have one physical web server and one database server but when we realized that the traffic was too much we decided to procure two more web servers though they are not yet fully utilized and we believe they will be able to accommodate the increased number of online users…"

The respondent added that "… to resolve the issue of many concurrent access of the e-learning system, we time tabled online quizzes and exams in order to reduce of the load on the server…" When probed further, the respondent narrated that "… we improved our architecture from one physical web server and one database server to three physical web servers and one database server. We also set up a load balancer (round robin load balancing algorithm) to distribute traffic to the other web servers. We were initially using he hashed load balancing algorithm but its performance was not desirable since…"

The respondent continued that "… we also used caching of frequently accessed web pages using the Redis software to reduce on the time spent querying the database for the information…" And lastly the respondent revealed that "… other lecturers also went ahead and used zoom instead of the e-learning system since the university had paid for enough zoom licenses for each college at the university. The lecturers also forwarded notes to the students via emails through the students' representative and they shared the notes…"

From the above discussion with the respondent at institution B, the researcher was able to derive five strategies that the institution applied. These were; network bandwidth upscaling, web Server upgrade, time tabled access, use of load balancing algorithm, information caching, and use of alternative platforms.

While at institution C, the researcher interviewed a respondent who serves as a systems administrator and the strategies applied at that institution were as below;

"… we have two terms which are short term and long term so, we decided to get someone to get us up to speed and we were using google classroom for the short term model…" The respondent further said "… we also decided to upgrade our server by increasing on our RAM and at the moment, that is what we did to accommodate the increased number of users on the e-learning system..."

From the strategies provided, the researched derived use of alternative platforms and web server upgrade as the strategies used to manage web server overload at institution C.

At institution D, the researcher interviewed a systems administrator who provided the strategies used at their institution to manage web server overload. The strategies were as below;

"… in order to reduce on the web server overload, we timetabled exams whereby students downloaded it, answered on a piece of papers, scanned it and uploaded it to the e-learning system…" The explained further that "… we also encouraged single browser login to the system to avoid multiple logins by the same user.

The respondent revealed that "…we acquired zoom licenses and we were able to conduct the lectures through zoom meeting application since the e-learning system could not handle the increased number of users…" And lastly, the respondent explained that "… contents uploaded on the e-learning system are evaluated to ensure that they meet the set standards…"

Single browser login, use of alternative platforms, time tabled access, and content evaluation were the strategies that the researcher was able to derive from the above strategies used the institution D.

The researcher was unable to get in touch with respondents at institution E due to time and unfavorable schedules.

Overall, qualitative data from the interviews was analyzed using content analysis whereby key words were picked from each statement to derive the web server overload management strategies used. The findings in this section revealed that all the 4 respondents (systems administrators) from the four institutions of higher learning (A, B, C and D) encouraged use of other alternative platform like zoom meeting application for lectures and other activities, 3 respondents (system administrators) from three institutions of higher learning (A, B and C) upgraded their web servers for the e-learning system to accommodate the increased number of users, 2 systems administrators from two institutions (B and D) time tabled e-learning system access for lectures and online examinations and quizzes and 1 system administrator from institution (D) encouraged single browser login to avoid multiple login by the same user as ways of reducing on web server overload for the e-learning system. The respondent from institution (D) further revealed that all the contents uploaded onto the web servers were first evaluated to ensure that they had the correct formatting and also to ensure that the file sizes were optimized. 1 respondent (system administrator and database administrator) from institution (B) used caching of information using the Redis software for frequently accessed information by users to reduce on the load put on the database to query for

information each time the same information was requested by another user. The respondent from institution (B) further used a load balancing algorithm (Round Robin algorithm) to distribute traffic to other web servers to avoid overload on some web servers and it also up scaled its network bandwidth to accommodate the growing number of e-learning systems users.

4.3.4: Policies, guidelines, technical staffing and information technology infrastructure at the selected institutions of higher learning in Uganda.

This section presents the finding on the different policies, guidelines, technical staffing and information technology infrastructures at the five selected institutions of higher learning in Uganda.

4.3.4.1: Policies, guidelines used at the selected institutions of higher learning in Uganda.

This section unveils the policies and guidelines used in the five selected institutions of higher learning in Uganda and data was obtained from the questionnaires sent to the respondents and interviews conducted. Out of the 24 respondents who answered this question, 11 respondents mentioned that one was required to have a user authentication in order to access the e-learning system as one of the guidelines, the respondents further elaborated that a user is required to have a username and password in order to login the system. This was aimed at preventing non authentic users from logging into the e-learning system thereby reducing the number of users on the system hence reducing of the volume of traffic sent to the web server from the e-learners. The findings further revealed that 8 respondents issued user guide manual inform of short videos and written documents as another way to guide users on how to use the system. Single browser login was another guideline emphasized to prevent multiple logins by the same user on different devices that was revealed to the researcher by 2 respondents. This was another guideline used to reduce e-learning systems web server overload. Findings from the data collected also revealed that 2 respondents mentioned that their institutions had an ICT policy (Information and Communication Technology) and 1 respondent from one of the institutions mentioned that their institution had the IODel policy (Institute of Open Distance and eLearning). The researcher further probed some of the technical experts on the different policies used at their institutions and it was found out that some institutions had policies that were awaiting approvals by their stakeholders within the institution. Figure 4.7 graphically illustrates the different guidelines and policies used at the higher institutions of learning in Uganda.

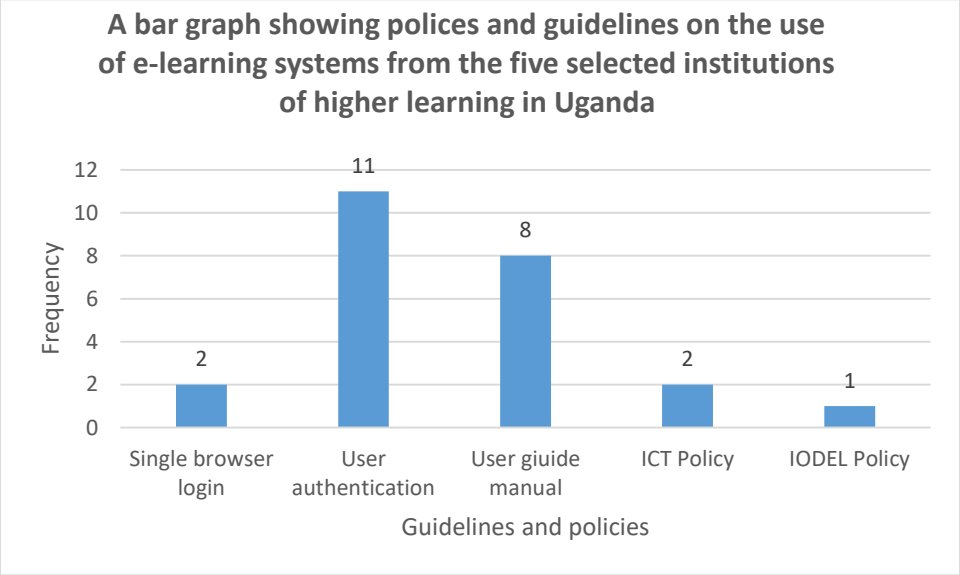


Figure 4. 7. E-learning policies and guidelines (Source: Primary Data)

4.3.4.2. Staffing at the selected institutions of higher learning in Uganda.

This study focused on the five selected institutions of higher learning in Uganda. In order to come up with technical recommendations to improve on the performance of the e-learning, it was important to also know the technical staffing composition. The researcher interviewed 4 systems administrators and 2 IT support staff. The researcher also found out that two systems administrators from two institutions played two roles that is; as a system administrator and a database administrator.

4.3.4.3. Information technology infrastructure

Table 4. 1. Summary of technology infrastructure for the five selected institutions of learning in Uganda

University	**Designation**	**Web server specification**	**Web server specification requirements demand** *(1. Does not meet, 2. Meets some, 3. Meets, 4. Exceeds, 5. Far exceeds)*	**Network specification**	**Network specification requirement meets demands** *(1. Does not meet, 2. Meets some, 3. Meets, 4. Exceeds, 5. Far exceeds)*	**Have a Framework/ Load balancing Algorithm**	**E-learning system hosting site**
A	Systems administrator and database administrator	Nginx web server software 8 Core Intel Xeon CPU, 16GB RAM, 1TB HDD	Meets	• 33Mbps though planning to upscale to 70 Mbps. • Ethernet cable connection • ISP is Research and Education Network	Meets *("But not sufficient")*	No	Hosting company outside the institution by Research and Education Network Uganda (RENU)

				Uganda (RENU)			
A	Systems administrator and database administrator	Nginx web server software  DELL EMC R7 spec.pdf	Far exceeds	• 2 Gbps network bandwidth upstream and downstream • Fiber connection • ISP is Research and Education Network Uganda (RENU)	Meets *("But needs up scaling")*	Yes (*Round Robin Load balancing Algorithm*)	At the institution by Research and Education Network Uganda (RENU)
C	Systems administrator	Apache server software	Meets	• 330 Mbps network bandwidth, • Ethernet cable connection • ISP is Research and	Meets some *("Not sufficient")*	No	Hosted at the institution by Research and Education Network Uganda (RENU)

				Education Network Uganda (RENU)			
D	Systems administrator	Apache server software	Meets	No response	Meets	Yes *("Cloud Hosting provides the best load balancing algorithm")*	Cloud hosting
E			No response		No response	No response	No response

4.4: Recommendations for web server overload management.

Technical staff were asked to provide their recommendations on some of the ways, measures and strategies and guidelines that would help to improve on the performance of the e-learning system used at the higher institution of learning in Uganda. Table 4.4 below presents some of the recommendations made by the technical staff from the selected institutions in order to improve on the performance of the e-learning system.

Table 4.4. Recommendations obtained from the technical staff from the five selected institutions of learning

Institutions	Respondent title	Recommendations
A	Systems and database administrator	• Clustering of the databases to reduce database load as users request for different files stored in database • Setting up a primary load balancer to distribute traffic to different web servers to reduce load put on a single web server. • Configuration of a secondary load balancer to back up the primary one in case of a failure in the primary load balancer. • Increasing on the number of web servers to meet the current demands of the users. The respondent explained that this can be made possible by fully utilizing the available web servers by setting up virtual servers to meet the demands of the increasing number of users. • Upgrading the relational database management systems from MySQL to PostgreSQL for faster database access. The respondent further elaborated that PostgreSQL is suited for applications that require a huge volume of activities that require both reads and writes whereas MySQL is only suitable for applications that require only a huge volume of reading.

B	Systems administrator	• Another respondent also recommended that all redundant network interface cards (NIC) on the servers should be fully utilized to increase on network accessibility and also in turn improving on the network speed. The respondent justified this point that having a dedicated web server for the e-learning system only would provide reliable resources during peak time of utilization of the e-learning system. • Increasing on the number of web servers to meet the current demands of the users by means of virtualization to increase on the number of servers. • Hosting e-learning systems on dedicated web servers to avoid web server suffocation.
C	Systems administrator	• Increasing the number of web servers to meet the current demands of the users.
D	Systems administrator IT Support staff	• Increasing the number of web servers to meet the current demands of the users. • Continuous training on course or learning content development by content developers was another recommendation mentioned. • Course content must be evaluated to check if they meet the standard requirement before being uploaded on to the web servers for access by users
E	No response	No response

These recommendations were provided by the experts identified in Table 3.2 in chapter three.

4.5: Conclusion

In conclusion, this chapter was mainly purposed to present the findings from the field after conducting the survey. The findings made it possible to achieve objectives (1) and (2) of the study and also provided answers to research questions (1) and (2) stated in section 1.4.2. The results were obtained by analyzing the qualitative and quantitative data collected from the survey. Microsoft Excel 2016 was used to analyze quantitative data whereas content analysis was used to analyze qualitative data derived from open ended questions and from the interviews. Findings from the survey were presented using descriptive statistics, and from these findings, the causes of web server overload of e-learning systems and strategies used to manage web server overload of e-learning systems at higher institutions of learning in Uganda were identified. This chapter also provided the researcher with web server overload management strategies that partly achieved research objective (3) from the recommendations provided by the experts. These further helped the researcher to come up with the suitable web server overload management strategies that can be used to improve on the performance of the e-learning systems at higher institutions of learning in Uganda. Chapter five discusses the detailed web server overload management strategies derived from recommendations provided by the experts identified in Table 3.3 in chapter three.

CHAPTER FIVE

Web server overload management strategies and guidelines for the e-learning systems.

5.0. Introduction

In chapter four, the causes of web server overload for e-learning systems at higher institutions of learning and the strategies used to manage web server overload for e-learning systems were identified. The identified causes of web server overload for the e-learning systems and the strategies used to manage them helped the researcher to achieve objectives (1) and (2) from the primary data collected from the survey. Recommendations from the technical staff and users of the e-learning systems contributed to identification of the specific strategies and guidelines that can be adopted by higher institutions of learning in Uganda in order to improve on the performance of the e-learning systems used. This chapter discusses the suitable web server overload management strategies and guidelines that the researcher derived from the different existing literatures on web server overload management and from primary data collected and analyzed from the field study. Therefore, this chapter addressed objective (3) of the study stated in section 1.3.1. and thus answering research question (3);

Which web server overload management strategies and guidelines can be recommended to improve on the performance of e-learning systems used at higher institutions of learning in Uganda?

5.1. Recommendations based on primary data

As discussed in section 3.4, this study used non-probability sampling method for qualitative research where sampling was purposively done. This sampling technique helped the researcher to generate useful information from the experts specified in Table 3.3. Input from objective (2) of the study helped the researcher to achieve objective (3) by recommending suitable web server overload management strategies and guidelines that can improve on the current e-learning system performance at the selected higher institutions of learning in Uganda and also for the future performance of the e-learning systems. The researcher based the recommendations on experts' contributions from primary data collected and also from related literatures. The researcher formulated the recommendations from the different experts into strategies and guidelines that can be used to improve on the performance of the e-learning systems at higher institutions of learning in Uganda. Table 5.1 below summarizes the strategies and guidelines formulated from recommendations from the primary data.

Table 5. 1. Web server overload management recommendations vs the strategies formulated (Source: Primary data)

No.	Recommendations	Formulated strategies
1	Clustering of the databases to reduce on the database load as users request for different files stored in database	Database clustering
2	Setting up a primary load balancer to distribute traffic to different web servers to reduce on the load put on a single web server.	Setting up a primary load balancer
3	Setting up a secondary load balancer to back up the primary one in case of a failure in the primary load balancer	Setting up of a backup load balancer
4	Increasing on the number of web servers to meet the current demands of the users. The respondent explained that this can be made possible by fully utilizing the available web servers by setting up virtual servers to meet the demands of the increasing number of users	Addition of web servers
5	Upgrading the relational database management systems from MYSQL to PostgreSQL for faster database access. The respondent further elaborated that PostgreSQL is suited for applications that require huge volumes of activities that need both reads and writes whereas MySQL is only suitable for applications that require only huge volumes of reading	Upgrade of relational database management systems to PostgreSQL
7	Another respondent also recommended that all server redundant network interface cards (NIC) should be fully utilized to increase on network accessibility and also in turn improving on the network speed	Utilization of all the available NIC (Network interface card)
8	Having a dedicated web server for e-learning systems specifically and having other systems hosted on other web servers. The respondent justified this point that having a	Dedicated server for e-learning system only

	dedicated web server for the e-learning system only would provide reliable resources during peak time of utilization of the e-learning system	
9	Continuous training on course or learning content development by content developers was another recommendation mentioned. The respondent further explained that these course contents must be evaluated to check if they meet the standard requirement before being uploaded on to the web servers for access by users	Web server files/ Content evaluation

5.2 Strategies and guidelines formulated from literature (secondary data)

Literatures from related studies discussed in chapter two, section 2.7 also contributed to the achievement of objective (3) of this study and provided answers to research question (3). This helped the researcher to consolidate the strategies and guidelines for the suitable web server overload management that can improve on the performance of e-learning systems in Uganda. Table 5.2 below summaries the strategies formulated from related literatures reviewed in section 2.8.

Table 5. 2. Web server overload management strategies from literature (secondary data)

No.	Web server overload management strategies	Strategies formulated
1	K-Means clustering algorithm using Exhaustive Criterion based Load Balancing (ECLB) algorithm, (Rajarajeswari, 2013)	Clustering of nodes (web servers) and application of load balancing
2	Load Balancing using peer-to-peer network, (Dominic and Francis, 2012)	Categorization of clusters based on file types
3	Load balancing implementation on Moodle LMS, (Sakikin et al., 2019)	Web servers health status monitoring software to check the health of the failover server

4	Random Allocation Load balancing with task scheduling, (Idrees et al., 2017)	Sufficient network bandwidth allocation
5	A framework for Load balancing and Load distribution among clusters, (Sharma & Saxena, 2011).	Clustering based on web server resources

5.3. Recommendations for web server overload management guidelines for e-learning systems used at higher institutions of learning in Uganda.

It is important to note that in order to develop the guidelines that can be used to manage web server overload for the e-leaning systems used at higher institutions of learning in Uganda, opinions from students who are the key beneficiaries of the e-learning systems was very important. Questionnaires were disseminated to students to find out the activities they carry out on the e-learning systems, frequency of e-learning systems usage, time spent while using the e-learning systems and the challenges they faced while using the e-learning systems. The results contributed indirectly in developing the web server overload management guidelines that can be used to improve on the performance of the e-learning systems putting into consideration the information provided by the students. Having known the activities carried out on the e-leaning systems, frequency of e-learning systems access, time spent on the e-learning systems and the challenges they faced while using the e-learning systems such as slow speed of accessibility, unavailability (system downtime), the researcher was able to develop guidelines which are applicable in handling the large number of concurrent users, handling requests that require more resources to process them and guidelines to keep the e-learning systems available. Knowledge of the details mentioned above contributed to the determination of guidelines that could be developed to keep the e-learning systems up and running at all times.

Also suitable web server overload management guidelines for e-learning systems used at higher institutions of learning in Uganda were developed based on the analysis of web server overload management strategies from primary data in table 5.1 and strategies from related literature in table 5.2. The researcher capitalized on a framework for Load balancing and Load distribution among clusters Sharma & Saxena (2011) which was deployed in a similar environment. With the help of

primary data, the researcher made additions to the framework based on strategies from primary data obtained from the technical staff and data from other literature. The additions included the strategies and guidelines summarized in table 5.1 and 5.2. The addition in this framework was made based on the strengths and weaknesses which are detailed in chapter two, section 2.7.5.

Furthermore, there was synthesis of web server overload management strategies and guidelines from the above mentioned framework with web server overload management strategies and guidelines from data obtained from the field. The researcher noticed similarities in the strategies and guidelines used in the framework for Load balancing and Load distribution among clusters by Sharma & Saxena (2011) and, the web server overload management strategies and guidelines obtained from technical experts from the field. The missing strategies and guidelines that were considered crucial by the researcher from the above framework were; the absence of secondary load balancer, absence of in-memory caching software instance, utilization of a non-reliable and inefficient RDBMS for the present development where large number of users are registered, and no data separation based on "Read" and "Read and Write" demand. Figure 5.1 below illustrates the framework for Load balancing and Load distribution among clusters by Sharma & Saxena (2011) and figure 5.2 illustrates the modification of the same framework with inclusions of the strategies and guidelines obtained from primary data.

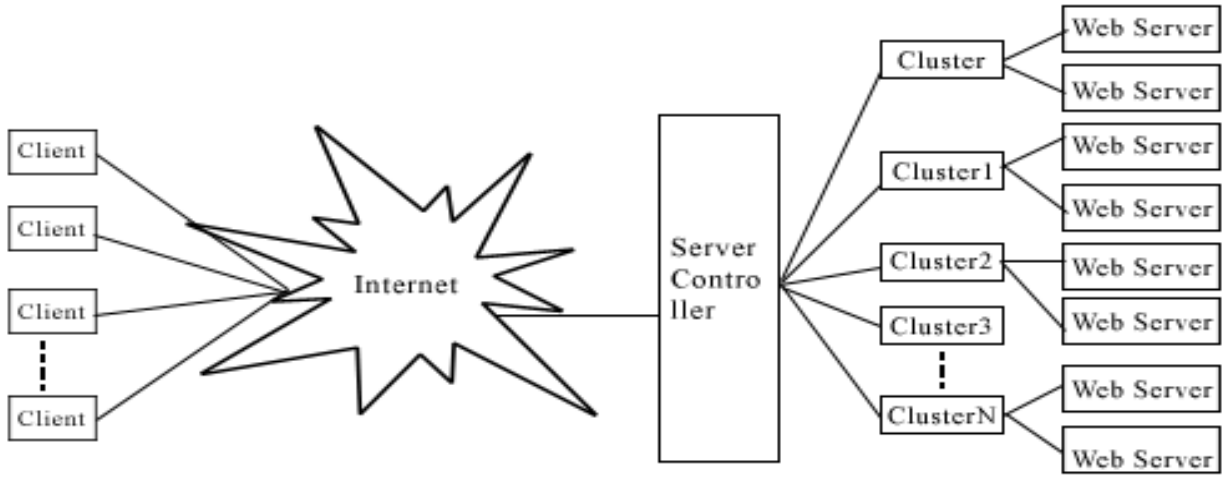


Figure 5. 1. System architecture where all the web servers are divided into clusters on the basis of their operational capabilities and Server Controller is responsible to manage Load balancing and Load distribution among these clusters (Source: Sharma & Saxena, 2011).

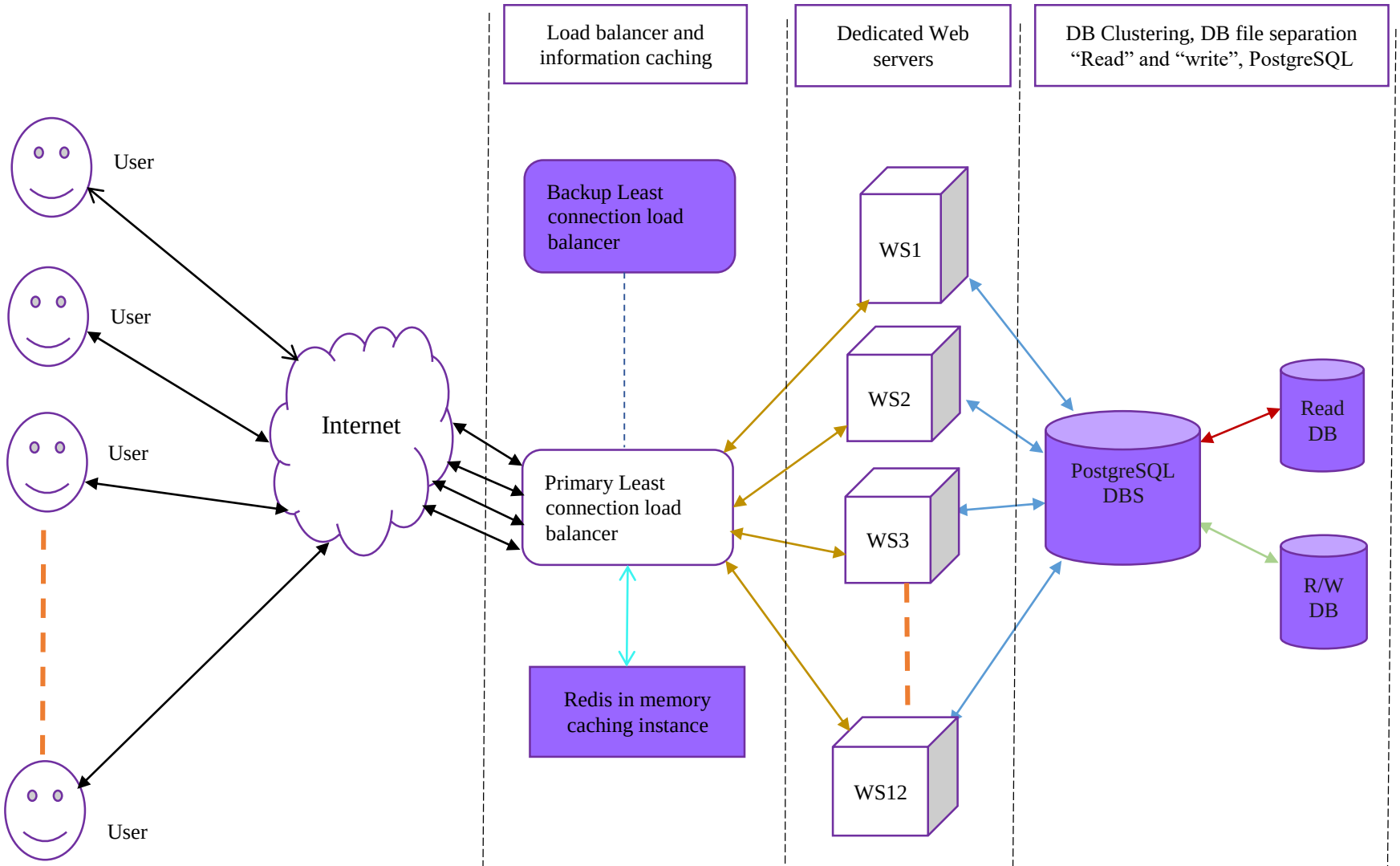
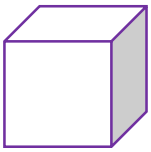
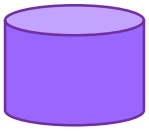
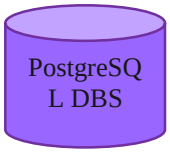
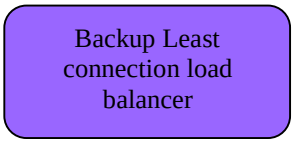
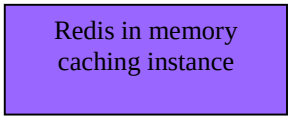


Figure 5. 2. Recommended web server overload management strategies and guidelines for e-learning systems used at higher institutions of learning in Uganda.

KEY			
	User of the e-learning system		Connection between the load balancer and the Redis caching instance
	Multiple user connection and server connection		Traffic distribution to the different web servers
	User connection to the e-learning system over the internet		Connection to read only database server
	Internet		Connection to Read and Write database server
	Synchronous connection between the primary load balancer and the backup load balancer		Web server
	Database server		

New strategies and guidelines added in to the framework for Load balancing and Load distribution among clusters (Sharma & Saxena, 2011)

	Upgrade of Relational Database Management system from MySQL to PostgreSQL.
	Read file separation
	Read and Write file separation
	Secondary or backup load balancer.
	In-memory caching software instance

5.4. Descriptions of the recommended web server overload management strategies and guidelines for e-learning systems used at higher institutions of learning in Uganda.

The above web server overload management strategies and guidelines were recommended to reduce web server overload for e-learning systems used at higher institutions of learning based on primary and secondary data. These strategies and guidelines were recommended because several literatures were in agreement with the primary data as summarized in table 5.2. The recommended web server overload management strategies and guidelines in figure 5.2 above are discussed in detail in the subsequent subsections below.

5.4.1. User.

This represents the users of the e-learning system who request for resources from the web servers over the internet through web browsers. The resources requested may involve Read only, Read and Write

or both. At this stage, the load balancer is put to use to redirect traffic to the suitable servers according to customized set of rules. Users then receive the requested resources from the web server as Hypertext Markup Language (HTML) pages.

5.4.2. Internet.

Internet is the global system of interconnected computer networks that uses the Internet protocol suite (TCP/IP) to communicate between networks and devices (Wikipedia, n.d). It has the capability of providing all kinds of information and supports human communication in number of ways. In the context of the study, users must have internet connection in order to access the different resources stored on the web servers, database servers and other servers. E-learning system users need internet connection to do online quizzes and examinations, upload assignments, download notes, interact with other users through the chat feature and also perform other activities. Internet is so paramount for the smooth operation of the illustration in figure 5.2. Fowler (2020) mentioned that internet service providers must be selected based on factors such as availability within the location of the institution, the bandwidth (upstream and downstream) rate being offered by the ISP which directly affects the transfer speed of traffic. Insufficient bandwidth was one of the causes of slow performance of the e-learning system revealed in the primary data collected and therefore technical persons need to be keen in deciding on this factor. Internet connection type is also another key factor that needs to be considered. Fowler (2020) insist that type of connection has a big influence on how fast the internet feels and also availability of customer support in case of glitches.

5.4.3. Primary Least connection load balancer

Field study strongly recommended the use of the above load balancing type. The load balancing types used in literature discussed in chapter two were found suitable for the current e-learning system usage as mentioned by one of the technical expert. Least connection load balancing is a dynamic load balancing algorithm where client requests are distributed to the application server with the least number of active connections at the time the client request is received (Kemptechnologies, n.d). With this type of load balancing, speedy processing of requests made by the clients is expected and thus improving on the performance of the e-learning systems.

In agreement with the recommendations made by the respondent during field survey, Khedr (2017) explained that load balancing ensures the improvement of system performance by restructuring the system workload with the aim of reaching the highest users' satisfaction with minimum throughput.

The author further elaborated that load balancing is mainly applied to avoid situations like having large difference in the servers' workload. As much as one of the institution revealed that it is using round robin load balancing method, Khedr (2017) explains that it is a static load balancing technique which aims at equal distribution of loads to the servers which does not take each server's capability into consideration. Least connection load balancing method therefore becomes the most suitable method since it takes into consideration the capability of each server.

5.4.4. Backup Least connection load balancer

In fulfillment of the objective 3, a backup load balancer is paramount.

Field study mentioned the importance of the backup least connection load balancer in case of a failure of the primary load balancer. Its major role is to enhance the availability of the e-learning system when the primary load balancer becomes inaccessible due incidences like a network failure. The backup load balancer takes over the role of the primary load balancer making it possible for traffic from users of the e-learning system to be distributed to the web servers having the resources they require. Delay in processing of requests from clients are avoided through automatic takeover of the role of the primary load balancer by the backup load balancer thus improving on the performance of the e-learning system. In agreement with the recommendation of a backup least connection load balancer, IBM (2021) argues that consideration of deploying a backup load balancer must be made in order to take over in case the active one fails. This guideline enhances the availability of the e-learning system in case the primary load balancer fails.

5.4.5. Redis in-memory caching instance

Redis is an open source (BSD licensed) in-memory data structure store used as a database, cache and message broker (Instaclustr, 2020). It supports various data structures such as strings, hashes, lists, sets, sorted sets with range queries, bitmaps and others. It is commonly used to store frequently accessed data in memory so that applications can be responsive to (Instaclustr, 2020)

In the primary data collected, it was mentioned by one of the respondents that Redis cache instance was used to store frequently accessed information like the university logo, home page and other information. This provided high response rate for the data that was already stored in the cache thereby reducing the load on the database and web servers that would be required to query for such information each time a new user requested for the same information. Caching therefore improves the performance

of the e-learning system because data does not have to be fetched from the original source. Data is stored in the RAM in a compressed format with good SQL support to enable quicker response to user requests (Maoyeri, 2019)..

5.4.6. Web server (WS)

The web server is responsible for accepting requests made by users and delivering the requested files. The web server is a software and hardware that uses HTTP (Hyper Text Transfer Protocol) and other protocols to respond to requests made by clients over the World Wide Web (Alexander, n.d). Its main function is to display the contents of the websites to the clients. The contents of the websites are stored, processed on demand and then delivered to the users through different protocols such as (SMPT) Simple Mail Transfer protocols, File Transfer Protocol (FTP) used for email and file transfer and storage respectively. For users to be able to access resources from the e-learning system, the hardware web server must be connected to internet to make data exchange with other connected devices possible.

In fulfillment of objective 3, field study recommended creation of more virtual servers to increase the number of web servers for handling traffic distributed by the load balancer rather than buying physical web servers which is not cost effective. From the field findings, most of the institutions of higher learning had powerful web servers with specifications specified in chapter four which were not efficiently utilized. Field study therefore recommended virtualization of these web servers in that each server performance is just like a physical server device running its own operating system with the help of a specialized software. According to Data Flair (n.d), resources such as memory, central processing unit (CPU) and storage space are shared among these virtual servers thereby cutting the expenses on addition of resources. Users are able to access the contents from these web servers through web browsers such as Google Chrome, Mozilla Firefox, Opera Mini, Safari, Microsoft Edge among others and the web servers must be available 24/7.

5.4.7. Database clustering (DBC)

Database clustering was one of the strategies used to answer research question 3 of this study.

Field studies recommended database clustering since its crucial in reducing the load on the database servers brought as a result of the database servers interacting with many users which necessitates multiple queries sent to the database for resource retrieval. In fact, when there are many queries sent

to the database, a single database server might become overloaded and this might in turn result to the e-learning system becoming unresponsive. Field study confirmed that unresponsiveness of the database server may also arise due to the complex “Read”, “Read and Write” queries in the job queue that may make the database and applications to run slowly.

Database clustering which involves having two database servers, one for data that requires “Read” only while another for data that requires “Read and Write” was highly recommended. This is intended to speed up database response for queries that do not require writing to the database and leaving “Read and Write” database server to handle requests that require computations and other complex queries. In addition, files stored in the database must be cleaned and evaluated to ensure that they have the correct file formats and file standards stipulated for all the stakeholders who use the e-learning systems to upload examinations, quizzes, notes and tutorials and other activities.

According to Krasimir (2019), MySQL database has a good reputation of reading-small data workload though at the cost of concurrency when mixed with write operations. The author also explained that MySQL database has stability issues which tends to corrupt under certain use cases and moreover, it is not suitable for providing read/write operation with high volumes. On the other hand, Harris (n.d.) credited MySQL for its security feature especially with Linux system over Windows based systems and its multi-threading capability to achieve more optimized performance.

NoSQL (Not only SQL) database is also another database management system highly appreciated for its flexibility, high performance, scalability among other attributes. Okman et al., (2011) on the contrary explains that it is less reliable because it compromises reliability and consistency for performance. The authors further elaborated that as far as security is concerned, NoSQL database especially Mongodb and Cassandra databases lack encryption for data files, they have very weak authentication system, and very simple authorization compared to relational databases.

PostgreSQL database management system being the database management system of interest was recommended because, according to Krasimir (2019), it is built with feature-rich, extendable and highly compliant to many standards with advanced data types not available in MySQL such as geometric/GIS, network address types, JSONB which can be indexed, native UUID, and time zone-aware timestamps. Furthermore, PostgreSQL has been praised for its ability to handle concurrency access better than MySQL and it is known for protecting data integrity at the transaction level hence making it less vulnerable to data corruption.

It is for the above strengths of PostgreSQL database management system that the researcher agreed with the recommendation obtained from data collected from the field which was to upgrade the database management system from MySQL to PostgreSQL. The researcher also during data collection discovered that none of the higher institutions of learning was running PostgreSQL DBMS yet respondents explained that PostgreSQL DBMS is reliable, flexible and is suited for large concurrency access by users. Respondents' explanations were in agreement with Krasimir (2019) who explained that PostgreSQL DBMS offers reliability, flexibility and supports both non-relational and relational data types. The author further emphasized that PostgreSQL DBMS manages concurrency access efficiently through its use of MVCC (Multiversion Concurrency Control) where "Reads" access do not block "writes" and vice versa. With the MVCC feature, processing of both "Read" and Read and Write" data are faster with limited interferences of blocking other access hence improving on the performance of the e-learning system. Based on the above strengths of PostgreSQL DBMS over the limitation of the other database management system, the researcher agreed with the recommendation of upgrading the database management system from MySQL to PostgreSQL since the literatures reviewed are also in agreement with the primary data collected from the field.

Below is a table that summarizes the strengths and weakness of the three selected database management systems which are MySQL, PostgreSQL and NoSQL (Not only SQL)

Table 5.3. Database management systems comparison

Attributes	**MySQL**	**PostgreSQL**	**NoSQL**
Concurrency access	Low	High	High
Overload function	Low	High	High
Consistency	High	High	Low
Scalability	Challenge with vertical scaling	No challenge	No challenge
Reliability	High	High	Low
Data types	Few	More	More
Data integrity	High	High	High
Security	High	High	Low
Performance	High	High	High
Read and Write speed for small datasets	Fast	Slow	Fast

Heavy data writes	Slow	Fast	Fast
Sourcing	Not open source	Open source	Open source

5.5. Conclusion

The major aim of this chapter was to recommend web server overload management strategies and guidelines that can be used to improve on the performance of e-learning systems used at the higher institutions of learning in Uganda. The findings from both primary data collected and secondary data from different sources helped the researcher to achieve objective 3 and also provided answers to research question 3. The recommendations were made by considering literature from other web server overload management strategies and also considering recommendations from primary data.

CHAPTER SIX

Validation of the recommended web server overload management strategies and guidelines

6.0. Introduction

The main aim of this research study was to recommend suitable strategies and guidelines that will improve the performance of e-learning systems that are used in higher institutions of learning in Uganda and this was achieved in Chapter five. The recommended web server overload management strategies and guidelines were based on the strategies and guidelines gathered from primary data collected and analyzed and also from existing strategies and methods used to improve on the performance of e-learning systems.

This chapter presents the validation results of the recommended web server overload management strategies and guidelines in fulfilment of objective four of this research study. The validation was done to seek experts' opinions on the relevance of the recommended web server overload management strategies and guidelines' components for the e-learning systems and the anticipated outcome or implications when these strategies and guidelines are implemented.

6.1. Participants

Twenty respondents were purposively selected to participate at this phase of the study because of their knowledge in systems and software design, development and maintenance of the systems and also wide knowledge on the different strategies and guidelines that can be used to improve on their performances. The participants were selected because of their active involvement in the field of software and systems design development that handle concurrency access by users during peak time. Some of the systems designed, developed and maintained by the selected participants include the e-learning systems, tax clearing systems, financial /banking systems and e-commerce systems. All the above mentioned systems are faced with web server overload during specific times and seasons that compel many users to access them to accomplish certain tasks bringing about concurrency access and generation of high traffic.

Only 17 participants responded and this gave a response rate of 85% which was good.

Response Rate calculation

$$\text{Response Rate} = \frac{\text{Number of questionnaires returned}}{\text{Total number of questionnaires sent}} * 100$$

Response Rate $= \frac{17}{20} * 100$

Response rate = 85%

Table 6. 1. Breakdown of participants and types of systems developed and maintained.

Participants	**Systems**	**Numbers**
Systems / software developer	Financial/Banking system	5
Systems / software developer	Uganda Revenue Authority (URA) tax clearance systems	3
Systems / software developer	E-learning systems	2
Systems / software developer	E-commerce system	5
Systems administrator	E-learning systems	2
Total		**17**

6.2. Validation criteria

Hevner et al. (2004) advised that a designed artifact must be tested for utility, quality and efficiency using well-grounded evaluation methods. Thus, a quantitative research method was used in the validation exercise in order to obtain experts' opinions on the recommended web server overload management strategies and guidelines for the e-learning system.

According to design science methodology which was adapted in this study (see section 3.1), the recommended web server overload management guidelines for the e-learning systems was validated. This was done in line with the notion that a designed artifact can be validated in terms of functionality, completeness, understandability, consistency, accuracy, traceability, performance, reliability and usability among others (Hevner et al., 2004; Offermann et al., 2009; Peffers et al., 2007).

Before the validation exercise was done, the researcher presented to the participants the developed web server overload management guidelines though email attachment and also in the introduction section of the google form (questionnaire) for clarity and demonstration of how the guidelines were presented in the design. The developed guidelines were also shared to make the users understand how

each guideline actually impact on the other. Follow-up with respondents were also made using phone calls for further explanation and clarification to ensure that the respondents understood the developed guidelines. In this study, two parameters were validated namely: relevance and anticipated outcome of the developed web server overload management guidelines on the e-learning systems when implemented. Below are the results obtained from the respondents;

Relevance of the developed web server overload management guidelines' components

This validation criterion was used to assess whether the strategies and guidelines' components were relevant in reducing web server overload for the e-learning systems during peak hours coupled with concurrency access. The relevance of the strategies and guidelines components were assessed using the factors below;

1) Least connection load balancing method is a suitable load balancing method for efficient distribution of traffic to the web servers.
2) A backup load balancer is important in enhancing the availability of the web servers in case of a failure of the primary load balancer.
3) Hosting e-learning systems on dedicated web servers improves their performance and efficient allocation of resources.
4) Web server virtualization is an economical strategy and meets the demand of many number of users.
5) PostgreSQL Database Management System is ideal for concurrent database access for the e-learning system files.
6) PostgreSQL database clustering is efficient in reducing the load on the database and reducing on the response time for database files.
7) Database content and file optimization improves on the performance of the e-learning systems.
8) Information caching software reduces on the response time for frequently accessed information from the web servers.

Anticipated outcome of the guidelines on the e-learning systems when implemented.

The validation criterion was used to validate the impact of the strategies and guidelines on the e-learning system if they are implemented. To determine the impact of the strategies and guidelines on the e-learning systems, the factors below were used;

i. Improvement on response time during concurrency access of the e-learning systems at peak hours.
ii. Reduction of web server down time for the e-learning systems
iii. Best utilization (optimization) of the web servers' capacity.
iv. Cost reduction on the procurement of more web servers and other resources for the e-learning system.

6.3. Presentation of findings from validation process.

Likert-scales measurement with the 5-point scale were used for this validation data collection exercise. The measurements options were; Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree on a numerical scale of 1 to 5. Data sets from the validation questionnaire was analyzed using bar graphs generated instantly by google forms as presented in the subsequent sections.

Validation questionnaire was designed using google forms and emailed to the purposively selected participants who were the software and systems developers from some of the identified ICT companies mentioned in figure 3.2. Results obtained from the participants were automatically generated and presented using bar graphs with frequencies and percentages presenting the number of number of respondents for each guideline. Likert-scales measurements with the 5-point scale of Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree on a numerical scale of 1 to 5 was used.

6.3.1. Relevance of the recommended web server overload management guidelines' components.

The validation questionnaire for this section comprised of eight questions to ascertain the relevance of web server overload management strategies and guidelines for the improvement of the e-learning systems performance. Reponses for each questions were obtained as below;

1) **Least connection load balancing method is a suitable load balancing method for efficient distribution of traffic to the web servers.**

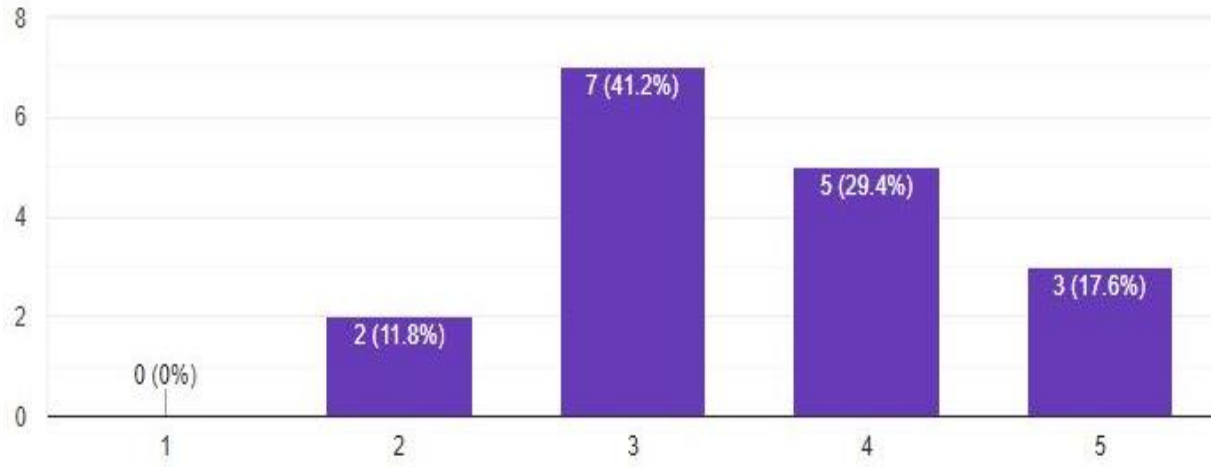


Figure 6. 1. Least connection load balancing method (Source: Primary Data)

Out of the 17 respondents who participated in the study, the graph above indicates that 0% strongly disagreed that least connection load balancing method is a suitable load balancing method for efficient distribution of traffic to the web servers, 11.8% disagreed, 41.2% took a neutral stand, 29.4% agreed and 17.6% strongly agreed with the strategy and guideline.

From the analysis presented in the graph, majority of the respondents (41.2%) neither disagreed nor agreed with the strategy and guideline which implies that they are not certain about the best load balancing method that is appropriate for the e-learning systems.

2) A backup load balancer is important in enhancing the availability of the web servers in case of a failure of the primary load balancer.

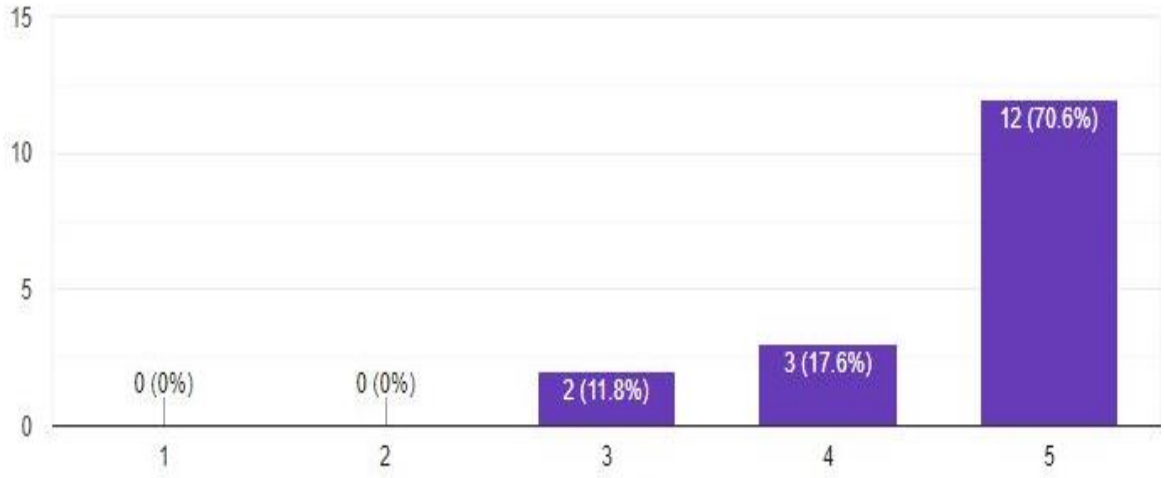


Figure 6. 2. A backup load balancer (Source: Primary Data)

Under this strategy and guideline, 0% strongly disagreed that a backup load balancer is important in enhancing the availability of the web servers in case of a failure of the primary load balancer, 0% disagreed, 11.8% took a neutral stand, 17.6% agreed and 70.6% strongly agreed.

According to Sadikin et al. (2019), load balancing implementation is the most possible solution to distribute the massive load during peak time. Therefore, the 70.6% which was the highest score confirms that a backup load balancer is important in enhancing the availability of the web servers in case of a failure of the primary load balancer.

3) **Hosting e-learning systems on dedicated web servers improves their performance and efficient allocation of resources.**

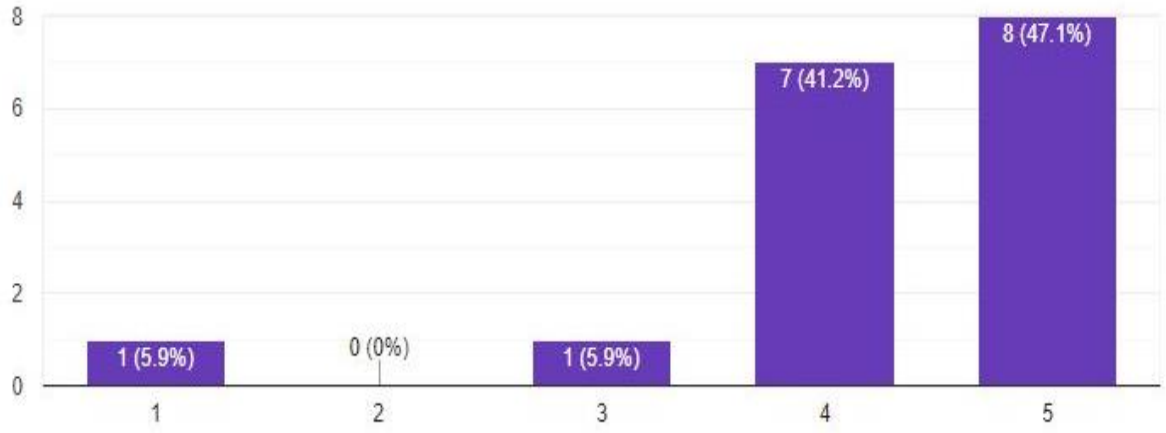


Figure 6. 3. Hosting e-learning systems on dedicated web servers (Source: Primary Data)

Under this strategy and guideline, 5.9% strongly disagreed that hosting e-learning systems on dedicated web servers improves their performance and efficient allocation of resources, 0% disagreed, 5.9% took a neutral stand, 41.2% agreed and 47.1% strongly agreed with the strategy.

The high score results indicate that hosting e-learning systems on dedicated web servers improves their performance of the e-learning system and ensures efficient allocation of web server resources.

4) **Web server virtualization is an economical strategy and meets the demand of many number of users.**

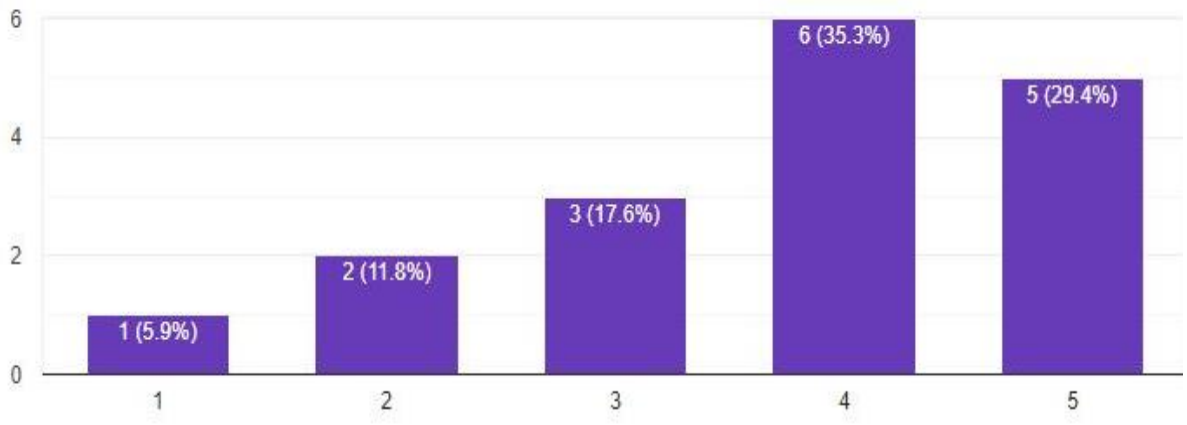


Figure 6. 4. Web server virtualization (Source: Primary Data)

Out of the 17 participants, 5.9% strongly disagreed that web server virtualization is an economical strategy and meets the demand of many number of users, 11.8% disagreed, 17.6% took a neutral stand, 35.3% agreed and 29.4% strongly agreed with the strategy and guideline.

Ali et al. (2015) mentioned that virtualization technology can be the perfect solution to resolve the problem of few number of server units. They further explained that insufficient number of servers to increase data center can be resolved by application of virtualization since it can maximize the use of resources because the function of three units of physical servers can be enabled simultaneously on one physical server unit.

From the interview sessions, the researcher found out that this strategy and guideline was not explored yet results from the validation phase confirms that the strategy and guideline is an economical strategy.

5) **PostgreSQL Database Management System is ideal for concurrent database access for the e-learning system files.**

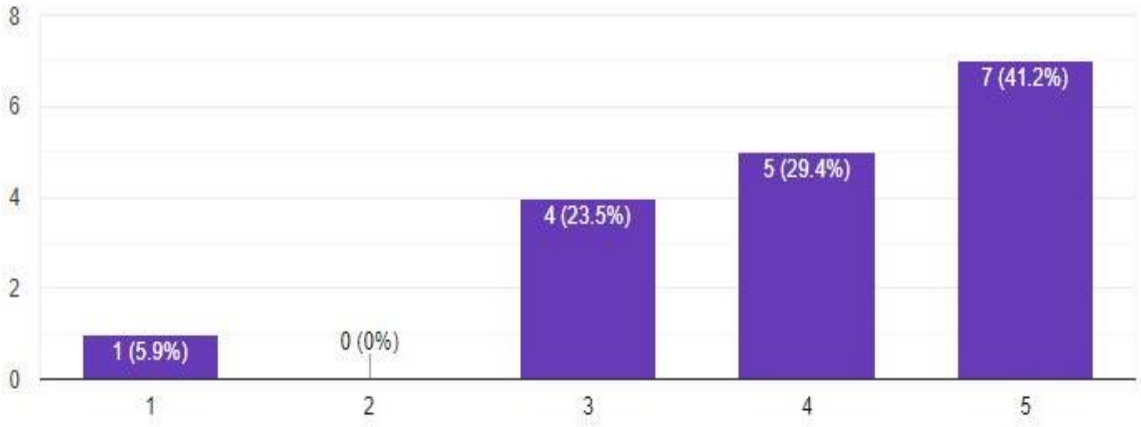


Figure 6. 5. PostgreSQL Database Management System (Source: Primary Data)

Under this strategy, 5.9% strongly disagreed that PostgreSQL Database Management System is ideal for concurrent database access for the e-learning system files, 0% disagreed, 23.5% took a neutral stand, 29.4% agreed and 41.2% strongly agreed with the strategy and guideline.

Ostezer & Drake (2022) mentioned that PostgreSQL database management system is capable of efficiently handling multiple tasks at the same time known as concurrency. In addition to the above mentioned capability, it is also able to achieve concurrency without the read locks which is made possible with the implementation of the Multiversion Concurrency Control (MVCC) which also ensures the atomicity, consistency, isolation, and durability of its transactions, known as ACID compliance.

The high scores by the participants indicates the relevance of PostgreSQL Database Management System in handling concurrency database access for the e-learning system as commented by one of the participants and below;

> The Recommended PostgreSQL DB is a very high efficient and highly recommended DB for Such Systems

6) **PostgreSQL database clustering is efficient in reducing the load on the database and reducing on the response time for database files.**

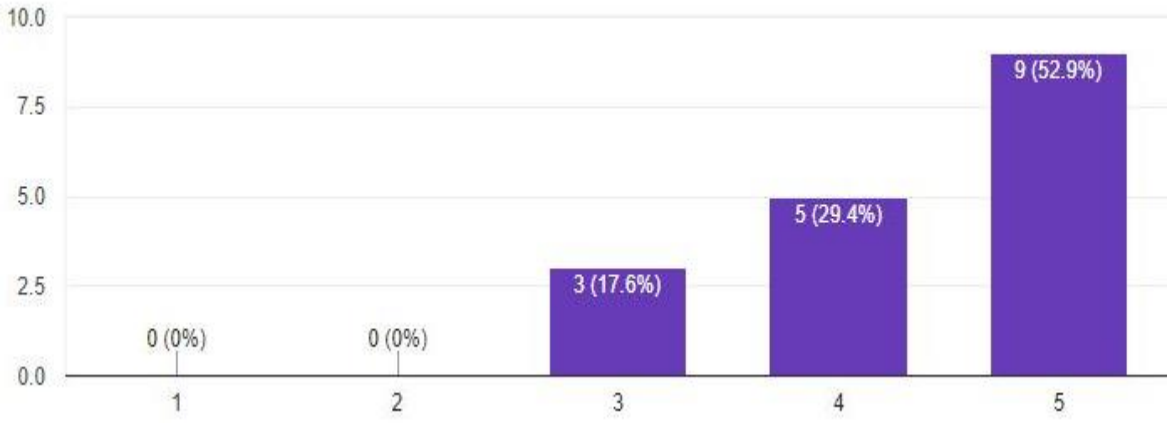


Figure 6. 6. PostgreSQL database clustering (Source: Primary Data)

Out of the 17 participants, 0% strongly disagreed that PostgreSQL database clustering is efficient in reducing the load on the database and reducing on the response time for database files, 0% disagreed, 17.6% took a neutral stand, 29.4% agreed and 52.9% strongly agreed with the strategy and guideline.

The highest percentage obtained indicates that the guideline is crucial in reducing the load on the database and reducing on the response time for database files.

7) **Database content and file optimization improves on the performance of the e-learning systems.**

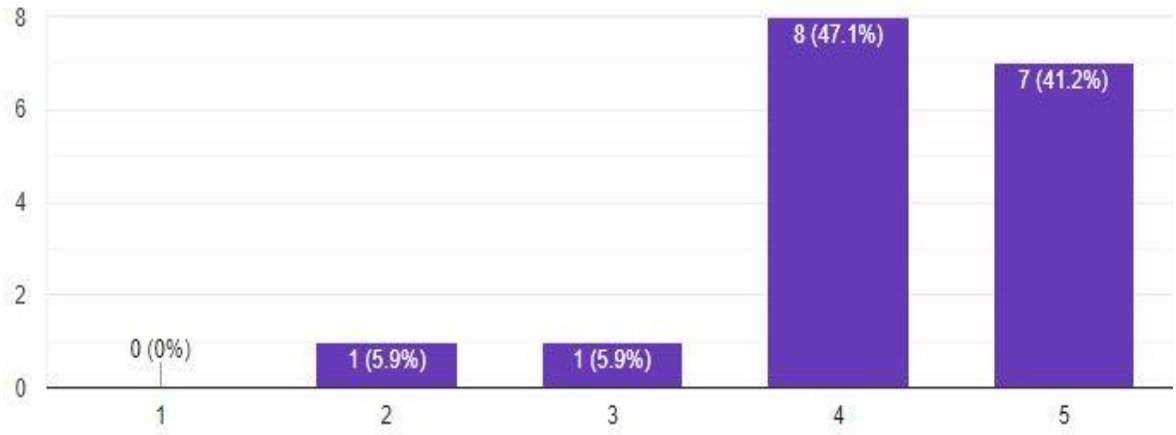


Figure 6. 7. Database content and file optimization (Source: Primary Data)

Under this strategy and guideline, 0% strongly disagreed that database content and file optimization improves on the performance of the e-learning systems, 5.9% disagreed, 5.9% took a neutral stand, 47.1% agreed and 41.2% strongly agreed with the guideline.

Database optimization is the best strategy of reducing database system response time (Garbus, 2019). Tiunov (2018) in agreement with the statement explained that database optimization can greatly be achieved through indexing which can boost database performance by 100x. He however noted that the choice of indexing type can be determined by the volume of data in storage. It is therefore necessary to understand the nature and volume of data in storage before choosing an indexing type to achieve the desired performance in terms of response time during database access.

8) **Information caching software reduces on the response time for frequently accessed information from the web servers.**

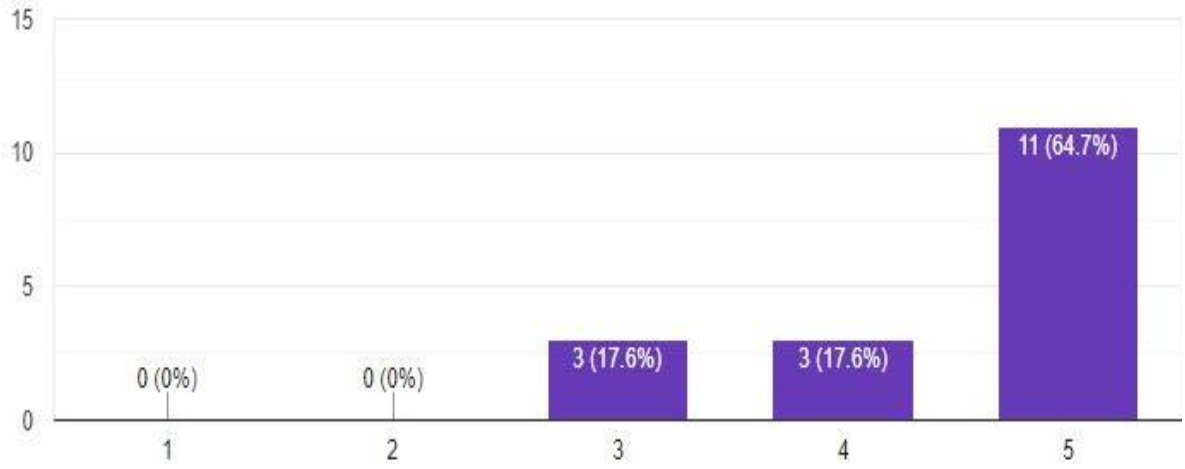


Figure 6. 8. Information caching software (Source: Primary Data)

Under this strategy and guideline, 0% strongly disagreed that information caching software reduces on the response time for frequently accessed information from the web servers, 0% disagreed, 17.6% took a neutral stand, 17.6% agreed and 64.7% strongly agreed with the guideline.

As indicated in the graph above, it is evident that information caching is crucial in reducing the response time for information accessed and hence improving on the performance of the e-learning system. One of the participants in agreement with the guideline explained as below;

Caching most of the content browsed/ searched for before reduces on the time taken to retrieve the required information by a new user. In this way it will improve the response rate as well.

Comments from the relevance of the developed web server overload management guidelines' components section.

Respondents were also requested to give their comments regarding the relevance of the developed web server overload management guidelines' components and below are the comments recorded;

In general, it improve performance if implemented well

The recommended strategy can solve many problems that is currently being faced by most institutions of Learning.

The recommended strategy works but can lead to overhead costs and redundancy. Although this can be improved by implementing an auto scaling mechanism at both loadbalancer and server level. This will improve the efficiency and effectiveness of resource utilization.

This enables provision of quick and timely access to information to the intended users.

6.3.2. Anticipated outcome of the developed guidelines on the e-learning systems when implemented.

From the developed web server overload management guidelines above, experts' opinions were also sought on the implication of the above web server overload management strategies and guidelines when implemented on the e-learning systems. Below are the experts' (systems/software developers) opinions on the implications when implemented.

i. **Improvement on response time during concurrency access of the e-learning systems at peak hours.**

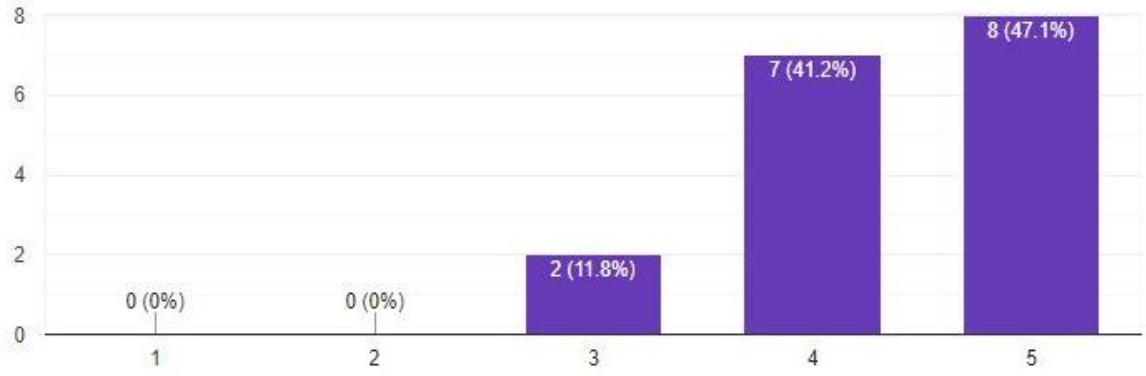


Figure 6. 9. Improvement on response time during concurrency access (Source: Primary Data)

Out of the 17 participants, 0% strongly disagreed that improvement on response time during concurrency access of the e-learning systems at peak hours will be achieved when the developed guidelines discussed in chapter five are implemented, 0% disagreed, 11.8% took a neutral stand, 41.2% agreed and 47.1% strongly agreed.

Based on the high scores obtained, it is therefore right to say that the developed guidelines will improve on the response time during concurrency access of the e-learning systems at peak hours.

ii. **Reduction of web server down time for the e-learning systems.**

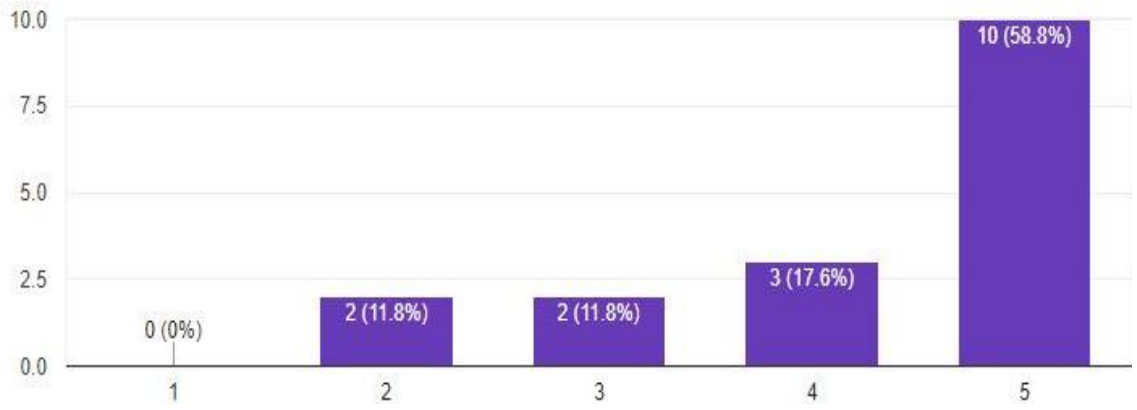


Figure 6. 10. Reduction of web server down time (Source: Primary Data)

Under this anticipated implication, the results show that 0% of the participants strongly disagreed that the recommended strategies and guidelines will reduce on web server down time for the e-learning system, 11.8% disagreed, 11.8% took a neutral stand, 17.6% agreed and 58.8% strongly agreed that the developed web server overload management guidelines will reduce web server down time for the e-learning system.

The feedback from the respondents confirms that the implementation of the web server overload management guidelines will reduce web server down time for the e-learning systems based on the high scores obtained.

iii. **Best utilization (optimization) of the web servers' capacity.**

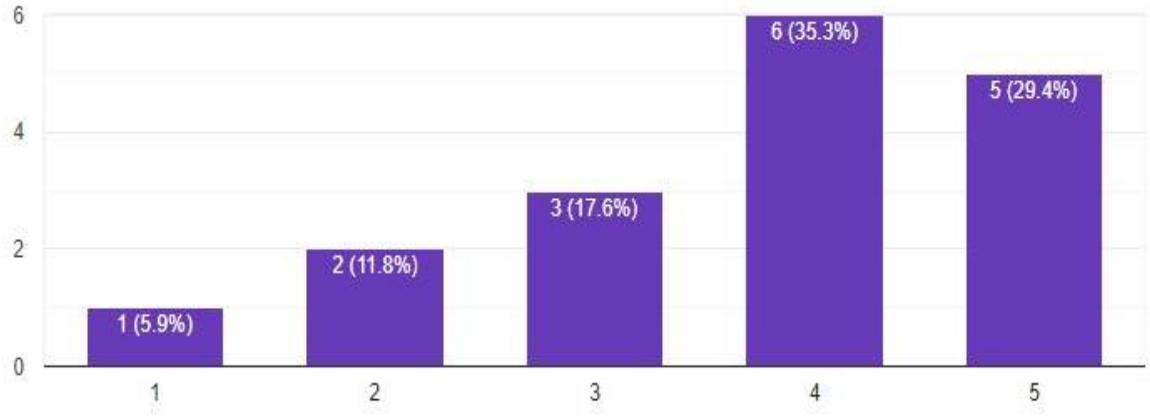


Figure 6. 11. Best utilization (optimization) of the web servers' capacity (Source: Primary Data)

The graph above indicates that 5.9% of the participants strongly disagreed that there will be best utilization (optimization) of the web servers' capacity, 11.8% disagreed, 17.6% took a neutral stand, 35.3% agreed and 29.4% strongly agreed with the implication.

Based on the high scores obtained, it is evident that when the web server overload management guidelines are implemented, there will be optimum utilization of the web servers' capacity.

Cost reduction on the procurement of more web servers and other resources for the e-learning system.

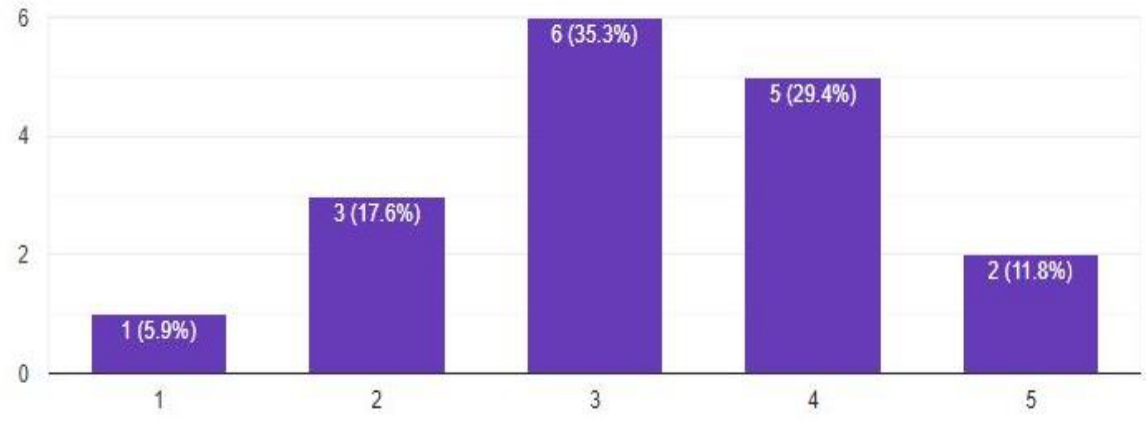


Figure 6. 12. Cost reduction on the procurement of more web servers and other resources (Source: Primary Data)

Under the cost reduction on the procurement of more web servers and other resources for the e-learning systems' implication, 5.9% strongly disagreed, 17.6% disagreed, 35.3% took a neutral stand, 29.4% agreed and 11.8% strongly agreed.

The highest score being neutral is an indicator the participants are not certain about the cost reduction implication when the recommended web server overload management guidelines are implemented. It is also evident from the graph above that the percentage of those who agreed and strongly agreed outweighs those who took a neutral stand and that still positions the implication on positive scale.

Comments from the anticipated outcome of the developed guidelines on the e-learning systems when implemented section

Participant were also requested to give their comments on the anticipated outcome when the developed web server overload management guidelines are implemented. Below were some of the comments recorded;

The cost implication still looks to be a bit high on the server end given the fact that we need dedicated servers for the balancers

seev comment above

Strategies should be planned and implemented for all loads on the server resources.

I strongly agree that for a better e-learning system to be efficiently implemented and used, the response time needs to be fast in terms of processing the queries.

I think Caching Information is the best way of improving performance of the server

You didn't mention about the Security tools; Security tools like Firewalls can also slow down the server.

6.3.3. Summary of validation results

The summary of the responses attained for the two validation criteria are summarized in the below tables (Tables 6.2 and Table 6.3)

Table 6. 2. Validation results for relevance of the web server overload management strategies and guidelines components for the improvement of e-learning systems performance.

No:	Validation Questions	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
1	Least connection load balancing method is a suitable load balancing method for efficient distribution of traffic to the web servers	0	11.8	41.2	29.4	17.6
2	A backup load balancer is important in enhancing the availability of the web servers in case of a failure of the primary load balancer.	0	0	11.8	17.6	70.6
3	Hosting e-learning systems dedicated web servers improves their	5.9	0	5.9	41.2	47.1

	performance and efficient allocation of resources.					
4	Web server virtualization is an economical strategy and meets the demand of many number of users.	11.8	0	35.3	29.4	23.5
5	PostgreSQL Database Management System is ideal for concurrent database access for the e-learning system files.	5.9	0	23.5	29.4	41.2
6	PostgreSQL database clustering is efficient in reducing the load on the database and reducing on the response time for database files.	0	0	17.6	29.4	52.9
7	Database content and file optimization improves on the performance of the e-learning systems.	0	5.9	5.9	47.1	41.2
8	Information caching software reduces on the response time for frequently accessed information from the web servers.	0	0	17.6	17.6	64.7

Table 6. 3. Validation results for implementation outcome or implications of the strategies and guidelines on the e-learning systems.

No:	Validation Questions	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)

i.	Improvement on response time during concurrency access of the e-learning systems at peak hours.	0	0	11.8	41.2	47.1
ii.	Reduction of web server down time for the e-learning systems.	0	11.8	11.8	17.6	58.8
iii.	Best utilization (optimization) of the web servers' capacity.	5.9	11.8	17.6	35.3	29.4
iv.	Cost reduction on the procurement of more web servers and other resources for the e-learning system.	5.9	17.6	35.3	29.4	11.8

6.4. Contributions from the validation process.

The validation results obtained and presented using the graphs above confirms that the developed guidelines are relevant in providing a solution to web server overload of e-learning systems used at higher institutions of learning in Uganda. Furthermore, the comments provided by the respondents reassures the stakeholders on the relevance of the developed web server overload management guidelines.

It is important to note that some comments were also made which must be considered to further enhance the performance of the e-learning systems. These comments are crucial in providing further information to the concerned stakeholders during the implementation of the developed guidelines. Below are some of the comments provided by the respondents as contributions in enhancing the recommended guidelines;

In the event that the institutions would consider scaling up the e-leaning system, auto scaling mechanism can be achieved at both the load balancer and server level as explained by one of the respondents in the comment. This gives confidence in implementing the developed guidelines for web server overload for the e-learning systems at higher institutions of learning having been reassured that scalability is possible in case of future demands.

The concern of cost implication being higher since a dedicated server is required as a load balancer was also raised by one of the respondents. This concern can however be addressed by opting for a software load balancer rather than hardware load balancer which is less costly. According to Luke P. (2016), software load balancer is installed on the server and consumes the processor and memory of the server. The author further explains that the software load balancer is efficient and cost effective because it implements a combination of one or more scheduling algorithms such as, Weighted Scheduling Algorithm, Round Robin Scheduling, Least Connection First Scheduling among others. Luke P. (2016) still goes on to explain that, the hardware load balancers on the other hand are specialized hardware deployed in-between the server and the client which can be a switching/routing hardware or even a dedicated system running a load balancing software with specialized capabilities. It is therefore not cost effective as compared to the software load balancer.

One of the participants also added that security tools such as firewalls slow down web servers. This also has to be considered when implementing the developed web server overload management

guidelines since it can also lead to slow response by the web servers. Mishal (2020) in agreement with the respondent explained that firewalls especially the software based limits computer's overall performance. The author emphasized that the processing power and the RAM resources are some of the factors which decide the computer's overall performance and with the software firewalls constantly running on the background, the processing power and the RAM resources are more utilized hence slowing down the performance of the web servers. The author however, recommends the use of hardware firewalls because they do not impact on the system performance since they do not rely on the computer resources.

6.5. Conclusion

The validation results presented in the previous sections indicate how relevant the developed guidelines are in a bid to improve on the performance of the e-learning systems. The scores obtained from each guideline reveal the magnitude of relevance each guideline has in improving the performance of the e-learning systems used at higher institutions of learning in Uganda. Upon successful implementation of the developed guidelines, it is anticipated that the outcome will have a positive impact on reducing web server overload for the e-learning systems based on the high scores revealed in the agree and strongly agree sections of the different validation questions by the participants mentioned in chapter three. There were also high neutral scores that outweighed agree and strongly agree scores in some questions as shown in tables 6.2 and 6.3 which revealed uncertainty for those guidelines which therefore calls for future research to extend this study in order to come up with guidelines that will bring light to the uncertainty presented with the neutral scores. Low scores obtained for the strongly disagree and disagree options indicate that all the recommended web server overload management guidelines were crucial in handling web server overload for the e-learning systems. These low scores were outweighed by the highest scores which indicates that none of the recommended web server strategies and guidelines were irrelevant in improving on the performance of the e-learning systems hence validation insights were drawn using the highest scores.

CHAPTER SEVEN

Discussion, Conclusion and Recommendations

7.0. Introduction

This chapter provides discussion of the entire research study, the conclusion and recommendations that could be considered for future research studies.

7.1 Discussion

7.1.1 Discussion of Findings

The first objective of the research study resulted into the discovery of the causes of web server overload of e-learning systems at higher institutions of learning in Uganda. The discovery made from the field findings unmasked some of the major causes of web server overload for the e-learning systems. Increased number of concurrent users on the e-learning system was one of the major causes of web server overload mentioned. The participants further explained that this normally happens during times when students are required to attend online classes, take on online examinations, tests and quizzes. All these activities require many students to login to the system at the same time to access the tests, quizzes or examinations hence slowing the performance of the e-learning system. A study by Ramana & Ponnavaikko (2018) expounded that as a result of drastic growth in the number of users, the number of request that arrive at the web servers make them overloaded and respond slowly. They further explained that whenever any web server responses are not up to the user's expectations, the website is affected in terms of popularity due to less interest on that website by the users. A study by Ibrahim et al (2021) also affirms that when there is high traffic and the web servers are unable to respond to requests, complaints are raised by users and this loses the reputation of the service providers in this case the e-learning systems customized by the different institutions of higher learning.

Insufficient web server resources such as RAM, HDD and others was another cause of the web server overload discovered during data collection stage. Majority of institutions of higher learning were ambushed by the outbreak of COVID-19 pandemic and the sudden transition from traditional learning to e-learning. Many institutions were not prepared for the change yet they were mandated to embrace the change. This transition left the institutions with no choice but to move on with the change yet technically they were wanting. According to Fedkin et al (2022), the performance and reliability of e-learning systems depend on the server characteristics such as the number and speed of processors

(CPU), amount of RAM, amount of disk space and bandwidth of network equipment. In attempt to improve on the performance of the e-learning systems, some institutions procured additional RAM, expanded on their Hard disk space because if online systems are not supported by sufficient IT resources, an excessive number of users could slow or even crash services and potentially cause losses to the institutions and their students.

Insufficient network bandwidth also contributed to web server overload for the e-learning system since it is not sufficient to accommodate the traffic to and from the server. This was evidenced in the data collected as majority of the institutions of higher learning have bandwidth that are not more than two Gigabytes per second (2Gbps) and they revealed that the bandwidth volume does not meet the current demands of the users. That being mentioned, Charles (2016) explained that the speed at which data travels begin to drop when the amount of network traffic approaches the network capacity. Furthermore, he explained that when the demand for services over the network is higher than the network bandwidth, there is network congestion hence creating negative impact from the users' perspective on the rate of data transmission and quality.

The second objective of the study was to explore the various web server overload management strategies used by the selected higher institutions of learning. The results obtained from data collected revealed that only one institution out of the five selected institutions has a load balancing algorithm (Round Robin load balancing method) used to distribute traffic to the virtual servers created. The respondent however revealed that the above mentioned load balancing method is not efficient and for the above reason, a plan to shift to a better load balancing method is being sought. According to Tripathi & Singh (2017), round robin load balancing method only works efficiently when all the servers have similar performance and are running equal load. This is not possible for the case of higher institution of learning since different activities carried out on the e-learning system such as online lectures, online examinations, online quizzes and online tests require different server resource allocation and the time duration that the servers take to accomplish those tasks vary.

Shift to alternative platforms was another strategy used to overcome the problem of poor performance of the e-learning systems in terms of response time. As explained, approximately 50 percent of website users anticipate pages to load in about 2 seconds or even less and just about 40 percent will abandon such websites if they use over 3 seconds (Abubakari, 2019). This explains why most higher institutions of learning opted to use other alternative platforms like Zoom meeting application, Google

Classroom, Microsoft Teams among others.

Web server upgrade by adding memory (RAM) was another strategy used by some higher institutions of learning to curb the web server overload problem. This was in line with Fedkin et al (2022) argument that the performance and reliability of e-learning systems depend on the web server characteristics such as the number and speed of processors (CPU), amount of RAM, the amount of disk space and bandwidth of network equipment. In the data collected and analyzed by the researcher, other higher institutions of learning up scaled some of these components such as the RAM and the network bandwidth. More detailed information about this is discussed in section 4.3.3.

Other strategies discovered during data collected from the field were single browser login which was highly empathized by one higher institution of learning. This was intended to prevent many connections by different devices yet by the same person. Time tabled access of the e-learning system was another strategy used by other higher institutions of learning to curb web server overload since massive connections at once would cause high concurrency access and eventually flood the web server with high traffic hence causing web server overload.

The third objective was to develop web server overload management guidelines that can be used to improve on the performance of the e-learning systems once adopted and implemented. The study provides eight guidelines that when collectively used can reduce web server overload for the e-learning systems hence improving on the performance of the e-learning systems. These guidelines include: the use of least connection load balancing method; configuring a backup or secondary load balancer; hosting e-learning systems on dedicated web servers; upgrading of the database server from MySQL to PostgreSQL Database Management System; clustering of PostgreSQL database into “read only” and “read and write” databases; optimization of the databases through indexing and caching of information using Redis in-memory software.

The first guideline was the use of least connection load balancing method to distribute web traffic to functional web servers based on the number of connections registered by each web server. This strategy prevents overload of some web servers as web traffic are directed to web servers with the least number of connections. Many scholars have pushed forward many load balancing methods in a bid to improve on the performance of web servers’ operation. The performance of web servers is immediately affected by the load directed to them. Therefore, controlling the load in the web servers is crucial (Jader et al., 2019). With the above argument, this study chose a least connection load

balancing method to improve on the performance of the web servers as Mesbahi & Masoud Rahmani (2016) support the use of load balancing mechanism to improve on system performance, maintenance of stability and availability. This study also recommended a backup load balancing method in case of a failure of the primary load balancer thus enhancing availability of the web server to the users.

A shift from traditional learning to e-learning has put pressure on the resources of the web servers and this calls for upgrade of the web server resources. This study therefore recommended hosting of e-learning systems on dedicated web servers to address the above mentioned issue since all the server resources such as the RAM, hard disk space, CPU are allocated to the e-learning system unlike in shared hosting where server resources are shared among other systems and websites hosted in that particular server.

Many scholars have also acknowledged the role played by web server virtualization in the world of information technology. Soni et al (2019) confirmed that many companies that used server virtualization have saved operational costs and also reduced the number of physical servers needed by utilizing a physical hard disk space. Moreover, hard disk space can be divided into several parts that can later be used by virtual server machines and thus the company does not need a lot of servers anymore because it can be accommodated and combined in 1 to 2 servers. Because of the above reason, this study recommended web server virtualization to save higher institutions of learning from buying more servers that would consume more space and reduce on their budget.

Based on field findings, the researcher recommended the use of PostgreSQL database management system for features such as high concurrency, ACID compliance (Atomicity, Consistency, Isolation, Durability). It also uses multi-version concurrency control (MVCC) which allows several writers and readers to work on the system at once. PostgreSQL is extremely capable of handling multiple tasks simultaneously and efficiently (Bhatia, 2022). PostgreSQL has received praises by many scholars and systems developers for its capability of handling multiple tasks simultaneously and efficiently.

PostgreSQL database clustering was yet another web server overload management guideline recommended based on the fact that some online activities require read only action while others require read and write actions. This necessitated database clustering of files into read only and read and write only to prevent locking of users who require read only action by read and write requests which take longer time. This guideline also scored highly in the validation process since it is efficient in reducing the load on the database and reducing on the response time for the requested files from

the database.

Database content and file optimization was another strategy recommended to improve on the performance of e-learning systems and also to reduce on web server overload for the e-learning systems. Aponso et al. (2017) in agreement with the strategy explained in their study that database optimization is the most imperative thing that should be considered and that it should be considered since the primary aim of the optimization is to find an optimal execution plan that can return results to particular users efficient and effectively. With this guideline, the researcher aims at improving efficiency and in turn improving on the response time of the databases.

The last guideline is caching of information frequently accessed by users to reduce the time taken to fetch the same information from the databases hence improving on the response time for the information requested. Given that there is rapid growth of web based services requested by people across the globe through computer and smartphones, there is a considerable inflow of internet traffic. Because of the aforementioned reason, web caching is one of the best solutions for improving the performance of Internet Web-based services (Truong* & Lam, 2022). Users experience faster responses for requests made and also reduced network bandwidth usage thereby increasing on service quality since frequently requested information are temporarily stored on system caches located closer to the users.

7.1.2 Methodological discussion

Research methods need to be carefully chosen to produce the desired results at the end of the research study. Wisler (2009) recommended a combination of both qualitative and quantitative research other than using either form by itself. The author further argued that a combination of both methods provides an expanded understanding of the research problems. For this reason, the study used mixed data collection methods.

The investigation of the causes of web server overload of e-learning systems at higher institutions of learning in Uganda was done through interviews which is a qualitative method. Interviews were selected to widely understand the different causes of web server overload for the e-learning systems and this was possible due to its capability that allows probing for more information from the purposively selected participants mentioned in chapter three. Furthermore, the different web server overload management guidelines used at the higher institutions of learning were also obtained through

interviews. This method enabled the researcher to dig in detail the different strategies used to manage web server overload and also elicited views and opinions from the participants on the appropriate web server overload management strategies and guidelines that they felt would help in improving on the performance of the e-learning systems used at their higher institutions of learning. With all the information gathered, content analysis was used to generate themes that were later used as inputs for the third objective.

The developed web server overload management guidelines were derived from solicited strategies and guidelines obtained from objective two and also from related literature thus ensuring that the developed guidelines fit into the study context.

Quantitative method inform of questionnaires was considered in the validation phase that fulfilled objective four. The validation questionnaire used Likert scales to capture the extent of agreement for each validation question, hence providing more quantifiable results. The developed web server overload management guidelines for the e-learning systems were validated in terms of their relevance in improving the performance of e-learning systems during concurrency access at peak time and the anticipated outcome or implications when they are implemented into the real environment. The reason for the validation phase was to understand the level of agreement with the developed web server overload management guidelines by the experts mentioned in chapter three. This was done in line with Avison and Heje (2009) argument that quantitative research enables information systems researchers to get answers to academic questions about the interaction of users and designed artefacts.

7.1.3 Limitations

Although the research questions were answered, there were some limitations that affected the results of the study. The limitations are presented as below;

For the interview session conducted to gather data for the first and second objectives, very few respondents participated which limited the volume of information collected. Most of the experts were not available in adherence to Standard Operating procedures (SOPs) introduced by the government of Uganda to curb the spread of COVID-19 and some of the available ones made appointments which were not honored. Had there been many experts with the required qualifications at the higher institutions of learning, the researcher would have collected various responses in line with the study

objectives thereby providing more informed presentations of the findings on the causes of web server overload and the strategies used to manage the web server overload.

Due to time constraint, the researcher only considered five higher institutions of learning in Uganda. The researcher however, believes that more information about other e-learning systems could have been obtained if more institutions of higher learning including private institutions were considered. This also limited the final results on other causes of web server overload for the e-learning systems and web server overload management guidelines since information from private institutions of learning were not sought.

During the data collection stage, some of the respondents from higher institutions of learning were hesitant in providing the necessary information required by the researcher for fear of exposing the challenges faced at their institutions regarding the use of the e-learning systems. This limited researcher's information on more pressing issues faced at the higher institutions of learning hence limiting the researcher's recommendation on other web server overload management strategies and guidelines because the information obtained were not very sufficient.

Although the researcher validated the developed web server overload management guidelines in fulfillment of the fourth objective, only seventeen participants were reached and these were all from Kampala. The small number was as a result of few experts who could easily be reached and who have hands-on practice and experience in web server management and systems design and development that involve high concurrency access. Most of the people had experience in website design and moreover static websites which do not attract most people. The researcher also believes that more reliable and informed opinions could have been sought if experts from all the regions of Uganda were sought.

7.2 **Conclusion**

This study aimed at improving the performance of e-learning systems used at higher institutions of learning in Uganda as education system incline towards e-learning. More specifically, the study investigated the causes of web server overload for e-learning systems used at higher institutions of learning in Uganda and determined the strategies used by the higher institutions of learning to manage the web server overload. In so doing, it was evident from the data collected by the researcher that, higher institutions of learning in Uganda do not have proper web server overload management

strategies especially during concurrency access at peak hours. As a result, higher institutions of learning experienced setbacks in institutional activities which led to postponing of online learning, rescheduling of online examinations, assignments, and other activities required to be done online. This was brought about by unavailability of the e-leaning system (system downtime), slow response by the system among other challenges. To circumvent the above mentioned challenges, higher institutions of learning considered use of other alternative platforms; web server upgrade by adding more memory, increasing the hard disk storage space, upscaling of network bandwidth; time tabled access to the e-learning system, single browser login among others. These strategies did not achieve much and therefore, this study developed guidelines that can improve on the performance of the e-learning systems used at higher institutions of learning in Uganda which were validated by technical experts for their relevance and anticipated outcome when implemented. These guidelines include: the use of least connection load balancing method; configuring a backup or secondary load balancer; hosting e-learning systems on dedicated web servers; upgrading of the database server from MySQL to PostgreSQL Database Management System; clustering of PostgreSQL database into "read only" and "read and write" databases; optimization of the databases through indexing and caching of information using Redis in-memory software. Further efforts are therefore required to implement the developed web server overload management guidelines and also explore more guidelines, strategies, mechanisms, frameworks among others that can supplement the developed guidelines to improve on the performance of the e-learning systems used at higher institutions of learning in Uganda.

7.3 Recommendations

Recommendations for practice

The researcher recommends implementation of the identified web server overload management strategies and guidelines and also test and evaluate it in the learning environment to ascertain its relevance and outcome in improving the performance of the e-learning systems in terms of response time during concurrency access at peak hours. This is because due to time and financial constraints, the recommended web server overload management strategies and guidelines could not be implemented

Furthermore, the researcher recommends further investigation considering other higher institutions of learning both government and private from all the regions in the country since only five government higher institutions of learning from central and northern regions were purposively selected. This is so

because when more institutions of higher learning from all the regions are considered, other unique challenges, strategies and guidelines can be gathered hence improving on the strategies and guidelines for future implementation.

Recommendations for future research

Future research can explore in detail how the different web server overload management strategies and guidelines adopted by the higher institutions of learning were exactly being applied on the e-learning systems. This is because the researcher could not explore in detail how the strategies and guidelines listed by the experts were being applied on the e-learning systems to reduce web server overload. This was due to security and privacy reasons explained by the responsible people and therefore they could not demonstrate how the strategies and guidelines were exactly being applied.

Future research should also be carried out to explore in detail how higher institutions of learning that have adopted the recommended web server overload management strategies and guidelines for their e-learning systems are performing. In this case, case studies of e-learning systems that have successfully implemented the web server overload management strategies and guidelines can be assessed to show actual benefits of the recommended strategies and guidelines like response time improvement during concurrency access during peak time among others.

Lastly, the researcher recommends extension of the research by investigating in detail the various techniques, methods and algorithms explored by other studies in line with the research topic. This would provide vast and reliable information that can be used to improve on the performance of e-learning systems.

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APPENDICES

Appendix A: Interview guide for the technical staff

MAKERERE UNIVERSITY

WEB SERVER OVERLOAD MANAGEMENT FOR E-LEARNING SYSTEMS: A CASE STUDY OF E-LEARNING SYSTEMS IN UGANDA

Consent: Brief description:

Hello, my name is Ejang Edina Nighty from School of Computing and Informatics Technology (CoCIS), Makerere University. I am conducting this research to gather insights on e-learnings system usage, to know the challenges e-learning system users face, find out the strategies that are currently used to improve the performance of e-learning system in order to recommend suitable solutions based on the information that you will provide in this interview. Your contribution will help in improving the performance of e-learning systems that are currently used at the different institutions of higher learning in Uganda. The target institutions in this research are; Makerere University, Kyambogo University, Makerere University Business School, Gulu University and Lira University.

Key terms.

E-learning system: A learning system based on formalized teaching but with the help of electronic resources.

Framework: A particular set of rules, ideas, or beliefs which you use in order to deal with problems or to decide what to do.

Policies: Rules, principles, guidelines or frameworks that are adopted or designed by an organization to achieve long term goals.

Procedures

- If you agree to be interviewed, I will conduct an interview with you lasting about 20-30 minutes.
- If a question makes you feel uncomfortable or you do not want to say anything we shall skip to the next questions. You are also free to disrupt the interview at any time you want.
- If there is a question you do not understand, please let me know and I will be happy to explain.

- I will not share your names or any other information that might identify you. No one except the survey staff will have access to the information you provide.
- The information you provide will be very useful in giving answers to the questions we would like answered.
- Your responses will **be COMPLETELY CONFIDENTIAL** and will only be used for research purposes and if shared in form of feedback your name will be attached to any findings.
- For future reference, I shall record the interview, and I kindly seek your permission to proceed with the recording.
- Do you agree to take part in the interview?

SECTION A: IDENTIFICATION

a1. What is your highest level of education? *(1. Philosophy of Doctorate (PhD), 2. Master's Degree, 3. Bachelor's Degree, 4. Diploma, 5. Certificate (Certifications))*

a2. Name of the University/ Higher institution of learning *(1. Makerere University, 2. Kyambogo University, 3. Makerere University Business School University, 4. Lira University, 5. Gulu University)*

a3. What is your designation at this University/ Higher institution of learning? *(1. Systems Administrator, 2. Network administrator, 3. Database Administrator, 4. IT Support staff, 5. Software developer, 99. Other (Specify)*

a4. What is the name of the e-learning system used at the University/ Higher institution of learning? *(1. Makerere University E-Learning Environment (MUELE), 2. Kyambogo University E-learning Management System (KELMS), 3. Makerere University Business School E-learning Platform (MUBSEP), 4. Lira University E-learning Environment, 5. Gulu University E-learning Environment (GUELE) 99. Other (Specify))*

SECTION B: E-LEARNING SYSTEM CHALLENGES

b1. Have you faced any challenge with the e-learning system? *(1. Yes, 0. No)*

b2. If yes, what are some of these challenges? *(1. Unavailability (system Downtime), 2. Slow speed of accessibility, 3. Lack of internet bundles, 4. Lack of computing device to connect to the e-learning system, 5. Difficulty to use the system 99. (Other Specify))*

b3. Under what circumstances do/did you face the above mentioned challenges? *(1. When uploading assignments, 3. When uploading notes, 4. When interacting with students through chats, 5. When*

managing learners, 6. When delivering and organizing curriculum, 7. When assessing learners, 8. When tracking and reporting 99. Other(specify)

b4. Has there been any strategy or measure to address these challenges? *(1. Yes, 0. No)*

b5. If yes, what are some of the strategies or measures used or being used to address these challenges?.....

b6. With the applied strategies, is there an improvement in the performance of the e-learning system? *(1. No improvement, 2. Little improvement, 3. Average improvement, 4. High improvement, 5. Highest Improvement)*

b7a. Are there any recommended polices/guidelines on the use of the e-learning? *(1. Yes, 0. No)*

b7b. If yes, what are some of these polices/guidelines? ……

b7c. Have you adhered to these policies/guidelines? *(1. Yes, 0. No)*

b7d. To what extent are these policies/guidelines being adhered to? *(1. To a Very Small Extent, 2. To a Small Extent, 3. To a Moderate Extent, 4. To a Large Extent, 5. To a Very Large Extent)*

b7e. If no, why have you not adhered to these policies/guidelines? ……..

b8a. Are there days that you were unable to access the e-learning system? *(1. Yes, 0. No)*

b8b. If yes, how often has this happened? *(1. Seldom (rarely), 2. Sometimes, 3. Often, 4. Usually (Most of the time), 5. Almost always)*

b8c. What do you think could have been the cause of the e-learning system inaccessibility? *(1. Network challenge, 2. Many users at the same time(Overload), 3. Limited RAM, 4. Limited HHD, 5. Limited Processor, 6, Hardware failure, 7. Power outages, 8. Viruses and malware, 9. Outdate operating system, 10. Outdated drivers, 11. Outdated software, 12. Poorly written codes, 99. Other specify))*

SECTION C: INFORMATION TECHNOLOGY INFRASTRUCTURE

c1. Is the e-learning system hosted within the institution? *(1. Yes, 0. No)*

c2. If no, who provides hosting services for your e-learning system? *(1. Hosting company outside the institution, 2. Cloud hosting (Cloud computing))*

c3. Do the server specifications on which the e-learning system is hosted sufficient to meet the demands of the e-learning system's users? *(1. Does not Meet, 2. Meets Some, 3. Meets, 4. Exceeds 5. Far Exceeds)*

c4. Please explain the reason for your choice in d3 above……

c5. Can you please describe the current server specifications on which the e-learning systems is hosted? …….....

c6. Can you please describe the server specifications that you would recommend to meet the demands for the e-learning systems?…….....

c7a. Are the current network specifications suitable to handle the network traffic from the e-learning system users? *(1. Yes, 0. No)*

c7b. If no, what network specifications would you recommend that can handle the network traffic from e-learning systems demands.....

SECTION D: SERVER OVERLOAD MANAGEMENT

d1. How do you rate the performance of the current e-learning system? *(1. Poor, 2, Fair, 3. Good, 4. Very good, 5. Excellent)*

d2. Please explain the reason for your choice in question **d1** above.

d3a. Have you experienced server overload during e-learning system access? *(1. Yes, 0. No)*

d3b. If yes, how were you able to tell that the server for the e-learning system is overloaded? *(1. Error code display, 2. Server request delays, 3. TCP connection denial, 4. Partial content delivery, 5. Request time Out messages, 99. Other (specify))*

d4. What do you think were/are the major causes of server overload of e-learning systems? *(1. Increased number of users, 2. Breakdown of other servers, 3. Viruses and worms, 4. Denial of Service attacks, 5. Limited RAM, 6. Limited HDD, 7. Limited CPU, 8. Outdated software (OS and other supporting software), 9. Low network bandwidth, 99. Other (specify))*

d5a. Is there a framework/ algorithm or strategy in place to manage the e-learning systems server overload? *(1. Yes, 0. No)*

d5b. If yes, what is this framework/ Algorithm or strategy? ……

d5c. Has this framework/ algorithm or strategy reduced on the server overload for the e-learning system? *(1. Yes, 0. No)*

d5d. If no, what are the challenges with the framework/ algorithm or strategy that is used?

d6a. Is there anything that you think can be done to improve on the current framework/ algorithm or strategy. *(1. Yes, 0. No)*

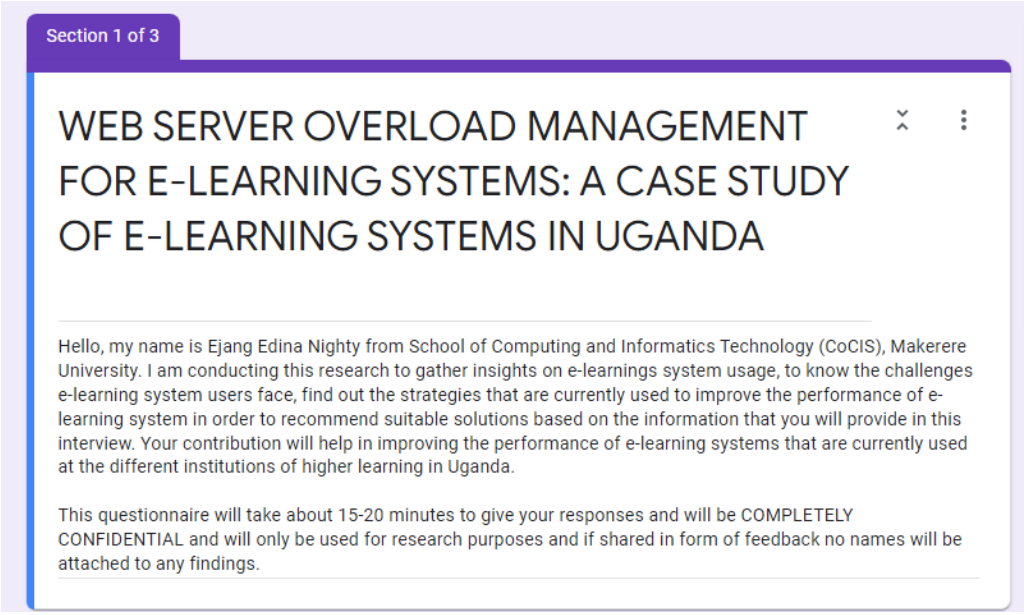
d6b. Please explain what you think can be done to improve on the current framework/ algorithm or strategy.

d7a. Do you have any recommendation besides the framework/ algorithm in place that you think can improve on the performance of the e-learning system? *(1. Yes, 0. No)*

d7b. Please feel free to give your recommendations.

Thank you

Appendix B: Questionnaire for students

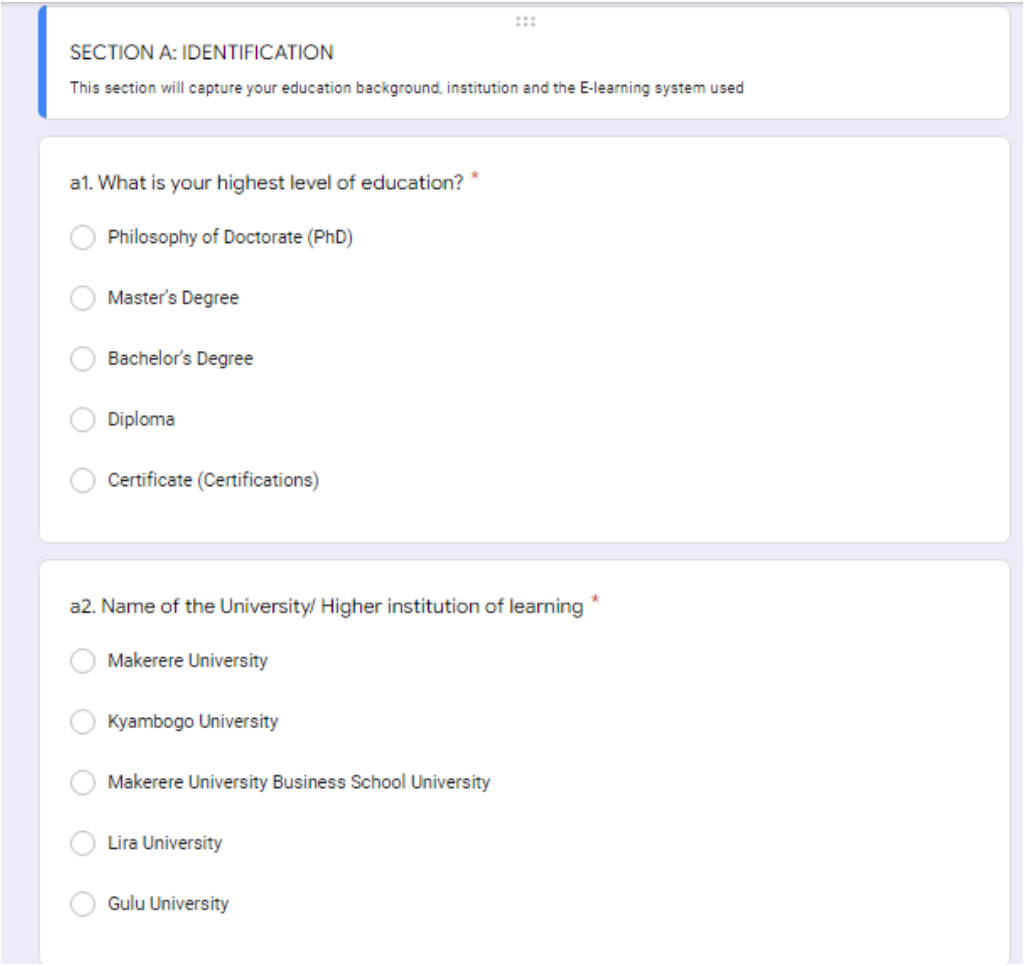


Section 1 of 3

WEB SERVER OVERLOAD MANAGEMENT FOR E-LEARNING SYSTEMS: A CASE STUDY OF E-LEARNING SYSTEMS IN UGANDA

Hello, my name is Ejang Edina Nighty from School of Computing and Informatics Technology (CoCIS), Makerere University. I am conducting this research to gather insights on e-learnings system usage, to know the challenges e-learning system users face, find out the strategies that are currently used to improve the performance of e-learning system in order to recommend suitable solutions based on the information that you will provide in this interview. Your contribution will help in improving the performance of e-learning systems that are currently used at the different institutions of higher learning in Uganda.

This questionnaire will take about 15-20 minutes to give your responses and will be COMPLETELY CONFIDENTIAL and will only be used for research purposes and if shared in form of feedback no names will be attached to any findings.



SECTION A: IDENTIFICATION

This section will capture your education background, institution and the E-learning system used

a1. What is your highest level of education? *

- Philosophy of Doctorate (PhD)
- Master's Degree
- Bachelor's Degree
- Diploma
- Certificate (Certifications)

a2. Name of the University/ Higher institution of learning *

- Makerere University
- Kyambogo University
- Makerere University Business School University
- Lira University
- Gulu University

a3. What is your main designation at this University/ Higher institution of learning? *

- Systems Administrator
- Network administrator
- Database Administrator
- IT Support staff
- Software developer
- Student
- Other...

a4. What is the name of the e-learning system used at the University/ Higher institution of learning? *

- Makerere University E-Learning Environment (MUELE)
- Makerere University Business School E-learning Platform (MUBSEP)
- Lira University E-learning Environment
- Kyambogo University E-learning Management System (KELMS)
- Gulu University E-learning Environment (GUELE)
- Other...

Section 2 of 3

SECTION B: E-LEARNING SYSTEM USAGE

This section will capture how e-learning system is used

b1. Have you ever used the above e-learning system?

- ○ Yes
- ○ No

b2. If no, what are the reasons for not using the e-learning system?

- ☐ Unavailability (System downtime)
- ☐ Slowness
- ☐ Insufficient internet bundles
- ☐ Lack of computing device to connect to the e-learning system
- ☐ Lack of computer skills
- ☐ Difficult to use
- ☐ Other...

b3. If yes, how often did/do you use the e-learning system?

- ○ Every day
- ○ Once a week
- ○ Twice a week
- ○ Thrice a week
- ○ More than four times a week
- ○ After 1 week
- ○ After 2 weeks
- ○ Once a month
- ○ Other...

b4. How much time do you spend on average on the e-learning system when you are using it?

- ○ Less than 1 hour
- ○ 1-2 hours
- ○ 3-4 hours
- ○ 5-6 hours
- ○ 7-8 hours
- ○ More than 8 hours

b5. What did/do you mainly use the e-learning system for?

- ☐ To upload assignments/quizzes
- ☐ To do online examinations
- ☐ To download notes
- ☐ To interact with course mate through chats
- ☐ Other...

b6. What is/was your experience from using the e-learning system?

- ○ Very good
- ○ Good
- ○ Average
- ○ Bad
- ○ Very bad

b7. Please can you explain the reason for your choice to question b6

Long answer text

Section 3 of 3

SECTION C: E-LEARNING SYSTEM CHALLENGES

This section will capture the e-learning system challenges faced during usage

c1. Have you faced any challenge with the e-learning system?

- ( ) Yes
- ( ) No

c2. If yes, what are some of these challenges?

- [ ] Unavailability (system Downtime)
- [ ] Slow speed of accessibility
- [ ] Lack of internet bundles
- [ ] Lack of computing device to connect to the e-learning system
- [ ] Difficulty to use the system
- [ ] Other...

c3. Under what circumstances do/did you face the above mentioned challenges?

- [ ] When doing quiz/exams/tests
- [ ] When submitting assignments
- [ ] When downloading notes
- [ ] When interacting with course mate through chats
- [ ] Other...

c4. Has there been any strategy or measure to address these challenges?

- ( ) Yes
- ( ) No

c5. If yes, what are some of the strategies or measures used or being used to address these challenges?

Long answer text

c6. With the applied strategies, is there an improvement in the performance of the e-learning system?

- ○ No improvement
- ○ Little improvement
- ○ Average improvement
- ○ High improvement
- ○ Highest Improvement

c7a. Are there any recommended polices/guidelines on the use of the e-learning?

- ○ Yes
- ○ No

c7b. If yes, what are some of these polices/guidelines?

Long answer text

c7c. Have you adhered to these policies/guidelines?

- ○ Yes
- ○ No

c7d. To what extent are these policies/guidelines being adhered to?

- ○ To a Very Small Extent
- ○ To a Small Extent
- ○ To a Moderate Extent
- ○ To a Large Extent
- ○ To a Very Large Extent

c7e. If no, why have you not adhered to these policies/guidelines?

Long answer text

c8a. Are there days that you were unable to access the e-learning system?

- ○ Yes
- ○ No

c8b. If yes, how often has this happened?

- ○ Seldom (rarely)
- ○ Sometimes
- ○ Often
- ○ Usually (Most of the time)
- ○ Almost always

c8c. What do you think could have been the causes of the e-learning system inaccessibility?

- ☐ Network challenge
- ☐ Many users at the same time(Overload)
- ☐ Limited Random Access Memory (RAM)
- ☐ Limited Hard Disk Drive space (HDD)
- ☐ Limited Processor (CPU)
- ☐ Hardware failure
- ☐ Power outages
- ☐ Viruses and malware
- ☐ Outdate operating system
- ☐ Outdated drivers
- ☐ Outdated software
- ☐ Poorly written codes
- ☐ Other...

Appendix C: Validation Google Form Questionnaire

Section 1 of 4

WEB SERVER OVERLOAD MANAGEMENT FOR E-LEARNING SYSTEMS: A CASE STUDY OF E-LEARNING SYSTEMS IN UGANDA

Dear respondent you have been selected to participate in this research study titled "Web server overload management for the e-learning systems: A case study of e-learning systems used in Uganda" because we believe you have the necessary skills and knowledge on web server operation.

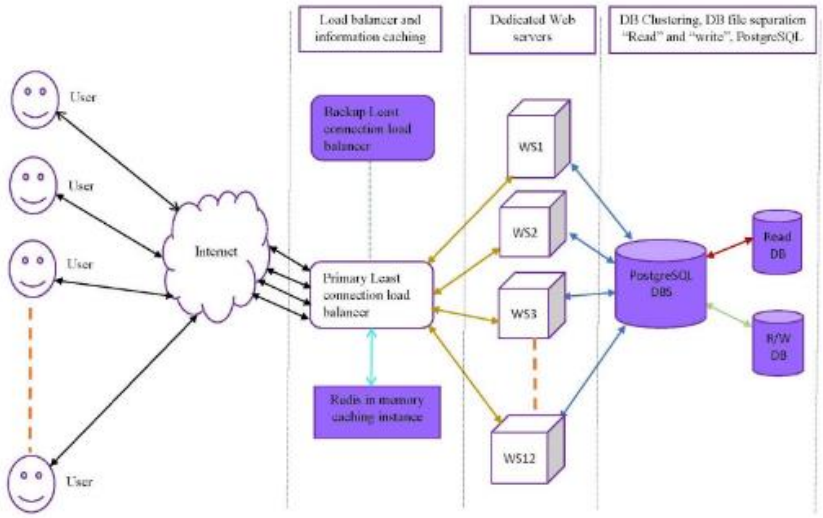
We earlier collected and analyzed data in February and March 2022 which contributed to the recommendation of web server overload management strategies and guidelines for the e-learning systems used at higher institutions of learning in Uganda as illustrated below.

Your response will help in validating the relevance of the recommended web server overload management strategies and guidelines' components for the e-learning systems and the anticipated outcome or implications when implemented. Your views shall be strictly used for the purpose of this study and will be treated with utmost confidentiality.

This questionnaire will take approximately 10 minutes to fill. Feel free to contact me through the contacts below if you have any questions about the research.
Thank you for your time.

Ejang Edina Nighty
Master of Information Technology Student,
Makerere University, Kampala.
+256 785317021
ejangedina@gmail.com

RECOMMENDED WEB SERVER OVERLOAD MANAGEMENT STRATEGIES AND GUIDELINES FOR THE E-LEARNING SYSTEMS



a1. Please select your highest level of education

- ○ Philosophy of Doctorate (PhD)
- ○ Master's Degree
- ○ Bachelor's Degree
- ○ Diploma
- ○ Certificate (Certifications)
- ○ Other...

a2. Please select your job title.

- ○ Systems Administrator
- ○ Network administrator
- ○ Database Administrator
- ○ IT Support staff
- ○ Software / Systems developer
- ○ Other...

SECTION B: RELEVANCE OF THE RECOMMENDED WEB SERVER OVERLOAD MANAGEMENT STRATEGIES AND GUIDELINES

In this section, you are required to choose your level of agreement regarding the relevance of the strategies and guidelines for web server overload management for the e-learning systems on a scale of (1 to 5)

b1. Least connection load balancing method is a suitable load balancing method for efficient distribution of traffic to the web servers

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b2. A backup load balancer is important in enhancing the availability of the web servers in case of a failure of the primary load balancer.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b3. Hosting e-learning systems on dedicated web servers improves their performance and efficient allocation of resources.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b4. Web server virtualization is an economical strategy and meets the demand of many number of users.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b5. PostgreSQL Database Management System is ideal for concurrent database access for the e-learning system files.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b6. PostgreSQL database clustering is efficient in reducing the load on the database and reducing on the response time for database files.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b7. Database content and file optimization improves on the performance of the e-learning systems.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b8. Information caching software reduces on the response time for frequently accessed information from the web servers.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

b9. Please provide your comments on the relevance of the recommended web server overload management strategies and guidelines for the e-learning system

Long answer text

After section 3 Continue to next section

Section 4 of 4

SECTION C: ANTICIPATED OUTCOME OR IMPLICATION OF THE STRATEGIES AND GUIDELINES ON THE E-LEARNING SYSTMS.

This section requires your level of agreement on the outcome or implications of the web server overload management strategies and guidelines on the e-learning systems when implemented.

c1. Improvement on response time during concurrency access of the e-learning systems at peak hours

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

c2. Reduction of web server down time for the e-learning systems

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

c3. Best utilization (optimization) of the web servers' capacity

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

c3. Best utilization (optimization) of the web servers' capacity

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

c4. Cost reduction on the procurement of more web servers and other resources for the e-learning system.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

c5. Please provide your comments in relations to the anticipated implications of the the recommended web server overload management strategies and guidelines for the e-learning system

Long answer text

Appendix D: Research activity plan

Activities	Jul-Aug	Sep	Oct	Nov	Dec	Jan-Feb	Mar	Apr	May	Jun	Jul-Nov	Dec-Jan
Proposal writing												
Proposal presentation to supervisor												
Preproposal defense												
Proposal change implementation												
Proposal submission												
Questionnaire and interview guide development												
First data collection												
First data analysis												
Design of recommended web server overload management strategies and guidelines.												
Validation Questionnaire development, data collection and analysis												
Report writing												
Dissertation proof reading												
Dissertation submission												

Dissertation Marking												
Making minor corrections after the defense and submission												

Appendix E: Instruments used in the research study

Instruments that were used in this study include;

1. Questionnaire
2. Microsoft Excel
3. Emailing services
4. Google forms
5. Microsoft word