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## Full Paper

# PROSPECTS OF CLOUD COMPUTING AS SAFE HAVEN FOR IMPROVING MATHEMATICS EDUCATION IN NIGERIA TERTIARY INSTITUTIONS

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### ABSTRACT

#### Abstract

Historically, mathematics education has been bedeviled by the deployment of instructional strategies that seriously stunt the growth of students. Methodologies and approaches of instructional delivery in tertiary institutions have raised the need for technological augmentation for both students and mathematics educators. Cloud computing yield itself to this quest by strengthening individualized learning via unrestricted access to infrastructure, platforms, content, and powerful web-based tools from anywhere within the private cloud architecture adopted by tertiary institutions in Nigeria. This paper considers broad safety concerns of this technological intervention and the prospects of improving mathematics education in tertiary institutions in Nigeria.

**KEYWORDS:** MATHEMATICS EDUCATION, CLOUD COMPUTING, DATA SECURITY

### 1.0 INTRODUCTION

Mathematics education is an umbrella term that encompasses all aspects of learning and teaching mathematics in schools and in other settings. Mathematics itself is an aid to representing and attempting to resolve problem situations in all disciplines. According to Odili (2012) it is a powerful means of communication, an intellectual endeavour and a mode of thinking. Mathematics is a discipline through which students can develop their ability to appreciate the beauty of nature, think logically and make sound judgement. Mathematics education is considered as an intersection with the nature of mathematics as a discipline. With focus on teacher education, mathematics education considers the design, implementation and effects of curriculum and instructional interventions; and contemporary developments in learning theories and technologies.

Technology, broadly understood, has been transforming human life in one way or another for thousands of years. But in the computer age, the pace of technological change is very rapid, altering schooling, work and social lives in ways that have significant consequences for young people (Craig, 2009). In rethinking education to cope with these changes at the threshold of the twenty-first century, innovation and research are indispensable tools. Failure to innovate, by and large, means repeating yesterday's educational programmes and strategies tomorrow (Raja, 2002). The society which education is meant to sustain is becoming transformed by trend such as automation, globalization, workplace culture and personal responsibility.

Within the demands of the time, both the education system and the educational process must be amenable. This calls for a fundamental qualitative transformation of

education in terms of its content, methods and outcomes. Education should seek to inculcate skills that are aimed at accelerating technological change, rapidly accumulating knowledge, increasing global competition and rising workforce capabilities (Partnership for 21<sup>st</sup> Century Skills, 2002). Schools must equip students who will ultimately spend their adult lives in a multitasking, multifaceted, technology-driven, diverse and vibrant world. The reality on ground has made it imperative for the education system to be more strategic, aggressive and effective in preparing students to succeed and prosper. Educational institutions must rethink what, but even more important, how and where we learn (Innovation Unit, 2014).

Although it is clear that technology is not the solution to present day education (Lokesh, 2013), utilizing emerging technologies to provide expanded learning opportunities is critical to the success of future generations. The level of penetration of ICT among students signals more than a change in pedagogy; it suggests a change in the very meaning and nature of mathematics education itself (Italiano, 2014). Schools all over the world are becoming an integral part of the broadband and technological transformation, harnessing the potentials of technology to drive and empower more personalized mathematics learning.

One of the specific ways technology is enhancing present day mathematics teaching and learning is through the utilization of the cloud. The cloud is a set of hardware, networks, storage, services, and interfaces that enable the delivery of computing as a service (Hurwitz, Bloor, Kaufman, & Halper, 2010). Cloud services include the delivery of software, infrastructure and storage over the internet, reducing cost and providing flexibility and mobility (Kovachev, Cao, & Klamma, 2011). These services are delivered via the internet from high-specification data centres in locations remote from the end user.

Broadly, the cloud can be seen as an on-demand access to computer services, applications, network and data anywhere (Powell, 2009). In an educational institution,

the cloud provides students with standard internet access that promotes the use of heterogeneous thin or thick client platforms (e.g. mobile phones, laptops, and tablets). Students make use of several self-services by connecting to wireless access points spread across their school. This has become a modern tool, a way of fact-based learning which allows students to do a lot of research using the web and various tools (Lokesh, 2014). In the process, students' critical and literacy skills are enhanced.

Active utilization of cloud services provided by educational institutions has grown in importance as a result of a new genre of students with learning needs vastly different from their predecessors (Thomas, 2011). Present day students require increase network access to sustain their culture of learning, leisure and social interaction. The computing power provided by the cloud avails the opportunity to extend students' mathematics learning beyond the walls of the classroom, thereby offering the learner greater participation and control of the learning process. Much flexibility, as provided by the availability of cloud services in institutions of higher learning, especially universities, is needed particularly in the teaching and learning of mathematics.

## 2.0 LITERATURE REVIEW

The review of related literature is done according to the following sub-headings, namely, the educational cloud, essential characteristics, cloud service models, cloud deployment models, the wireless network technologies in tertiary institutions, and cloud architecture for tertiary institutions.

### The Educational Cloud

According to the National Institute of Standards and Technology (NIST) (as cited in GTSI, 2009), cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be provided with minimal service provider effort. Typically, cloud services run in a web browser requiring the user to have only basic components while enjoying high speed, bandwidth and computing power. This

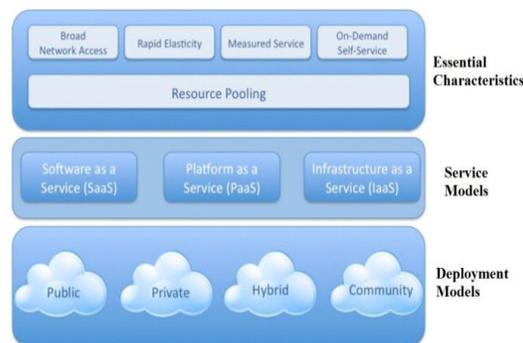
simplicity is why the emergence of cloud services is fundamentally shifting the economics of IT-based businesses (Harms & Yamartino, 2010).

Education has not remained unaware of this trend in migration to the cloud (Niharika, Lavanya, Murthy & Satya Sai Kumar, 2012). Presently, virtualized resources are being provided to educational institution over the internet, without users having knowledge of, expertise in, or control over the technology infrastructure. More students are enriching their educational experience daily through network access provided by private cloud services.

To grasp the extent of utilization of cloud services in education, it is important to briefly study the acceptable model of cloud computing.

**Figure 1:** NIST Visual Model of Cloud Computing Definition (Source: Niharika et al, 2012)

### Essential Characteristics



Most commentators on cloud computing agree on five key characteristics

- i. **Broad Network Access:** Services are provided over the network and accessed through standard mechanism.
- ii. **Rapid Elasticity:** The cloud gives the user the impression that the services are infinitely scalable. The service needs to be available all the time and it has to be designed to scale upward for high periods and downward for lighter ones (Hurwitz et al, 2010).
- iii. **Measured Service:** A cloud environment has built-in system that

bills users. In educational institutions such as the public universities in Benue State, students are given a number of hours daily to access the cloud, logging in with their user accounts as created on the university portal after payment of tuition fees.

- iv. **On-Demand Self-Service:** The cloud allows the user to request an amount of computing facility needed automatically, without requiring direct human interaction with a service provider.
- v. **Resource Pooling:** Computing services such as storage, processing, network, bandwidth, and virtual machines are dynamically assigned and reassigned according to the user's demand.

### Cloud Service Models

Cloud service delivery is divided into three models. They are infrastructure as a service, platform as a service, and software as a service. Infrastructure as a Service (IaaS) is the delivery of computer hardware for customized needs of the user. Such computer hardware include resources like servers, networking technology, storage, and data centre space. Educational institutions benefit maximally from networking technology (wireless network) and access to servers.

Platform as a Service (PaaS) is the capability provided to the user to deploy onto the cloud user-created or acquired applications created using programming languages and tools supported by the provider.

Software as a Service (SaaS) implies the provision of applications which are accessible to users from various client devices through a thin interface such as a web browser. The private cloud services of the tertiary educational institutions offer web-based email, virtual library, among other application services.

### Cloud Deployment Models

The NIST recognizes four deployment models for cloud services.

- i. **Public Cloud:** The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services. Popular examples are the Amazon Cloud and Google Cloud.

- ii. Private Cloud: This cloud infrastructure is operated solely for a single organization. It is managed by the organization or a third party, and may exist on-premises or off-premises. The ICT Directorate of the Universities power the private cloud service on-premises, and serves the entire university community.
- iii. Community Cloud: This cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns.
- iv. Hybrid Cloud: This cloud infrastructure is a composition of two or more clouds that remains unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g. Cloud bursting for load-balancing between clouds).

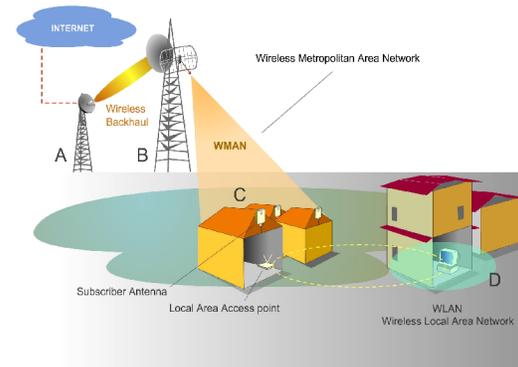
### The Wireless Network Technologies in Tertiary Institutions

Considering cost and technical factors, higher educational institutions are seeking private cloud services to provide a common interface, common identity infrastructure, and common service attributes (Katz, Goldstein, & Yanosky, 2009). Universities are turning into network hubs, as mobile devices are carried by students and staff, and these devices are communicating with the world around them (Steijaert, Boyle, Leinen, Melve, & Mitsos, 2012). Educational institutions are responding to the availability of cloud services by enforcing the use of a limited set of services such as official e-mail, internal institutional portal, and e-library services. Users are increasingly connecting to the wireless network on campus. One of the primary requirements for benefiting from the wide range of services rendered by the university cloud is access to the school's wireless network. The term "wireless network" refers to two or more computers communicating using standard network rules or protocols, but without the use of cabling to connect the computers together (Bakardjieva, 2014).

For a telecommunications network to work, connectivity needs to be ensured at different levels by the elements present (Neto, 2004). The wireless network is basically a system of

radio technologies deployed in the 2.4GHz and 5GHz bands.

Best (2003) presented a hypothetical network installation as depicted in Figure 2.



**Figure 2:** Connectivity in Wireless Networks  
(Source: Best, 2003)

This schematic diagram shows two radio towers (A and B), houses and other buildings (C), and a personal computer inside a building (D). Radio tower A is connected through a wired link to an Internet Point of Presence owned by an Internet Service Provider (ISP). The ISP radio tower could belong to any of the telecommunications companies with presence in the university (e.g. Airtel, Glo, Etisalat, or MTN). So, the PC shown at point D is ultimately connected to the Internet by several wireless links.

To start with, a point-to-point connection is used between radio towers A and B, with only one antenna (i.e. one receiver/transmitter) in both extremities. According to Neto (2004), the purpose of this connection is typically to transmit over long distances (in the order of tens of kilometres). Several of these links can be used, one after the other; in this way the signal will be transmitted, in "hops", to a potentially remote location. This is normally referred to as wireless backhaul.

The connection from B to C is a point-to-multipoint connection. This means that radio tower B is now radiating to and receiving from several stations of type C – i.e. several buildings with base stations, or access points. This is normally called a Wireless Metropolitan Area Network (WMAN) (Neto, 2004).

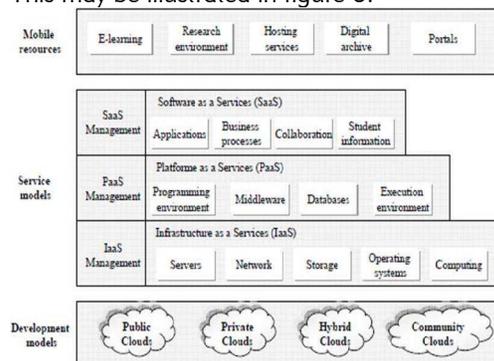
Finally, there is a radio connection between the subscriber equipment mounted on the side of the building (point C) and the individual

personal computer inside the building (point D). This is what is normally called a Wireless Local Area Network (WLAN). An outdoor repeater may be required to redistribute the signals from the access point in a situation where there are blockages in the direct line of site (LOS) between the base station (access point) and the personal computer (PC).

For a PC to access the wireless network, it must possess a network interface card (NIC) or a network adapter card. Most modern laptops and mobile devices come with in-built network cards. Such Wi-Fi enabled systems can track signals from base stations available at the offices of the Deans and Heads of the various colleges/faculties and departments of the institution. The usual transmitting proximity ranges from 100 metres indoors to 350 metres outdoors (Bakardjieva, 2014).

### 3.0 CLOUD ARCHITECTURE FOR TERTIARY INSTITUTIONS

According to Mircea and Andreescu (2011), the architectural pattern of using cloud computing in tertiary educational institutions may be described starting from the development and supply of services and resources offered to the schools' communities. This may be illustrated in figure 3.



**Figure 3:** Cloud Architecture for Tertiary Institution (Source: Mircea & Andreescu, 2011)

As shown in figure 3, students and staff benefit from mobile resources as e-learning, expanded research environment, e-mail hosting services (for instance @uam.edu.ng), digital archive and student portal services. The services models indicate areas of direct impact of the three service models of cloud computing. The widest area of impact is the availability of wireless Internet network as a service.

### Benefits of the Cloud

Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and services) which can be dynamically re-configured to adjust to a variable load (scale), allowing also for optimum resource utilization (Vaquero, Merino, Caceres, & Lindner, 2009). This pool of resources is typically exploited by a pay-per-use model which the infrastructure provider offers through customized Service Level Agreement. At the tertiary education level, the infrastructure provider is the ICT Directorate of the institutions.

The goal of utilizing the cloud as a tool is the achievement of virtual communities of educators, researchers and practitioners working in collaborative groups to advance their practices (Thomas, 2011). Students stand to gain from online services from anywhere within the hotspot and anytime access to powerful web-based tools. It lets both the teachers and the students to access, share and publish documents, class calendars or web pages (Miseviciene, Budnikas, & Ambraziene, 2011).

There is also 24 hours access to infrastructure and content. Resource sharing, network speed and flexible access are all accompanying benefits of the cloud to students. The cloud services of the universities allow offline usage with further synchronization opportunities. Uncountable research materials can be sourced from the National Virtual Library and other linked library services. This functionality of the cloud is gradually changing the way students do research in the school.

### 4.0 A SAFE HAVEN FOR MATHEMATICS EDUCATION

Mathematicians work on the important practical issues of their era, which have always required both the development of the subject together with the tools to support this. Pascal's and Leibniz's mechanical calculating machines, Napier's logarithms, Babbage's difference engine, Newman's Colossus and Turing's Bombe for crypto-analysis at Bletchley Park are just few examples of computational tools which have been fundamental to the evolution of digital technologies to support mathematical developments. In this respect

mathematics is, and has always been, a dynamic problem solving activity for which humans have continued to develop and exploit new tools (Clark-Wilson, Oldknow, & Sutherland, 2011).

The level of penetration of cloud computing in Nigerian tertiary educational institutions can be best explained by the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT as propounded by Venkatesh, Morris, Davis and Davies (2003) provides a useful tool for educational administrators needing to assess the likelihood of success of new technology interventions.

Venkatesh et al (2003) theorize that four constructs will play a significant role as direct determinants of user acceptance and usage behaviour: performance expectancy, effort expectancy, social influence, and facilitating conditions. These determinants are in turn influenced by key moderators such as gender, age, voluntariness, and experience. Thus, the degree to which cloud computing helps both teachers and students of mathematics education attain gains in performance, the ease associated with the cloud technology, the availability of organizational and technical support infrastructure, and the social benefits that are derivable, all contributed to the appeal of the cloud to tertiary educational institution in Nigeria.

Despite this appeal, a primary concern that cloud computing adopters have is the security of enterprise information (Tout, Sverdluk, & Lawver, 2009). Large amount of student, teacher, and institution data are placed in the hands of third party service providers, particularly in the public cloud model. Where such applies, it is critical that teachers, school administrators, and educational regulatory bodies take steps to ensure that the cloud services that are used in the tertiary institutions comply with all applicable laws and otherwise protect data from improper use or transfer (Mutkoski, 2014). A seamless integration of cloud security controls with campus-wide departments and their various applications will be necessary for maintaining high level of information assurance of such applications, including their confidentiality, integrity, and availability.

A wide range of educational institutions in Nigeria are presently operating the private

cloud model hosted by the ICT directorates of the schools (Iji, Abah, & Anyor, 2014). The choice of the model over popular commercial cloud enterprises reduces the risk of security breaches at data centres. In a campus-hosted cloud ecosystem, Trusted Virtual Data (TVD) technologies are often adopted to address the need for strong isolation and integrity guarantees (Berger et al, 2009). The TVD implements controlled access to networked storage based on security labels and enforces isolation constraints and integrity checking. With such efforts in place, mathematics educators and students in tertiary institutions in Nigeria can focus on leveraging on the power of cloud computing to achieve the goals of their respective programmes of study.

The methodology and approach of instructional delivery at the tertiary educational level call for technological augmentation on the part of both students and instructors. The utilization of cloud technology offer students the opportunity to appropriately use ubiquitous wireless network to access, manage, integrate and evaluate information, construct new knowledge, and communicate with others in order to participate effectively in the society (Partnership for 21<sup>st</sup> Century Skills, 2002). With the aid of available cloud services, students of mathematics education can drive more personalized learning, forming a positive image of their discipline (Artigue, 2012).

The cloud by its very nature allows mathematics education students endless opportunities to engage in advanced researches and even in online entrepreneurial outfits. Uncountable research materials can be sourced from synchronized virtual libraries and other linked instructional content repositories. Such readily available support to conventional classroom instruction stands to improve the students' mathematical reasoning and problem solving skills. It opens up more frontiers for the expansion of knowledge and enriched learning experience.

## CONCLUSION

The cloud has come to stay in tertiary education in Nigeria as a tool for hooking students to the information grid. Though there are safety concerns in cloud adoption, campuses across the country are already

leveraging on the dividends of mobile and wireless technology, considering the ubiquity of smartphones and other computer devices among present-day student population. Mathematics education is being improved by transforming opportunities offered by cloud computing into active learning strategies that put students in charge of their own learning.

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