A cloud computing architecture for e-learning platform, supporting multimedia content.

By

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Declaration

I, the undersigned, declare that the work contained in this thesis is my original work. I acknowledge that all references are accurately recorded and that, unless otherwise stated, all work herein is my own.

Signature........................................................................................................ Date...........................................
Acknowledgements

All praise and honor to the Lord God Almighty, the giver of Life and all wisdom!!

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“Jeremiah 29:11”
Dedication

To my love, Nyarai Y.D.B. and the Gamundani Clan.
Abstract

E-learning based platforms that support multimedia content to enhance interactive learning demands large disk space. Despite research ground covered under e-learning circles, less attention has been devoted to solicit the best methods to address the disk space challenge at minimal cost. This research focuses on advancing a best architecture that meet the need for storage space when developing interactive multimedia e-learning based portals. The research aim is met through an extensive study of relevant research work already covered and through implementation of the findings by simulation of the identified and reconfigured architecture – a Cloud Computing IAAS. The latter was achieved through use of the CloudSim toolkit. Some of the key findings of this research are that: to precisely test the performance of viable architectures, there has to be a robust platform for such experiments. The main conclusions drawn from this research were that, there is room to improve on existing architectures to scale down on development costs so attributed to e-learning portals that are interactive in stature. Storage can be built from exiting personal computers through harnessing the cloud computing functionality design as most of the personal computers are not fully being used by their owners. This research culminate by recommending the need to explore on best simulator packages that can be used to test the functionality of cloud computing based architectures as this area is still very tentative and lacking in coverage, yet a vital tool for advising the adoptability of emerging solutions which are hosted in the cloud.

Key words: E-learning, Multimedia, Architecture, Cloud Computing, Storage, CloudSim, Simulation, Interactive.
Acronyms

ADL-SCORM - Advanced Distributed Learning-Sharable Content Object Reference Model
AICC - Aviation Industry Computer- Based Training Committee
ARIADNE - Alliance of Remote Instructional Authoring and Distribution Networks for Europe
ASTD - American Society for Training and Development
CD-ROM - Compact Disc Read Only Memory
CPU - Central Processing Unit
DVD - Digital Video Data
GB - Giga Byte
HP - Hewlett Packard
IAAS - Infrastructure As A Service
ICT - Information and Communication Technology
IT - Information Technology
LMS - Learning Management Systems
LSTA - Library Services and Technology Act (US)
MIPS - Million of Instructions Per Second
PAAS - Platform As A Service
PC - Personal Computer
SAAS - Software As A Service
TV - Television
USA - United States of America
VM - Virtual Machine
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CHAPTER 1: RESEARCH INTRODUCTION

1.0 Introduction

This chapter provides the reader with background information on the e-Learning challenges that impelled research for a solution to address the aforementioned dare. The focus of this research is discussed and justified and the overall research aim and individual research objectives are identified, it ends by giving a research outline structure, which acts as a map to the reader.

1.1 Background

E-learning based platforms that support multimedia content to enhance interactive learning demands large disk space (Paul Pocatilu, 2010). To curb the challenge of disk space and decongest the server(s) what should be done? In setups where there is a pool of networked computers or computers that can join a network for a dedicated period, what is happening to all the idle space and processing power? What solution is there to the storage space challenge for e-learning platforms that supports multimedia content?

Figure 1.1: E-learning System (Pocatilu, 2010)

A close glance at a simple e-learning structure as presented in Figure 1.1, depicts the three main players in the e-learning ecosystem as the e-learning server, the network and the e-learning client. Paradoxical to this illustration, many depicts the existence of e-learning clients as the
dorminant player, there is in that light a single network and a single e-learning server, though scientifically it can mean two different words in different formats. There is little attention being paid in most researches on e-learning based systems on how best the e-learning clients can also contribute to the server space and thereby increase throughput to e-learning based systems.

“Learning management systems (LMS’s) are already made available in SaaS model, But for most LMS providers, cost structure for providing LMS in SaaS model is currently governed by ‘old’ way of server infrastructure management (in-house or rented), which is then as-is passed on to the customer’. (Manish Gupta, 2010),

It is on this background highlighted above, that part of this research work is built upon. There is cost involved in hosting e-learning systems, the stages at which such costs weather in monetary terms or otherwise needs to be traced and constituted individually to specific development stages of the e-learning life cycle. There is greater opportunity to explore the best ways in which certain costs could be minimized or avoided if proper attention is given across the spectrum.

1.2 Research focus

“E-learning systems usually require many hardware and software resources,”(Paul Pocatilu, 2010) based on this quantifiable fact, the researcher was triggered to explore the best solution to this challenge, guided by the main research question and identified personal objectives highlighted in the next subsection of this chapter. The main focus of this research following the background information outlined above, therefore was to explore the best resources available that can alleviate the challenge many e-learning system developers face especially for platforms that carry a substantial volume of multimedia content.

The problems experienced in e-learning systems as a medium used to enhance learning and dissemination of information has particularly contributed to the formulated pilgrimage towards a solution that can best be implemented in e-learning systems. The search for such a solution was in light of addressing the challenges at the grass root level that is at the development stage of e-learning systems. Having observed that many institutions are able to launch and host e-learning
based systems to enhance their learning criteria, there is a limitation of storage space. In trying to address a challenge herewith presented as:

“The process of E-learning is not a perfect one……Course material used in e-learning sometimes is unattractive and non-compelling.” (John Eklund, 2003)

“Business divisions who have special and particular needs and mid-size and small companies continue to face stiff challenges and financial crunch to implement e-learning programs and solutions to fit their scale.” (Aaron, 2007)

To address this challenge, there was a motivation to look at the best cost cutting and resource efficient way in which e-learning systems can be developed and deployed at scales that best suits the business or institutions’ requirements. In particular, attention was given to storage capacity as one of the variables that demands some huge financial investments as sometimes a substantial volume of space is required, which in turn triggers sourcing of more servers to meet the ever increasing demand for space.

One of the features that strongly are a check list when testing the quality of e-learning systems as highlighted by this statement:

“……….. as the subject of the course is state of art and thus should be updated regularly. There should be high level of interaction as well…”,(Harold F O'Neil, 2006)

Indicates multimedia content based e-learning systems are the solutions called for, however to host such e-learning platforms in a cost effective routine, what avenue can be followed?
1.3 Overall Research Aim and Individual Research Objectives

The main question that this research will attempt to answer is outlined thus: -

“Is there an architecture that can be used to host e-learning systems built with multimedia content to enhance interactivity in learning circles?”

The following objectives have been identified to be of paramount importance in helping answering this aforementioned question:

1. Exploration of the e-learning architectures that support multimedia content.
2. Critical assessment of the effectiveness of current e-learning architectures.
3. Proposal and implementation of a possible architecture.
4. Recommendations to the educational community, through a generic e-learning architecture that addresses the challenge of hosting multimedia e-learning systems.

It should be made clear to the reader, at this stage that these objectives are not loosely stated but are closely looped to formulate an intertwined structure that precisely answer the research question presented herein. In that light, one objective builds from the other. Objective 1, demystifies any misunderstanding or generalizations that may exist around the key word that formulate the backbone on this research, it is only after clearly outlining the context in which the term, architecture is being used, that e-learning architectures will best be explained. Objective 3 therefore form the main reason why a literature review in this thesis is mandatory.

It is objective 3 that form the critical section of this research through results of the literature review under objective 1 and 2, that the architecture is proposed and tested through simulation so that a conclusion will then be reached recommending the next route possible around the e-learning research fraternity fulfilling Objective 4.
1.4 The Value of this research

This research work will contribute enormously to the development of the e-Learning discipline in a number of important ways:

1. By providing a critical review of issues pertinent to the implementation of e-Learning (what is hindering interactive e-Learning systems and what can possibly be implemented as a solution to that effect);
2. By critically examining existing models and frameworks to support interactive e-learning systems that constitute multimedia content;
3. By obtaining the views of a variety of researchers in the field of e-learning on existing architectures in e-Learning, an affluent picture of e-Learning can emerge, allowing a meaningful comparison between theory and practice, from which an improved understanding of e-Learning development issues at programming and deployment levels can be derived, particularly with regard to scalable alternatives in hosting e-learning systems and support the interactive learning drive, in today’s dynamic educational needs.

(Gerald Friedland, 2007) has this to say, “Based on a brief overview of the history of educational multimedia systems and a rough analysis of the current situation, venturing a glimpse into the future, one can argue that educational multimedia is (still) a vivid and relevant area for research.” (Friedland Gerald, 2009) This statement backs up the need for this research to venture into the future and suggest another approach to enhance educational multimedia systems inform of e-learning based hosting architectures.

1.5 Research Outline structure

Chapter 1: Introduction
Chapter 2: Literature Review
Chapter 3: The Proposed Architecture
Chapter 4: Research methods
Chapter 5: Implementation – Simulation
Chapter 6: Conclusion and Recommendations
1.6 Chapter Summary

At the beginning of each chapter, there is a brief outline of what the chapter is going to cover; this is an aid to the reader for a quick appreciation of concepts being highlighted at a snapshot as the chapter unfolds in greater detail. Chapter 1 was mainly focusing on the background information in a bid to give tone to the research. Building up the research focus as well as outlining the Research Aim. The reader is logically taken through the formulation of research objectives and a validation of the research itself. The chapter is wrapped by listing the outline structure of the entire research work.
CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This Literature Review will examine the main issues surrounding e-learning architectures that support multimedia content, to solicit relevant facts that will aid in proposing a possible architecture that can be employed by e-learning system developers. The chapter also hunts for the effectiveness of e-learning architectures that supports multimedia content. Based on the review of literature gathered to support research objective 1 & 2, a summary of emerging issues will be availed at the end of this chapter which forms the basis for the next chapter.

The study within this review of literature focuses on objectives 1 and 2 as set out in sub-section 1.3 of the introductory chapter (the third objective will partly be addressed through the vehicle of data analysis, while the final objective – objective 4 – is derived as a result of the findings from objectives 1, 2 and 3).

By exploring the above highlighted areas of literature, a significant contribution will be made to this research. E-learning architectures that support multimedia content will be evaluated. Similarly, an assessment of the effectiveness of current e-learning architectures (if any) formulated to incorporate multimedia content, will earth needy area(s) which is the main aim of this research in light of the e-learning research field. In effect, the value of studying the aforementioned literature areas will be to provide a meaningful discussion and analysis of e-Learning, in a structured way, to facilitate a critical understanding of architectures that host multimedia content. At the end of this major section it is hoped that a critical understanding of key issues is exhibited, that the reader will be better informed in these areas and that there will emerge a clear focus, and justification, for empirical research in the field of e-Learning architectures specifically with the aim of hosting interactive e-learning systems - multimedia based.
2.2 Definitions

In the first instance, a sensible starting point is to investigate what is meant by the term e-Learning. Additionally, the extended term, architecture – which gives the e-learning term a different dimension altogether needs to have a working definition for a meaningful discussion to subsume. Lastly providing a clear understanding of what multimedia constitute especially in light of e-learning systems, as importantly emphasised by (Ron Hubbard, 2007), “The confusion or inability to learn comes AFTER a word the person did not have defined and understood.” The following is a review of the three terms that formulates the backbone of this research:

- E-learning
- Multimedia
- Architecture

2.2.1 E-learning

“E-Learning is the convergence of learning and the Internet”, this definition by Banc of America Securities brings to our attention two terms learning and e-learning, hence the existence of the internet provides a link between learning and student. However, Elliott Masie, The Masie Center Further expands the definition to read, “E-Learning is the use of network technology to design, deliver, select, administer, and extend LEARNING,” which breaks down the activities involved for e-learning to come to being. The version that Robert Peterson, Piper Jaffray employ to define the very term presented here as, “We define e-Learning companies as those that leverage various Internet and Web technologies to create, enable, deliver, and/or facilitate lifelong learning,” takes e-learning as a form of a business line, it further brings to our attention a new term “web technologies.” At least this is straightforward at this point.

A definition based on internet and network by Marc Rosenberg (2001) confines e-learning to the internet as: the use of internet technologies to deliver a broad array of solutions that enhance knowledge and performance. It is based upon three fundamental criteria:

- networked
- delivered to the end-user via a computer using standard internet technology
- focuses on the broadest view of learning

Allison Rossett (2001, p161) defines e-learning as: Web-based training (WBT), also known as e-learning and on-line learning, is training that resides on a server or host computer that is
connected to the World Wide Web. This definition conjures with the representation that e-
learning is technology based thus, training that is delivered partially or entirely through
electronic hardware, software, or both. These two definitions perhaps come the closest as to how
most learning professionals define e-learning.

Another one that pretty much stays within the network framework is Clark Adrich (2004). He
defines e-learning as: a broad combination of processes, content, and infrastructure to use
computers and networks to scale and/or improve one or more significant parts of a learning
value chain, including management and delivery. Originally aimed at lowering management cost
while increasing accessibility and for measurability of employees, e-learning is increasingly
being used to include advanced learning techniques such as simulations and communities of
practice and to include customers and vendors as well.

Digging deeper into other definitions e-learning in other dimensions is presented with ambiguous
attachments in that some authorities argue that there is no precise and agreed definition for e-
learning to date. Reviewing the statement below from Dublin, L. (2003), the term e-learning is
ambiguous to those outside the e-learning industry, and even within its diverse disciplines it has
different meanings to different people.

Many terms have been used to define e-learning in the past. For example web-based
training, computer-based training or web-based learning, and online learning are a few
synonymous terms that have over the last few years been labeled as e-learning. Each of this
implies a "just-in-time" instructional and learning approach (Harold F O'Neil, 2006). Regardless
of the definition you chose to use, designers, developers, and implementers make or break the
instructional courses and tools. E-learning is simply a medium for delivering learning and like
any other medium, it has its advantages and disadvantages. E-learning covers a wide array of
activities from supported learning, to blend or hybrid learning (the combination of traditional and
e-learning practices), to learning that occurs 100% online. These definitions are in tandem with
previously presented definitions for the purposes of this research, e-learning is thus defined as, “a
platform that is used to host learning resources for easy of access by recipients through viable
access methods that employ available data transfer channels.”
Manville (2003) defines e-learning as: including not only Internet-published courseware, but also the tools for managing, modularizing and handling the following:

- Different kinds of content and learning objects (including both electronic and non-electronic forms, and even traditional classroom instruction).
- Just-in-time and asynchronous learning, such as virtual labs, virtual classrooms and collaborative work spaces.
- Simulations, document repositories and publishing programs.
- Tools for prescribing learning, managing development pathways and goals and handling e-commerce and financial transactions related to learning.
- The utilities and capabilities for supporting informal learning, mentoring, communities of practice and other non-training interventions.

In other words, e-learning does most everything in the corporate world related to learning except for training! This presents a research need that need to be explored in light of this shortfall.

Gilbert (1998) said that performance has two aspects: behavior being the means and its consequence being the end. Learning is similar in that it also has two aspects: a learning method or experience being the means and the resulting skills or knowledge being the end (consequences).

E-learning is defined also as the use of innovative technologies and learning models to transform the way individuals and organizations acquire new skills and access knowledge (Moeng, 2004). He further defines learning as a collaboration of information, interaction, collaboration, and in-person.

2.2.2 Architecture

To contextualize the definition of architecture, prefixing it with either software or e-learning gives it meaning, for it means different things to various application areas (Clark, 2005). Software application architecture is the process of defining a structured solution that meets all of the technical and operational requirements, while optimizing common quality attributes such as performance, security, and manageability. It involves a series of decisions based on a wide range
of factors, and each of these decisions can have considerable impact on the quality, performance, maintainability, and overall success of the application.

Philippe Kruchten, Grady Booch, Kurt Bittner, and Rich Reitman (2009) derived and refined a definition of architecture based on work by Mary Shaw and David Garlan (1996). Their definition is: “Software architecture encompasses the set of significant decisions about the organization of a software system including the selection of the structural elements and their interfaces by which the system is composed; behavior as specified in collaboration among those elements; composition of these structural and behavioral elements into larger subsystems; and an architectural style that guides this organization. Software architecture also involves functionality, usability, resilience, performance, reuse, comprehensibility, economic and technology constraints, tradeoffs and aesthetic concerns” (Grady Booch, 2009).

Martin Fowler (2003) outlines some common recurring themes when explaining architecture. He identifies these themes as:
“The highest-level breakdown of a system into its parts; the decisions that are hard to change; there are multiple architectures in a system; what is architecturally significant can change over a system's lifetime; and, in the end, architecture boils down to whatever the important stuff is.”

Bass, Clements, and Kazman (2003) define architecture as follows:
“The software architecture of a program or computing system is the structure or structures of the system, which comprise software elements, the externally visible properties of those elements, and the relationships among them. Architecture is concerned with the public side of interfaces; private details of elements—details having to do solely with internal implementation—are not architectural.”

For the purposes of this research a working definition of architecture the researcher deemed necessary to adopt the definition given by Philippe Kruchten et al. (2009) It is comprehensive in nature as it integrates the various components that formulate software architecture.
2.2.3 Multimedia

Multimedia is a term that was coined by the advertising industry to mean buying ads on TV, radio, outdoor and print media. It was originally picked up by the PC industry to mean a computer that could display text in 16 colors and had a sound card. The term was a joke when you compared the PC to the Apple Macintosh which was truly a multimedia machine that could show color movies with sound and lifelike still images.

There are a number of terrific software packages that allow you to create multimedia presentations on your computer. Perhaps the best and most widely known is Microsoft’s PowerPoint. With PowerPoint a user can mix text with pictures, sound and movies to produce a multimedia slideshow that's great for boardroom presentations or a computer kiosk but difficult to distribute.

J. Hepple (2011) presents that, eventually, in the not too distant future, the digital movie imbedded in web pages will become the presentation delivery system of choice relegating PowerPoint to the dustbins of software. If you have ever browsed a DVD movie disk on your computer you've seen that future.

The basic elements of multimedia on a computer are:

- Text
- Still images
- Sound
- Movies
- Animations

The Definition of Multimedia by Penny Loretto (2011), presents Multimedia as the use of computers to present text, audio, video, animation, interactive features, and still images in various ways and combinations made possible through the advancement of technology. This is an exciting new field for those interested in computers, technology, and creative career options. Multimedia can be accessed through computers or electronic devices and integrates the various forms together. One example of multimedia would be combining a website with video, audio, or text images, which clearly spells the need for substantial amount of disk space.
2.3 E-learning architectures supporting multimedia content

The IMS LIP final specification by El-Khatib K (2003, V1.0, p10) does provide the following structures to support the implementation of "any suitable architecture" for learner privacy protection. However, focus was more centered on addressing privacy principles as depicted in Table 7.2, Appendix D.

**LTSA Architectural Model for E-Learning**

![LTSA Architectural Model for E-Learning](image)

*Figure 2.1: LSTA system components (El-Khatib K, 2003)*

A close look at this architecture clearly shows the display of learning resources and multimedia components for this setup is not being housed under a single shell. There is a possible danger in slowing delivery of the e-learning resources to end-users in such an architectural setup. It is much convenient to compute delivery latency at a go than at different delivery levels.

“As with rapid growth of the cloud computing architecture usage, more and more industries move their focus from investing into processing power to renting processing power from a specialized vendor.” *(Paul Pocatilu, 2010)*

From this nugget, the cloud computing architecture presented here is availed on rental from a specialised vendor. This pause an opportunity to look on how best users or organisations can be specialised vendors in own capacity to effectively make use of the available resources.
“The technical standards for connecting the various computer systems and pieces of software needed to make cloud computing work still aren’t completely defined.” (John Eklund, 2003; Aaron, 2007)

Well, cloud computing maybe presented as a viable architecture as indicated here, there is still a loophole that needs research attention in light of being able to define computer systems and pieces of software that will enable the cloud computing architecture a worth tool for use.

“Every decade or so, the computer industry's pendulum swings between a preference for software that's centrally located and programs that instead reside on a user's personal machine. It's always a balancing act, but today's combination of high-speed networks, sophisticated PC graphics processors, and fast, inexpensive servers and disk storage has tilted engineers toward housing more computing in data centers. In the earlier part of this decade, researchers espoused a similar, centralized approach called "grid computing." But cloud computing projects are more powerful and crash-proof than grid systems developed even in recent years.” (Aaron, 2007)

It is from these facts that incrementally confidence for conducting this research and increase options to the existing board of knowledge, can be built.

2.4 The effectiveness of E-learning architectures

A close glance at the following case study unveils some of the focus that the implemented e-learning systems architectures were inclined towards:

“However, most of them are focusing on content management, meta-data specification, or other areas with little reference to security and privacy. For example: - The AICC focuses on practicality and provides recommendations on e-learning platforms, peripherals, digital audio and other implementation aspects. - The ARIADNE focuses mainly on meta-data specification of electronic learning materials with the goal of sharing and reusing these materials.” (El-Khatib K, 2003)
It is easier to advance a solution that addresses how to host content alone based systems than multimedia content based systems. This present a great challenge to the e-learning design and implementation chores as a result, there is great need to explore this avenue in a holistic approach.

ADL-SCORM is mainly concerned with specifying how instructional content should be treated (El-Khatib K, 2003 ; Su-Chen WANG, 2008). Instructional content is mainly descriptive in nature, well if it embeds multimedia in it, the focus inclined by ADL-SCORM review are towards handling not hosting of such instructional content. As an additional requirement to produce a complete piece of work, the need to complement efforts made by advancing a possible hosting architectural setup that can both house the instructional content and provide elastic space for future storage needs, cannot be overemphasised.

Cloud computing delivers infrastructure, platform, and software that are made available as subscription-based services in a pay-as-you-go model to consumers. These services are referred to as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) in industries.(Paul Pocatilu, 2010) Being an emerging discipline, the cloud computing setup still passes to be high cost option and deterring to some users. A close analysis of Table 7.3 (Paul Pocatilu, 2010), Appendix D: Tables, Page 70 will aid in clarifying this fact.

It is noble to explore better ways in which this model can be used hence implemented on a low to no cost range, as supported by the following statement:

“Cloud computing is a promising solution for most industrial applications that could help industry players transform some of their IT infrastructure expenditures into a more flexible on-demand resource provisioning cost model.” (Janna Quitney Anderson, 2010; Rodrigo N.Calheiros, 2011; Soumya Banerjee, 2009)

The current cloud computing architecture involves the existence of data centers that are able to provide services to the clients located all over the world. In this context, the cloud can be seen as a unique access point for all the requests coming from the customers/clients. It is from this setup that a motivation to conduct this research so as to identify the best ways in which the datacenter
components of the architecture can be localized and make use of available resources to the maximum potential is obtained.

Even if it seems not very reasonable, the cloud computing provides some major security benefits for individuals and companies that are using/developing e-learning solutions, like the following:
• improved improbability – it is almost impossible for any interested person (thief) to determine where is located the machine that stores some wanted data (tests, exam questions, results) or to find out which is the physical component he needs to steal in order to get a digital asset. As such, benefits presented by the e-learning architecture are recipe enough to aid exploration of best options to advance solutions hosted in the same fashion. (Paul Pocatilu, 2010)

The fact that cloud computing has the most unique characteristic of Virtualization makes possible the rapid replacement of a compromised cloud located server without major costs or damages. It is very easy to create a clone of a virtual machine so the cloud downtime is expected to be reduced substantially;

The other security benefits that accrue to cloud computing presented here as:
• centralized data storage – losing a cloud client is no longer a major incident while the main part of the applications and data is stored into the cloud so a new client can be connected very fast. Imagine what is happening today if a laptop that stores the examination questions is stolen; (Paul Pocatilu, 2010)
• monitoring of data access becomes easier in view of the fact that only one place should be supervised, not thousands of computers belonging to a university, for example. Also, the security changes can be easily tested and implemented since the cloud represents a unique entry point for all the clients. (Paul Pocatilu, 2010) These exposes one feature worthy pursuing— the datacenter for centralised control and management of resources.

“…Cloud computing aims to apply that kind of power—measured in the tens of trillions of computations per second—to problems like analyzing risk in financial portfolios, delivering personalized medical information, even powering immersive computer games, in a way that users can tap through the Web. It does that by networking large groups of
servers that often use low-cost consumer PC technology, with specialized connections to spread data-processing chores across them.” (Aaron, 2007; Su-Chen WANG, 2008)

After analyzing this statement, it can be ascertained that it is expensive to secure servers, why not use idle space in most of personal computers around say in an institution setup where there is potential to have a pool of computers that can join a network setup. How much cost can be reduced by exploiting such an avenue?

The following subsections will look into the tools that shall act as a basis for testing the proposed architecture for validation of this research.

2.5 The Resource Allocation algorithm

Following functionality of architectures reviewed, it is ideal to look at literature that explain the sole functionality of the resource allocation algorithm to ensure that there is sanity at the datacenter in that by efficiently monitoring tasks in their various states of execution; the datacenter is in a position to precisely monitor its pool of resources. Resource allocation here is in a dynamic fashion, in that user requests are unpredictable and disk space requested varies with an application being developed.

We advanced a resource allocation algorithm that was tested and proven for its efficient management and monitoring of resources at the datacenter by Yaziq Onat Yazir et.al(2010), in their research on Dynamic Resource allocation in computing clouds through Distributed Multiple Criteria Decision Analysis.

```
ResourceAllocation =
Choose t in taskpool(self) with taskStatus(t) = unassigned do
Let n = placementNode(t) in
If n ≠ undef then
  RequestResourceLock (n, t)
potentialNode(t):=n
taskStatus(t) := allocated
setTimer(self, t)
else
  Warning (“Cannot find suitable node”)
```
The execution being done by the algorithm above is straightforward in nature in that, a task is checked for its status from the task pool or table, a task that has an “unassigned” state, is picked and a Node is identified from the pool of nodes. Once a Node is allocated a task and its confirmed it can execute the task requests with resources available (a functionality of the agent assigned at the node that constantly communicate with the datacenter agent of that node), the node to engage itself in a “Lock” state so that when the next round robin check of available nodes is done, the node is skipped. It is the node agent that has the functionality of creating virtualized processors for a dedicated period of the task’s execution processing cycles.

A task will only be considered executed if a commit confirmation status is reported back to the datacenter agent by the assigned node agent. Otherwise the datacenter agent reports a reschedule of the task to a node that can execute the task completely.

2.6 The CloudSim Simulator

What formulates the CloudSim architecture as a simulation tool, as illustrated by Fig 2.2 below, which displays the various layers of the simulator, suffice to select it as the right tool for this research task. We define our simulator thus:

CloudSim: a new, generalized, and extensible simulation framework that allows seamless modeling, simulation, and experimentation of emerging Cloud computing infrastructures and application services. (Rajkumar Buyya, 2009; Rodrigo N. Calheiros, 2010; Rodrigo N. Calheiros, 2011)

It is from this definition that one can safely indicate that the CloudSim tool is fully packed with structures, modules and the test environment that enable modeling of cloud computing architectures before their execution into real clouds. In a sense here is a tool that minimizes the risk of unqualified results or decision points. It is important to note that like any other software packages it is also without its setbacks.

Simulation for this research using the CloudSim tool, will be done at the CloudSim simulation layer which provide support for modeling and simulation of virtualized setups, data center setups.
as well as dedicated management interfaces for virtualization variables such as memory, storage and bandwidth. The fundamental issues such as provisioning of hosts to VMs, managing application execution, and monitoring dynamic system state are handled by this layer. It is therefore at this layer that the efficiency of resource allocation criteria chosen is tested. Such implementation can be done by programmatically extending the core VM provisioning functionality (Rajkumar Buyya, 2009; Rodrigo N. Calheiros, 2010; Rodrigo N. Calheiros, 2011).

![Layered CloudSim architecture](image)

*Figure 2.2 Layered CloudSim architecture* (Rajkumar Buyya, 2009; Rodrigo N. Calheiros, 2010; Rodrigo N. Calheiros, 2011)

The top-most layer in the CloudSim stack is the User Code that exposes basic entities for hosts (number of machines, their specification and so on), applications (number of tasks and their requirements), VMs, number of users and their application types, and broker scheduling policies.

Host is a CloudSim component that represents a physical computing server in a Cloud: it is assigned a pre-configured processing capability (expressed in millions of instructions per second – MIPS), memory, storage, and a provisioning policy for allocating processing cores to virtual
machines. (Rajkumar Buyya, 2009) The existence of this feature in the CloudSim simulator makes it an ideal simulator for use in this research, where the Host will represent personal computers that have the capacity to lease space to datacenter building.

(For an appreciation of the directory structure of CloudSim toolkit used here – see appendix A.) Virtualization is one of the key processes that have to be tested under cloud computing architectures; it is therefore a plus for having a CloudSim as a testing tool for it has the module that is specifically responsible for such functionality as illustrated on the CloudSim architecture in figure 2.2. Virtualization in practice can thus be defined as... the process of creating VM instances on hosts that match the critical characteristics (storage, memory), configurations (software environment), and requirements (availability zone) of the SaaS provider.

The novel features that CloudSim can offer are presented herewith as:-

(i) Support for modeling and simulation of large scale Cloud computing environments, including data centers, on a single physical computing node;
(ii) A self-contained platform for modeling Clouds, service brokers, provisioning, and allocations policies;
(iii) support for simulation of network connections among the simulated system elements; and
(iv) Facility for simulation of federated Cloud environment that inter-networks resources from both private and public domains, a feature critical for research studies related to Cloud-Bursts and automatic application scaling… (Rodrigo N.Calheiros, 2011)

2.7 Justification of Why CloudSim and Simulation

Given the structure of the proposed architecture which was the main agenda of this research, which is diagrammatically represented in Chapter 3, Fig 3.1. The need to have a simulator that could test the allocation of resources for such architecture found the CloudSim to have been the best tool for use for reasons outlined below.

“...simulation environments play an important role.” (Rodrigo N.Calheiros, 2011) As they are the yardstick with which to measure the viability and applicability of the presented ideas herein.
The use of real infrastructures such as Amazon EC2 and Microsoft Azure for benchmarking the application performance under variable conditions is often constrained by the rigidity of the infrastructure. Hence, this makes the reproduction of results that can be relied upon, an extremely difficult undertaking. Further, it is tedious and time consuming to re-configure benchmarking parameters across a massive scale of cloud computing infrastructure over multiple test runs. Such limitations are caused by the conditions prevailing in the cloud based environments that are not in the control of developers of application services. Thus, it is not possible to perform benchmarking experiments in repeatable, dependable, and scalable environments using real cloud environments (Rajkumar Buyya, 2009; Rodrigo N.Calheiros, 2011), thus the justification for resorting to simulation tools.

The CloudSim offers some of the following scalable opportunities hence improve the quality of researches being conducted in cloud computing based architectures.

(i) Testing of applications can be executed in repeatable and controllable variations;
(ii) There is room to tune the system bottlenecks before deploying on real clouds; and
(iii) experiment with different system variables and resource performance scenarios on simulated infrastructures for developing and testing adaptive application provisioning techniques (Rodrigo N.Calheiros, 2011)

As supported by literature in the same context, herewith are some of the advantages the CloudSim can yield.

(i) Time effectiveness: it requires very less effort and time to implement Cloud-based application provisioning test environment and
(ii) Flexibility and applicability: developers can model and test the performance of their application services in heterogeneous Cloud environments (Amazon EC2, Microsoft Azure) with little programming and deployment effort. (Rajkumar Buyya, 2009; Rodrigo N. Calheiros, 2010; Rodrigo N.Calheiros, 2011)

The other simulators available have their setbacks which fail to scale to the rationale of the CloudSim toolkit, for simulation of cloud computing environments. The CloudSim toolkit supports both system and behaviour modelling of Cloud system components such as data centers,
virtual machines (VMs) and resource provisioning policies. (Rodrigo N. Calheiros, 2011) These features can not easily be integrated in other simulators as done with the simulator in question.

The analysis that was done below of some of the GridSim Simulator functionality and its extensions which after an effort to advance them to test cloud computing based architectures, they have been left behind for lacking in functionality and applicability.

……..although the aforementioned toolkits are capable of modeling and simulating the Grid application management behaviors (execution, provisioning, discovery, and monitoring), none of them are able to clearly isolate the multi-layer service abstractions (SaaS, PaaS, and IaaS) differentiation required by Cloud computing environments. In particular, there is very little or no support in existing Grid simulation toolkits for modeling of virtualization enabled resource and application management environment….. (Rodrigo N. Calheiros, 2011)

The fact that there is no pioneering entails the use of CloudSim as a simulator as evidenced by the statement below, which gives the energy to pursue its capabilities in this field of cloud computing. Several researchers from organisations such as HP Labs in USA are using CloudSim in their investigation on Cloud resource provisioning and energy-efficient management of data center resources. (Rodrigo N. Calheiros, 2011)

The fact that the components to be tested are fully covered with the CloudSim tool, which other researchers also advised as follows, The infrastructure-level services (IaaS) related to the clouds can be simulated by extending the Datacenter entity of CloudSim. (Rodrigo N. Calheiros, 2011) This is guaranteeing enough to support our choice of the CloudSim simulator. Again it was observed by other researchers that, CloudSim does not enforce any limitation on the service models or provisioning techniques that developers want to implement and perform tests with. (Rodrigo N. Calheiros, 2011)

Simulation frameworks such as CloudSim are important, as they allow evaluation of the performance of resource provisioning and application scheduling techniques under different usage and infrastructure availability scenarios. (Rodrigo N. Calheiros, 2011)
2.8 Emerging issues and need for further research

The study of relevant e-Learning literature revealed that e-Learning is a complex and moving landscape. (Biggam, 2009; Sasikumar, 2008) In the first instance, there is no agreed definition of e-Learning. (Rodrigo N. Calheiros, 2010) Other sources highlight on network connectivity; others support infrastructures, and some medium of access and delivery. Similarly, although there were many research papers focused on e-learning, papers that cemented the three key words of this research were not readily available. It was either there is a link between e-learning and architecture or e-learning and multimedia. Summarily this can be depicted as in the Venn diagram below.

![Venn diagram](image)

*Figure 2.3 set distribution – A representation of findings on the 3 key variables*

However in assessment of the Literature review the main concern rather is a different picture that pictorially can be presented as in the figure below:

![Venn diagram](image)

*Figure 2.4: set distribution – A representation of proposed configuration of the 3 key variables*
The development of e-learning solution cannot ignore the cloud computing trends (Paul Pocatilu, 2010), supports the study need that explores how best cloud computing as a technology should be incorporated in developing e-learning systems. An observation for the divorce of e-learning systems and the support of the underlying infrastructure (Dong, 2009), also presents another research concern to find the best way of joining the two variables. Brusilovsky (2004) also supports the same need in his research focus on adaptive e-learning.

Based on the findings of the review done in this section, it is therefore mandatory to propose such an architecture from existing models that represent a close layout to one depicted above. A Cloud computing architecture has therefore after a critical review been singled out as an ideal model that can easily be customisable to suit the requirements of this research. The strongest feature of virtualisation that enables consolidation of heterogeneous applications as seen by Rahul et.al.(2010), is one to capitalise on as also supported by literature trends in Table 7.1, Appendix D.

The review of literature stressed the need to have in place an infrastructure to support multimedia in e-learning platforms. With the emphasis on cost cutting as highlighted before, unveils the need to operate under confined budget constraints as many institutions and organisations are not prepared to spend an extra dollar after securing server and personal computers for their users or employees. As clearly outlined by Qian Zhu et.al (2010), in the statement, “The goal should be to keep the resource budget to a minimum, while meeting an application’s needs.” Alexandras Paramythis et.al(2005) also states that, “The development of e-learning material is costly,” spells a great need to reduce the cost effect in the development process.

Guidelines and Models on e-Learning support infrastructures were reviewed. Meaningful guidelines were identified as a necessary prerequisite to preparing scalable e-Learning environments that are both interactive and resource efficient. However, the guidelines and models, although useful in part, tended to concentrate on the needs of end users, exposing the developers of such e-learning systems a big challenge of having to worry on themselves how best to improve and deploy e-learning portals to a pool of end users who have ever dynamic application requisites, hence varying QoS variations, whereas algorithms such as those suggested
by A. Capone et.al (2006), addresses the QoS variables, however this research will select the storage component mainly.

A crucial issue for the development of e-Learning systems is that recommendations on future directions ought to be based on research using valid and reliable methods of data collection. Unfortunately, empirical data on e-learning architectures are few and far between; for example, there is little research based on how best to improve e-learning infrastructures that are scalable in nature meeting the resource efficient usage test.

In other words, there is a continuing need for research in the section of architectures that can improve e-learning availability, effectiveness and improvements as a mandatory requirement to address this dynamic and viable research field. The suggested architectures especially cloud computing are still too broad to understand for easy of adoption. It is in the interest of this research to therefore look at a single layer and implement it to address the most overlooked yet key aspect of learning which enables e-learning availability – the development and hosting stage. It is at that stage that the cloud computing architecture if well synthesised into precise layer constituents and their functionality, the IAAS layer will be of key interest to this research.

The research aim outlined in section 1.3 of chapter 1, and the aforementioned review of literature supports the need to propose a possible architecture that aid hosting of multimedia content. To arrive at a deeper understanding of why addressing the storage concern, a revisit of the definition and description of multimedia content given in section 2.1 of this chapter will present as one among the setbacks why instead of implementing interactive e-learning based systems, most institutions will resort to run merely a basic informative e-learning portal, because the cost of securing extra hardware is considered with reservations and deemed restrictive in nature.

2.9 Chapter Summary
The Literature review was mainly focused on understudying work done by others which has a direct impact on the focus of this research. The Chapter mainly concentrated on defining key terms, analysing similar architectures, assessed the resource allocation algorithm selected, explained the simulator and justified the choice for a simulator among other options.
CHAPTER 3: PROPOSED ARCHITECTURE

3.1 Introduction

This is one of the brief yet crucial chapter for this research, for it outlines the proposed architecture, describes the concepts behind the functionality of the proposed architecture. It is after defining this architecture that the next section designs the research strategy to be used for testing the functionality and feasibility of this architecture.

In embarking on the design and description of the architecture, this section is partly addressing research objective 3, as outlined in section 1.3 of this research paper. Of particular importance is its contribution to the overall research aim, which thus read: “Is there an architecture that can be used to host e-learning systems built with multimedia content to enhance interactivity in learning circles?” The major functionality attributes of this proposed architecture are described and a resource allocation mechanism to manage, monitor and control resource requests is explained.

3.2 The Proposed Architecture

The architecture being proposed by this research is in light of building a cloud computing IAAS, architecture making use of the pool of available high computing power say in an institution setup where one can have the privilege of say more than hundred (100) computers in operation at any given instance. It is after a painful observation that many organizations are spending much financial resources to secure more servers to build up storage space. As that might be the case, the researcher, is advancing the idea that, there is idle space on these personal computers in networks, take for instance a user who has a machine with 250GB, rarely does that user use even a quarter of that storage space if he/she is using that computer for normal business operations. For that space not in use, if one can borrow half of it and do the same to all other computers, how much storage space can one build?

Figure 3.1 is a sample representation of the idea on paper. After such an initial design, what needs to be explored further is how the storage space is going to be managed? Where will it be managed from? Who will be managing storage? Why do one need the space?
Proposed Architecture

Figure 3.1 Proposed architecture diagram

In the next section of this chapter, definition of the functionality of such architecture is advanced. As depicted in the diagram above, resources (i.e. disk space) is being forwarded to a central computer labeled “data center”, which implies, this is the hub of this setup. Given such a scenario, one now need to strategize on how best to manage this pool of storage space and subsequently be in a position to allocate it to requesting applications in this instance, users are specifically concerned about creating a pool of storage capacity and processing power to be in a position to host an e-learning portal that can incorporate multimedia content to enhance interactivity in the learning environment as already reviewed under Chapter 2’s findings.
3.3 The Functionality of the Proposed Architecture

The functionality of this proposed architecture mainly revolves around the datacenter activities in acquiring, managing and allocating disk space to application requests in the operability of the e-learning system. It will be noble to have an algorithm that efficiently manages the pool of resources at the datacenter. Since the datacenter will be the main control board, the Nodes/personal Computers will communicate through the datacenter. It is the datacenter’s responsibility to have an update status of each and every node so that at every request for resource allocation it can route the request to a node that has the necessary resources to host that request. Basically there are a set of activities that transpires at the node and the rest of core activities are centrally executed at the datacenter, all the same the monitoring and management of those activities is centrally done at the datacenter.

The Node activities that the datacenter monitors can be summarized as in Fig 3.2.

![Node Activities Diagram](image-url)
These activities will be monitored at the datacenter; it is not the node’s responsibility to execute these processes. As a consequence of this setup, there is a possibility of a pool of resources at the datacenter that need to be monitored in terms of their state at any given instance. It is also the responsibility of the datacenter to populate its task bank with statuses of each task. Ideally the tasks can either be in a state of “unassigned” implying it will be waiting in the queue for execution. In another state, a task can either be “allocated,” which implies it would have been allocated to a specific node, in the allocated state, the node may be busy or taking forever to finish execution of its tasks, there may have to be “migration” decisions to reassign it to another node, if it is successfully find a processing slot, it will be in the “running” state. A successful processed task should a have “commit” state.

3.4 Research Methods

This section discusses and justifies the research strategy and data collection techniques (Simulation) to be adopted in the empirical collection of data for this study. Details on the framework for analysis of the qualitative data are provided.

Chapter 2 identified a gap in existing research in that there was ample evidence on the need for a scalable architecture that narrows its focus to the implementation of cost effective architectures in e-learning based infrastructure.

Importantly, although a focus of the empirical work will be to gather results on the feasibility of the proposed architecture in a cloud computing e-learning based architecture to cope with e-Learning application requirements, results will also be collected on scalability of the proposed architecture. By comparing theory with practice – i.e. comparing the Literature Review findings with the (simulated results) ‘real world’ – the researcher will be better positioned to pass recommendations to the educational community of the existence of a scalable architecture that can address part of the e-learning challenges highlighted which surrounds the implementation of e-Learning systems. This section – Research Methods – will provide the details of the research strategy adopted to address the research issues identified in previous chapters, together with the means of collecting data for analysis and the analysis approach to be adopted.
3.5 Research Design and Methodology

This research is going to halt at its results after implementing an algorithm that allocates resources in a cloud computing architecture setup at the datacenter which is the hub of what happens within the confines of such architecture. It is the understanding of this research that the performance of the resource allocator algorithm will give a fair analysis of the viability of the proposed architecture. However not every variable can be tested by the approach employed in this context, as such certain variables will be held constant and assumed to be operating at normal working graduations. The main variables to be held constant will be the network bandwidth, machine processing power and uptime and downtime of machines is presumed and set at predictable intervals.

The cloudsim Simulator is going to be used as the main tool for the simulation of the algorithm for resource allocation, which dynamically allocate resource, why dynamic? The selection of a dynamic approach to resource allocation is in light of the fact that, user demands and intervals for resource request and apportionment is not uniform; it varies from time to time.

3.6 Approach to data Analysis

A resource allocation algorithm that dynamically allocates resources is going to be advanced to the CloudSim tool; its performance shall form the basis for data collection in the form of graphical representation of variables being tested per given test case. It is an analysis of the graphical performance of each test case against defined variables that this research will be able to pass conclusions thereof. Figure 3.3 below illustrates graphically the approach that will be adopted to analyze data from the simulation to be conducted.
To reach at the final conclusion, at least a point where the author can safely conclude that the research has been successful or not, evaluation of the simulation results based on normal functionality trends of datacenter as revealed in work covered by previous researchers will be executed.

Figure 3.4 Cloudlet processing update process
The simulation dataflow (Figure 3.4) also summarises the functionality of the data center broker and the various processes that run between the two. As such the output of the simulation are mainly centred on what transpires at the data enter as it receives requests, from end nodes and how it apportions space as it receives leases from hosts i.e. personal computers.

![Simulation data flow](image)

*Figure 3.5 Simulation data flow.*

### 3.7 Chapter Summary

This is one of the most crucial chapters of this research as outlined in the introductory part of the chapter. The main thrust of this chapter was to expose the researcher’s ideas in the form of the proposed architecture, as well as detailing the functionality of such architecture. The major section of this chapter which was mainly concerned with defining the route the research was going to be handled along in light of the methodology to be employed as outlined under: Research Design and Methodology section. A well paved route as to how results were going to be solicited and analyzed was central to the focus of this chapter. The Chapter is wrapped by giving an approach to data analysis which lay bare the technique for processing results once availed.
CHAPTER 4: FINDINGS, ANALYSIS AND SYNTHESIS

4.1 Introduction

This chapter reports on the findings from the implementation through simulation of the proposed architecture’s functionality. In the first instance, the results of the simulation are discussed. It is after the section on the e-learning architecture findings description that analysis and synthesis takes place, in terms of not only comparing and contrasting the findings from both existing and proposed architecture – findings are compared and contrasted against the findings in the literature review. Thus, this chapter describes, analyzes and synthesizes the research result and the findings from the literature review as well.

This is the section of the research paper where the final decisions are reached based on the findings from the simulation done for the functionality of the proposed architecture. It is the results which forms the basis for a guided recommendation to the e-learning community that this research is going to be wrapped up on. In essence, this is the most crucial milestone for this research pilgrimage. This chapter reveals the findings after implementing the research strategy described in Chapter 3 Research methods. The research concentrates on the functionality of the proposed architecture, the various activities that ensue at the datacenter gives this research a yardstick with which to measure the feasibility and viability of this research to the e-learning community at large. The output of this chapter will feed into the next chapter and ultimately meet the last research objective as outlined by the research objectives formulated in Chapter 1.

4.2 Simulation Results and Discussion

It is the intension of this section to reveal the results of the simulation done using the research strategy outlined in Chapter 3. A discussion for each displayed result will be engaged in, especially in light of the overall research aim. Mainly the graphical displays presented in the following review are the main output from the simulation done using the CloudSim simulator.
As represented in the Graph of Figure 4.1, the nature of distribution patterns for requested CPUs, Used CPUs and available CPUs projected over a period of an hour, is such that there may be a high demand for CPUs during the initial 10-20 minutes once the CPUs to the requested number are gathered, one will have a normal performance in resource scheduling at the datacenter for any demand for CPUs in this instance, the main agenda is to build up as much storage and processing power as possible.

This seemingly depicts a normal distribution graph, in essence, relating this graph to Graph in figure 4.1, during the 10-20 minute peak period the average machine usage is up because of the high concentration of jobs at the datacenter.
Figure 4.3: Graph of Number of Waiting /Running Jobs

As in the previous graphs, the graph in Figure 4.3 depicts the same nature of functionality at the datacenter revealing almost the same trend. There is generally a sizeable number of waiting jobs during the same 10-20 minute peak range spelling a deficiency in availability of resources.

Figure 4.4: Graph of Virtual Machine Creation (%)

This display is somewhat devoid of other previous representations, for the fact that, it now displays the concentration of creation of virtual machines, at Host machines, to meet the resource processing requests at the datacenter. It is not easy to follow the pattern formulated here as it is highly clustered in nature. Basically Virtual machines are created as and when needed, at the same time, they are destroyed as and when they have finished processing jobs assigned to them. As virtual machines are highly depended on host machines, there is a general trend that such virtual machines’ viability highly depends on the availability of a host, thus why it is important to observe the functionality of this variable, how it operates within the vicinity of the hosting machine.
4.3 Analysis and Synthesis of Results

The simulation results from the expected functionality of a normal cloud computing architecture based on results of typical simulations using the CloudSim simulator are normal. The big challenge however, is the existence of testing metrics to quantify the results to reach a precise conclusion. From a qualitative analysis, the results are averagely in a functional order for the set of variables that were advanced for this typical simulation where concentration was mainly channeled towards the allocation, execution, virtualization and host usage. If one, as per the requirement of this research, produce an output for use to the e-learning community under the recommendations section of the next chapter of this paper, one would however advise and strongly recommend further tests using any viable tools of the same architectural functionality advancing a variation of variables not only limited to what this research might have sampled in reaching its conclusion. The architecture may perform differently under different network setups, especially considering the fact that network bandwidth as one of the determinant factors of
functionality that can have enormous contributions either negatively or to a certain screwed direction was not tested for lack of proper technology for a testing environment, the existing simulators for cloud computing that supports both a test for virtualization and network topology are expensive to implement and in most cases not easily accessible to the learning community.

If one were the pass a rating of the results of this simulation based on the qualitative analysis, one will graduate our confidence rate at 60%, implying the results reliability is set at the same rate, for a number of solid reasons, some already highlighted above. A simulation and a real world setup are two unique environments, simulations are easy to manipulate and results so produced will have a partiality towards the test variable being tested, this is a different scenario with real operational environments were all the environmental variables imposes their existence at untimed intervals.

Another factor which also worries could be the shift of trend of results is the latency rate, for the purposes of this research such a variable was not tested, however its contribution to the overall performance of the proposed architecture is one that cannot completely be ignored. Therefore, there is still room to improve the decision points reached by this research if better metrics are advanced and better tools for simulation are also used. (For a snippet view of the simulation results, see Appendix B, Page 63)

### 4.4 Chapter Summary

This chapter was mainly concerned with positioning the whole research focus into perspective as it dealt with the research output and gave the researcher a thoughtful moment to pass a conclusion of the findings of the research. The chapter looked at simulation results and discussed the very results in line with the outlined research objective already formulated in Chapter 1. The Chapter then analyzed the same results in light of the findings from the literature review backed by the defined research objectives in Chapter 1.
CHAPTER 5: CONCLUSION AND FUTURE WORK

5.1 Introduction

This chapter revisits the overall aim and specific objectives of this research study. The findings are summarized and related to the specific research objectives: Exploration of the e-learning architectures. Implementation of the proposed architecture through simulation. Conclusions from this research work are derived and linked to the research objectives, and based on these conclusions, recommendations are made. The limitations of this work are also highlighted. Importantly, the issue of managing the implementation of the recommendations is addressed. The contribution of this research to knowledge is clarified.

The overall aim of this research was to advance an exploration for an architecture that can be used to host e-learning systems built with multimedia content to enhance interactivity in learning circles.

This section will revisit the research objectives outlined above and in a nutshell to wrap up the findings of this research work to arrive at some conclusions. The previous chapter was widely looking at issues, to narrow down the focus a summary is now needed which is going to be presented in this chapter. Some recommendations along the same line of study in this field will be discussed, in terms of how to further the research potential in the field of e-learning. Importantly, the contribution of this research to the development of interactive e-learning platforms will be clarified. Also a reflection on the research process that was employed in this study is included. In adopting this structure, it is intended that the research work will be concluded so as to reflect on whether or not the objectives stated at the start of this research have been met, including consideration of the value of this study. Guidance will be offered on how this research work can be progressed.
5.2 Research Objectives: Summary of Findings and conclusions

This section will inform the reader of the findings and offer a view on what the research is outputting. Please note, these are personal observations by the researcher and may not be Turing correct until scientifically proven or otherwise.

5.2.1 Research objective 1: Explore e-learning architectures that support multimedia content.

From the literature review done and covered in Chapter 2, it is from the findings of the literature covered that architectures which support e-learning with multimedia content are a sizeable number. This leaves a whole lot of work to be done in this area, in a bid to enhance interactivity in e-learning based systems between course providers and the students. However there is a biased shift in looking at the entire e-learning atmosphere in a comprehensive nature, where in other cases some institutions or stakeholders view e-learning platforms as a waste of resources and an unworthy investment. Some of the challenges for lack of multimedia e-learning platforms are a commonly cited setback of cost, which envelop the other variables such as bandwidth, processing power and storage capacity of servers.

A lack of an agreed definition on e-learning is posing quite a challenge in advancing e-learning dimensions as they unfold despite the technological advances that floods the modern computer world. The majority seem to be battling with what e-learning is all about. After all has been said and done, one can conclude that, there are deterrence’s to hosting of scalable e-learning platforms that need to be addressed fully and logically, that will see a better equipped e-learning environment.

5.2.2 Research Objective 2: Critically assess the effectiveness of current e-learning architectures.

From the few e-learning architectures again exposed by the literature review findings, the general trend is such that most of them on the other hand are mainly focused on addressing didactic concerns. (Thomas, 2009) On the other extreme, there are either focused with the end product
where the tutor and student are key players in the e-learning ecosystem. Nonetheless less attention is being paid to the initial ground work thus needed for an e-learning system to be there – precisely, the developers of e-learning platforms are lacking full representation is most of the papers that are dwelling on key issues that affect either positively or negatively e-learning system operability and success thereof. Most worrying is the major factor that, there is assumed knowledge when proposing e-learning platforms – the assumed knowledge is reflected in the lack of detailed literature that covers the various options for architectures that institutions can employ to host e-learning platforms.

Based on some of these observations here, one can conclude that: the e-learning community and a pool of researchers still have a long way to go in soliciting detailed information on cost effective ways e-learning platforms can be build, hosted, run and maintained. There is enormous room for improvement here. The fact that most researchers keep hiding under the statement, “e-learning is fairly a new discipline in computing science and information systems,” deters the whole adventurous expertise in upcoming efforts to accept that well even more than a decade has passed, so many conference and papers have since been written on e-learning, and it is high time, to stop writing on the origins of e-learning but on the best ways to catapult it to the next development levels within the confines our resources

5.2.3 Research Objective 3: Propose and implement a possible architecture.

In proposing an architecture that could possibly be implemented to host e-learning platforms that supports multimedia content for the main aim of encouraging interactivity in the learning circles, it was after the pain of observing the still loops in researches being carried out in the e-learning vicinity, resources are being left idle and most researchers are proposing models that are resource hungry at the end of the day. For the great work that has been done for those who proposed the cloud computing avenue, there is still room to scale down the efforts and segment it to manageable models that can be implemented for individual levels at low to no cost rental charges. We conclude therefore that: there is still room to scale down on available options to cater for the low to no cost applications for the architectures available for hosting e-learning platforms.
From the findings of this research, especially during simulation of the proposed architecture, there is still a huge challenge to find a simulation platform that can be implemented to test the feasibility of cloud computing based architectures repeatedly. As a result the reliability of the results and recommendations that may be passed from simulations carried out using available simulators is still very skeptic in nature. We therefore conclude that, **research in the cloud computing architecture simulators is still very tentative and lacking on precision.**

It is therefore from the conclusions that have been highlighted in this section that the next section 6.3: **Recommendations** is going to be built. The recommendations are thus going to be based mainly on the conclusions whereas the conclusions were based on research findings as covered by this ending section.

### 5.3 Recommendations and Future Work.

Based on the conclusion from the findings in pursuit of research objective 1, as highlighted above: **there are deterrence’s to hosting of scalable e-learning platforms that need to be addressed fully and logically,** it is ideal to therefore recommend that e-learning system development, functionality and maintenance be approached in an inclusive manner such that any bottlenecks be addressed at the right levels within the whole lifecycle. We strongly recommend that researches in the development of e-learning architectures comprehensively exhaust the very architectures as well, it is biblically espoused that, a house build on sand will not stand the storm weather, in the same token e-learning system developers have a mandate to explore the best architectures for implementation of robust and dependable e-learning platforms. The benefits of being on the lookout for hindrances to effective e-learning implementation architectures are two fold in that security strategies are implemented precisely when they are needed and reliability of the developed systems will be scaled better.

Taking the conclusion passed under review of research finding of objective 2, in **Section 6.2.2 - the e-learning community and a pool of researchers still have a long way to go in soliciting detailed information on cost effective ways e-learning platforms can be build, hosted, run and maintained,** one can recommend for the need to channel research focus on cost effective ways to
develop and deploy e-learning based systems. The benefits of imploring such avenues are in light of increasing coverage and awareness to the greater world, in the understanding that e-learning is there as a vehicle to enhance learning in the best way possible. The more options one can explore and implement the better the educational system at all levels is cushioned and heightened.

There is still room to scale down on available options to cater for the low to no cost applications for the architectures available for hosting e-learning platforms. In as much as there is greater appreciation of the wide efforts that researchers have devoted in scavenging at every possible way e-learning platforms can be hosted for easy of access 24/7/365, the need to refine all these efforts to produce finer pieces of work still remain a mandate rather than an option, it is therefore a recommendation from this research that, there be further researches along these lines. The main advantage of scaling down the focus being an opportunity to integrate the core aspects of the available architecture to construct a robust shell that can protectively house e-learning sensitive skeletal designs.

It is in the interest of this research as also observed under research objective 3, that it has been concluded: research in the cloud computing architecture simulators is still very tentative and lacking in precision. Following this conclusion, one can find it ideal to suggest that, simulators that will aid in testing and validation of cloud computing architectures be researched on further.

In the interest of encouraging future researches in this filed of e-learning architectures and cloud computing architectures, one can present the following questions as presented by other researchers as well, specifically within the context of cloud computing hosting.

- But are all applications ready to be moved to the cloud? At what cost?
- New technologies create new challenges, and when it comes to cloud computing, a key issue remains unsolved: What will data governance look like in a cloud enabled world?
- How can organizations guarantee that their users will quickly and willingly move to a cloud-based business application infrastructure? (Al-Zoube, 2009)
Figure 5.1: Cloud-Enabled business applications

- How far have the key elements of this Exceed on Demand been exhausted: fast and easy access to cloud-enabled business applications?

5.4 Limitations and Potential Problems

There are limitations to this research, as well as the implementation of the data analysis technique employed. The results of this research cannot be generalized to the wider research community. For the purposes of this research to address the limitation of generalizations, a tested and tried research strategy was used, appealing to the concept of relatability rather than generalizability, although not immediate, can take place over a period of time-incremental generalizability- as more empirical researches are implemented.
Quantifying the performance of provisioning (scheduling and allocation) policies in a real Cloud computing environment (Amazon EC2, Microsoft Azure, Google App Engine) for different application models under transient conditions is extremely challenging because:

(i) Clouds exhibit varying demands, supply patterns, system sizes, and resources (hardware, software, network);
(ii) users have heterogeneous, dynamic, and competing QoS requirements; and
(iii) Applications have varying performance, workload and dynamic application scaling requirements. (Rodrigo N. Calheiros, 2011)

As Cloud computing is still an emerging paradigm for distributed computing, there is a lack of defined standards, tools and methods that can efficiently tackle the infrastructure and application level complexities. It is therefore one of the greatest huddle for this research, even after settling for one simulator- CloudSim.

For progress sake and in light of addressing some of the setback highlighted here, this research advanced some assumptions which saw holding of some variables to constant, though in a practical setup will not be ideal. For instance an assumption that the bandwidth will be good and hold at constant. Leasing of space from personal computers was also based on the assumption that the very users of those PCs will not switch off the computers. However further variables such as power consumption were left at standstill.

5.5 Overall Concluding Note:
The author safely conclude that the objectives set for this research were all met; however recommendations for further studies in improvement of simulation tools for a better output of researches of this nature is emphasized. Before implementing this proposed architecture the author recommend for a test of all other variables herein not tested.
Bibliography


APPENDIX A: Directory Structure of CloudSim Toolkit 2.0

Directory Structure of CloudSim Toolkit 2.0
---------------------------------------------

$CLOUDSIM/ -- top level CloudSim directory
    classes/  -- The CloudSim class files
    doc/     -- CloudSim API Documentation
    examples/ -- CloudSim examples and Class Diagram
    jar/      -- CloudSim jar archives
    lib/      -- external libraries
    src/      -- CloudSim source code
    test      -- CloudSim unit tests

Software Requirements : Java version 1.6 or newer
-----------------
CloudSim has been tested and ran on Sun's Java version 1.6.0 or newer.
Older versions of Java are not compatible.
If you have non-Sun Java version, such as gcj or J++, they may not be
compatible.
You also need to install Ant to compile CloudSim (explained in more details
later).

Installation and Running CloudSim Toolkit
---------------------------------------------
You just need to unpack the CloudSim file to install.
If you want to remove CloudSim, then remove the whole $CLOUDSIM directory.
NOTE: You do not need to compile CloudSim source code. The JAR file is
provided to compile and to run CloudSim applications.
* cloudsim.jar -- contains CloudSim class files only

To compile and run CloudSim applications, do the following step:
1) Go the directory where the CloudSim's Examples reside
   In Unix or Linux: cd $CLOUDSIM/examples/
   In Windows: cd %CLOUDSIM%\examples\
2) Compile the Java source file
   In Unix or Linux: javac -classpath $CLOUDSIM/jar/cloudsim-2.0.jar:.
   cloudsim/examples/CloudSimExampleX.java
   In Windows: javac -classpath %CLOUDSIM%\jar\cloudsim-2.0.jar:.
   cloudsim\examples\CloudSimExampleX.java
3) Running the Java class file
   In Unix or Linux: java -classpath $CLOUDSIM/jar/cloudsim-2.0.jar:.
   cloudsim.examples.CloudSimExampleX
   In Windows: java -classpath %CLOUDSIM%\jar\cloudsim-2.0.jar:.
   cloudsim.examples.CloudSimExampleX
NOTE:
* $CLOUDSIM or %CLOUDSIM% is the location of the CloudSim Toolkit package.
Learning CloudSim
------------------
To understand how to use CloudSim, please go through the examples provided
in the $CLOUDSIM/examples/ directory.
Compiling CloudSim : Using Ant
-----------------------------
This release contains a simple buildfile for compiling CloudSim classes.
APPENDIX B: SNIPPETS OF THE SIMULATION

Opening: C:\Users\Attlee\Documents\NetBeansProjects\JavaApplication1\dataset\auvergrid.gwf.machines
Starting the CloudSim-Alea-2.1
Starting CloudSim version 5.0
Entities started.
CloudResource/Host count: 6
0.2015627461970667 next
List of resources:
id = 14, name = clrlgce032, CPUs = 186, CPU rating = 1, machines = 93, props=
id = 6, name = clrlgce010, CPUs = 112, CPU rating = 1, machines = 56, props=
id = 10, name = clrlgce021, CPUs = 84, CPU rating = 1, machines = 42, props=
id = 22, name = obc4, CPUs = 56, CPU rating = 1, machines = 28, props=
id = 26, name = adm5, CPUs = 48, CPU rating = 1, machines = 24, props=
id = 18, name = iut153, CPUs = 38, CPU rating = 1, machines = 19, props=
Total available MIPS power = 524.0 MIPS in 524.0 CPUs
>>> 10 so far arrived, in queue = 1 jobs, at time = 4732
>>> 20 so far arrived, in queue = 1 jobs, at time = 159039
>>> 30 so far arrived, in queue = 1 jobs, at time = 204220
>>> 4680 so far arrived, in queue = 1 jobs, at time = 1294654
>>> 4690 so far arrived, in queue = 1 jobs, at time = 1296937
>>> 4700 so far arrived, in queue = 1 jobs, at time = 1297180
>>> 4710 so far arrived, in queue = 1 jobs, at time = 1297477
>>> 4720 so far arrived, in queue = 1 jobs, at time = 1297720
>>> 4730 so far arrived, in queue = 1 jobs, at time = 1298017
>>> 4740 so far arrived, in queue = 1 jobs, at time = 1298447
>>> 4750 so far arrived, in queue = 1 jobs, at time = 1298802
>>> 4760 so far arrived, in queue = 1 jobs, at time = 1299137
>>> 4770 so far arrived, in queue = 1 jobs, at time = 1299437
>>> 4780 so far arrived, in queue = 1 jobs, at time = 1299676
>>> 4790 so far arrived, in queue = 1 jobs, at time = 1307620
>>> 4800 so far arrived, in queue = 1 jobs, at time = 1312234
>>> 4810 so far arrived, in queue = 1 jobs, at time = 1323968
>>> 4820 so far arrived, in queue = 1 jobs, at time = 1331429
>>> 4830 so far arrived, in queue = 1 jobs, at time = 1335348
>>> 4840 so far arrived, in queue = 1 jobs, at time = 1337609
>>> 4850 so far arrived, in queue = 1 jobs, at time = 1339372
>>> 4860 so far arrived, in queue = 1 jobs, at time = 1340165
>>> 4870 so far arrived, in queue = 1 jobs, at time = 1341947
>>> 4880 so far arrived, in queue = 1 jobs, at time = 1343022
>>> 4890 so far arrived, in queue = 1 jobs, at time = 1343077
>>> 4900 so far arrived, in queue = 1 jobs, at time = 1343138
>>> 4910 so far arrived, in queue = 1 jobs, at time = 1343149
>>> 4920 so far arrived, in queue = 1 jobs, at time = 1343197
>>> 4930 so far arrived, in queue = 1 jobs, at time = 1343211
>>> 4940 so far arrived, in queue = 1 jobs, at time = 1343271
>>> 4950 so far arrived, in queue = 1 jobs, at time = 1343327
>>> 4960 so far arrived, in queue = 1 jobs, at time = 1343378
>>> 4970 so far arrived, in queue = 1 jobs, at time = 1343412
>>> 4980 so far arrived, in queue = 1 jobs, at time = 1344249
>>> 4990 so far arrived, in queue = 1 jobs, at time = 1345539
End of submission... 4993

Machine usage = 14.14 % (used time/avail time) failures included. 0.0 % of failures.
Weighted machine usage = 14.14 % (used MIPS/avail MIPS) failures included. 0.0 % of failures.

0 = failed; Collected = Success + Failed : 4994 = 4994+0 | non-delayed = 4959
Total sched. time = 2076.0 ms | Makespan: 1473682.0239999998 active/avail=0.0 / 524.0
CHECK awsd: 1.0, Check slowdown=1.0001838799753695 -> 4994.918296596996/4994
Machine usage = 14.14 % 208371.35714503768/1473667.5391999998 active/avail=0.0 / 524.0

Rough slowdown = (avg. wait time + avg. runtime) / avg. runtime = 1.000000457382264
Avg. runtime = 21863.55 seconds.
Shuting down the auvergrid.gwf_JobLoader... with: 1006 fails.
Sim_system: No more future events
Gathering simulation data.
clrLcge021 wusage = 0.0%, usage = 0.0%
iut153  wusage = 0.0%, usage = 0.0%
clrLcge032: Warning - Gridlet #5999 owned by Alea_2.1_scheduler is already completed/finished.
Therefore, it is not being executed again

clrLcge010: Warning - Gridlet #5987 owned by Alea_2.1_scheduler is already completed/finished.
Therefore, it is not being executed again

obc4  wusage = 0.0%, usage = 0.0%
adm5  wusage = 0.0%, usage = 0.0%
Simulation completed.
==================== END OF TEST 1 =====================
-----------------------------------------------
Now scheduling 12000 jobs by: FCFS, using blue_12000.swf data set.
.
.
.
.
.
.
.
CloudResource/Host count: 1
0.2015627461970667 next
List of resources:
id = 6, name = blue_gene0, CPUs = 1152, CPU rating = 1, machines = 144, props=
Total available MIPS power = 1152.0 MIPS in 1152.0 CPUs
Shuting down - last gridlet = 12000 of 12000
>>> 10730 so far arrived, in queue = 1 jobs, at time = 4293530
End of submission... 10731

-----------------------------------------------------------------------
Machine usage = 66.52 % (used time/avail time) failures included. 0.0 % of failures.
Weighted machine usage = 66.51 % (used MIPS/avail MIPS) failures included. 0.0 % of failures.
-----------------------------------------------------------------------
0 = failed; Collected = Success + Failed : 10731 = 10731+0 | non-delayed = 2464
Total sched. time = 57352.0 ms | Makespan: 4357182.008
CHECK awsd: 8.612, Check slowdown=517.742619124589 -> 5555896.045825965/10731
Machine usage = 66.52 % 2898366.552388827/4357164.1256 active/avail=0.0 / 1152.0
-----------------------------------------------------------------------
Rough slowdown = (avg. wait time + avg. runtime) / avg. runtime = 14.75456537821857
Avg. runtime = 3595.54 seconds.
Shuting down the blue_12000.swf_PWALoader... with: 1269 fails
Sim_system: No more future events
Gathering simulation data.
blue_gene0: Warning - Gridlet #12477 owned by Alea_2.1_scheduler is already completed/finished.
Therefore, it is not being executed again

Simulation completed.

============= END OF TEST 1 ===============
APPENDIX C: TABLES

TABLE 7.1: Categorization of related work on resource consolidation in multiple server data centers.

<table>
<thead>
<tr>
<th></th>
<th>Non-Virtualised</th>
<th>Virtualised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Utilisation</td>
<td>-</td>
<td>Almeida et.al., Wood et.al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bobroff et.al., Hermenier et.al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wang et.al., Van et.al.</td>
</tr>
<tr>
<td>Migrations Cost</td>
<td>-</td>
<td>Hermenier et.al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Van et.al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Khanna et.al.</td>
</tr>
<tr>
<td>Global Configuration</td>
<td>Walsh et.al.;</td>
<td>Almeida et.al., Wood et.al.</td>
</tr>
<tr>
<td></td>
<td>Tesauro et.al.</td>
<td>Bobroff et.al., Hermenier et.al.</td>
</tr>
<tr>
<td></td>
<td>Bennani et. Al.</td>
<td>Wang et.al., Van et.al.</td>
</tr>
<tr>
<td></td>
<td>Chess et.al.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tesauro, Das et.al.</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.2 The Ten Privacy Principles Used in Canada

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Accountability</td>
<td>An organization is responsible for personal information under its control and shall designate an individual or individuals accountable for the organization's compliance with the privacy principles.</td>
</tr>
<tr>
<td>2. Identifying Purposes</td>
<td>The purposes for which personal information is collected shall be identified by the organization at or before the time the information is collected.</td>
</tr>
<tr>
<td>3. Consent</td>
<td>The knowledge and consent of the individual are required for the collection, use or disclosure of personal information, except when inappropriate.</td>
</tr>
<tr>
<td>4. Limiting Collection</td>
<td>The collection of personal information shall be limited to that which is necessary for the purposes identified by the organization. Information shall be collected by fair and lawful means.</td>
</tr>
<tr>
<td>5. Limiting Use, Disclosure, and Retention</td>
<td>Personal information shall not be used or disclosed for purposes other than those for which it was collected, except with the consent of the individual or as required by the law. In addition, personal information shall be retained only as long as necessary for fulfillment of those purposes.</td>
</tr>
<tr>
<td>6. Accuracy</td>
<td>Personal information shall be as accurate, complete, and up-to-date as is necessary for the purposes for which it is to be used.</td>
</tr>
<tr>
<td>7. Safeguards</td>
<td>Security safeguards appropriate to the sensitivity of the information shall be used to protect personal information.</td>
</tr>
<tr>
<td>8. Openness</td>
<td>An organization shall make readily available to individuals specific information about its policies and practices relating to the management of personal information.</td>
</tr>
<tr>
<td>9. Individual Access</td>
<td>Upon request, an individual shall be informed of the existence, use and disclosure of his or her personal information and shall be given access to that information. An individual shall be able to challenge the accuracy, completeness, and sensitivity of the information and have it amended as appropriate.</td>
</tr>
<tr>
<td>10. Challenging Compliance</td>
<td>An individual shall be able to address a challenge concerning compliance with the above principles to the designated individual or individuals accountable for the organization's compliance.</td>
</tr>
</tbody>
</table>

Author: Yazig Onat Yazir et. al.

Author: El-Khatib, K., Korba, L., Xu, Y., and Yee, G. October-December 2003
Table 7.3 Average fees for cloud computing services ...(Rodrigo N. Calheiros, 2011)

<table>
<thead>
<tr>
<th>Provider</th>
<th>Average CPU cost (per hour)</th>
<th>Average bandwidth cost (per GB/month)</th>
<th>Average storage cost (per GB/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon</td>
<td>0.11$</td>
<td>0.12</td>
<td>0.15$</td>
</tr>
<tr>
<td>Google</td>
<td>0.10$</td>
<td>0.11$</td>
<td>0.15$</td>
</tr>
<tr>
<td>Microsoft</td>
<td>0.12$</td>
<td>0.125$</td>
<td>0.15$</td>
</tr>
</tbody>
</table>