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NIGEDU CLOUD: Model of a National e-Education Cloud for Developing Countries

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Abstract

To achieve global competitiveness, governments in developing countries are evolving and implementing information technology policies, to enable their countries participate in the current ICT revolution. One barrier to attaining the education objectives of the policies is inadequate national ICT infrastructure and services. The inadequacy of ICT infrastructure and services is attributed to inadequate government funding, which in turn becomes difficult for education institutions to own and use sophisticated ICT facilities. In spite of inadequate funding, the gap can be reduced if education institutions in developing countries have access to ICT infrastructures available in developed countries. A technology platform that makes this possible is cloud computing. The design for national cloud computing model is proposed in this paper. This model is envisioned as a good strategy for achieving the education-related objectives of the Nigeria's national IT policy. By this model, the government would be responsible for providing high-end computing infrastructure and e-education services to educational institutions in the country. This model will provide affordable access to technologies for e-education, enabling more collaboration, and better education outcomes in developing countries.

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Keywords: Cloud Computing; e-Education; SaaS; PaaS; IaaS; National cloud infrastructure

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1. Introduction

To achieve global competitiveness, governments in developing countries (e.g. India, Pakistan and Nigeria), are evolving and implementing Information Technology (IT) policies, to enable their countries participate in the current ICT revolution. In Nigeria, the government through the National Information Technology Agency (NITDA) created the National IT policy, with the goal "*to make Nigeria an Information Technology capable country in Africa and a key player in the Information society by the year 2005, using IT as the engine for sustainable development and global competitiveness*" [1, p. iii]. Stated in the policy is that IT would be used for Education, Creation of Wealth, Poverty Eradication, Job Creation, and to attain Global Competitiveness [1, p. iii]. One barrier to attaining the education objectives of the national IT policy is inadequate national ICT infrastructure and services [2]. These infrastructure and services include a national Internet backbone, e-education software and services, high-performance servers, storage and power. This barrier is fundamental to the digital divide between developed countries and developing countries [3]. Inadequate ICT infrastructure and services for education is attributed to inadequate government funding [4], which in turn becomes difficult for education institutions to own and use sophisticated ICT facilities and services. The gap can be reduced if education institutions in developing countries have access to the same ICT infrastructures and services available in developed countries [5]. A technology platform that makes this possible is Cloud Computing (CC).CC would enable developing countries, such as Nigeria, access education-related infrastructures, applications and content from anywhere, providing low-cost, affordable, pay-per-use access to these facilities [6].

Despite the popularity of CC, adoption on a national scale requires adequate cloud readiness. CC is a form of distributed computing that makes its operation absolutely dependent on the Internet [7]. Since, one of the attributes of the cloud readiness index is the availability of Internet (broadband) [8], the motivation for proposing a CC model for education in Nigeria is premised on Nigeria having the highest Internet growth rate in Africa [9]. In this paper, the design of a model for a national CC e-education infrastructure is proposed. This model is envisioned as a strategy to achieving the education-related objectives of the Nigeria's national IT policy. By this model of e-education, the government would be responsible for providing computing infrastructure and e-education services to educational institutions in the country. This model will provide affordable access to technologies, enabling more collaboration, and lead to better education outcomes in developing countries. The remaining part of this paper is structured as follows: Section two contains an overview of CC and its Reference architectures. Related works is presented in section three. Section four discusses the challenges in implementing national IT policy and proposes cloud computing as a solution. The design and description of the proposed CC model to drive the use of ICT in the mainstream of education is the subject of section five. Section six concludes with further research directions.

2. Overview of cloud computing

The on-going advances in distributed and grid computing have enabled individuals and organizations access to computing resources over a network [10; 11; 12]. In recent times, the emergence of CC has enable anywhere and anytime access to advanced data storage and management facilities [13], compute cycles and business applications. CC offers lower cost for IT infrastructure that is scalable as demand increases or decreases [7]. CC is defined as: "A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [14]". Some characteristics of CC include: scalability, elasticity, virtualization, availability [15; 16], lower infrastructure costs, and reliability [10]. CC specifies three main types of service offerings- Infrastructure as a

Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) [14; 15]; with four deployment models-private, public, hybrid and community cloud [10].

2.1. Cloud Computing Reference Architectures (CCRA)

CCRA is a technology-neutral abstraction that defines the role and relationships between actors in the CC context [17; 18]. A recent survey [19] analyzed key differences between nine CCRA based on concerns at the business and architectural level. IBM CCRA [20] was reported to have provided more service management details. In this paper, we adapted the architectural concepts of the IBM CCRA. The IBM CCRA is modular architecture that defines the roles (cloud consumer, cloud provider, cloud developer) and corresponding architectural elements for CC operations. The provider in IBM CCRA offers the infrastructure and a common cloud management platform (CCMP). The available service delivery models are IaaS, PaaS, SaaS and Business-process as a service (BPaaS). The CCMP anchors the Business Support Services (BSS) and the Operational Support Services (OSS). The BSS enables business-related activities, while the OSS enables infrastructure and operational services of the CCMP.

3. Related work

Governments of some developed countries (Japan, United States-US, and the United Kingdom-UK) have already begun exploring national cloud strategies. The Magellan project [21] is funded through the US Department of Energy (DOE), Office of Advanced Scientific Computing Research. The goal of the project was to exploit the potential role of CC to provide the computing needs for the DOE office of Science, serving the needs of data-intensive computing workloads. The US government, through its Federal Cloud Computing Initiative (FCCI) [22] announced its first cloud-computing project Apps.gov (http://apps.gov). The main objective of the FCCI is to make CC services accessible and easy to procure for federal agencies. The IBM/Google Academic CC Initiative (ACCI) [23] is a joint university initiatives to assist computer science students acquire the required skill in developing cloud infrastructures and applications. The UK Government's CIO office announced the establishment of a private Government CC Infrastructure: G-Cloud [25]. The G-Cloud initiative will provide IaaS, PaaS and SaaS, to the public sector, procured via the Government Application Store [26]. Japan's Ministry of Internal Affairs and Communications outlined the ICT Hatoyama Plan. The plan involves the creation of a nationwide CC infrastructure called the Kasumigaseki Cloud by 2015 [27].

On the use of the cloud for education related activities, Masud et al., [28] introduced CC to increase the scalability, flexibility and availability of e-learning systems. Having considered the issues and advances of traditional e-learning models, the authors explored the migration of e-learning systems out of the schools to a CC infrastructure. In their proposal, schools will focus on the education process, content management and delivery while the cloud provider takes care of system construction, maintenance, development and management. Vujin et al., [6], demonstrated the use of a CC infrastructure to effectively improve the teaching and learning process. The proposed model is a private cloud, implemented as part of the institution's existing infrastructure, which provides users (students and faculty) access to virtualized infrastructure, environment and services. The approach presented in this paper extends these models, by proposing a national cloud infrastructure that offers lower cost for e-education and reduces the operation complexities. Tan, et al., [20] classified CC technologies used in educational institutions into e-learning, communications and administration used by faculties, students and administrators. In this paper, we defined users of an education cloud to include faculty (lecturers), researchers, students and administrative staffs.

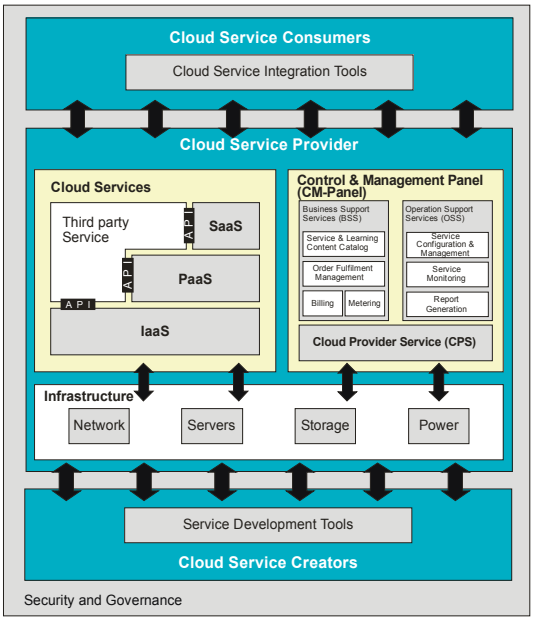

Figure 1: Architecture of the Nigedu Cloud platform

4. National IT policy implementation strategy: Cloud computing

The deployment of an e-education cloud gives Nigeria the opportunities to increase her participation in the ICT revolution [29] with many advantages such as; an effective means of handling the expected average and peak resource utilization of such e-education solutions[7; 30]. These solutions serve hundreds to thousands of students with varying resource demands, making it a candidate for the cloud. The elasticity of CC enables addition or/and removal of resources [30]. Consequently, the risk of over-provisioning (minimal utilization of huge IT resources) and under-provisioning (insufficient IT resources) by using static datacenters is reduced, because of the ability for rapid scaling up and down [30]. Furthermore, CC in education eliminates storage constraints, data losses and crash recovery processes as data is stored in the cloud [1], and provides ubiquitous access to education services and resources to researchers, faculty, students, and administrators. Adopting CC for education offers huge cost savings for governments [16] through datacenter consolidation, aggregation of demands, and multi-tenancy [31]. In the following sub-sections, we present the design of an e-education cloud we called: Nigedu Cloud (figure 1). Nigedu Cloud is a model for a government-funded and administered cloud platform for e-education. The design of the architecture of Nigedu cloud was adapted from the IBM CCRA [20].

4.1. Roles in Nigedu cloud platform

The Nigedu cloud defines three roles: Cloud Service Consumer, Cloud Service Provider and Cloud Service Creator. The government (through its technology agency) is the Cloud Service Provider. The government provides and maintains cloud services to the consumers. The cloud consumers are tertiary institutions, which includes universities, polytechnics and colleges of education in Nigeria. The cloud customers request, consume and manage cloud services some of which may include course management systems, enrollment

management systems, e-examination systems etc. The cloud services are offered based on a billing model adopted by the provider. The tertiary institutions can access the available cloud service offerings via a catalog available on a management and control platform of the Nigedu cloud and can manage their service profiles from there. The cloud service creator(s) are independent third-party government or private entities responsible for the design, development, deployment and maintenance of cloud services, provisioned via the Nigedu cloud platform. These third-party contractors utilize the development functionalities provided on Nigedu cloud to build new cloud services.

4.2. Nigedu Cloud Design Considerations

Nigedu cloud could be deployed as a hybrid cloud, in which some aspects of the facilities are sourced from service providers in the public domain. For example, compute services could be sourced from Amazon EC2, Serv Path or GoGrid. Third party developers can create APIs for institution-specific customization of education-related Free and Open Source Software (e.g. Moodle). Reusable learning contents and resources can be shared openly via Google drive or DropBox. These contents can also be made available for purchase on a learning content store provided by third-party service creators. Other potential third-party services and providers are: Billing-*Aria Systems, eVapt, OpSource, or Zuora.* Storage -*Amazon S3 or CTERA Portal*. Back-up and Recovery- *JungleDisk or Zmanda Cloud Backup*. PaaS databases-*Google Bigtable or Amazon SimpleDB.*

5. Conclusion and future work

In spite of the security and privacy concerns, legal and vendor-lock challenges associated with CC [32], CC is still the most popular model for IT resource provision and usage. Embarking on a national cloud project holds huge economic advantages for and increases the participation of developing countries in the on-going ICT revolution. Adopting a national cloud strategy would require active partnership between governments, education sectors and the private sector. The government would have to foster the development and improvement of national Internet backbones by leveraging on existing telecommunication infrastructures [15]. Also, government would have to establish definite legal frameworks and standards for cloud security, privacy and service reliability. There is need for active discussions and ideas sharing among government, tertiary institutions and private sector IT firms, on how best to integrate the cloud into the current practices in higher education. The authors hope that the model proposed in this paper, would trigger the evolution of national infrastructures initiatives to furnish educationally disadvantaged areas with multiple learning content and educational resources. Further researches should seek to identify best practices that would address the variety of pedagogical, social-cultural, technical, political, and economic issues surrounding the adoption of such national cloud infrastructures and services.

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