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A Phase Approach for Adopting Private Clouds as a Collaborative Platform for Nigerian Universities

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Abstract
Cloud computing is creating a new era for information technology by providing a set of services that appears to have infinite capacity, immediate deployment and high availability at trivial cost. It is the result of the evolution of computing and communications technology from a high-value asset to a simple commodity. In this evolution, the focus shifts from the concept of computing as a physical thing to computing as a service, like electricity, that is accessible from the nearest network connection. An organization, which is under increasing pressure to provide computing services at the lowest possible cost, can choose either public or private clouds to meet these needs. However, driven by concerns over security, regulatory compliance, control over quality of service, and long-term costs, many organizations choose internal private clouds. Private clouds provide the same cost and flexibility benefits as public clouds and also enable an organization to control the quality of service delivered to their users. In addition, private clouds allow an organization to better secure data and meet governance regulations which is usually a major concern when using public clouds. Many universities spend huge amount of money yearly on ICT infrastructure. About ninety percent of ICTs budgets are consumed by computing requirements that can be centralized and standardized enabling one to do more with less resource. This paper tries to make a ca se for the private cloud as a better platform for collaboration among the Nigerian universities and to propose a safe strategy for migration into the private cloud.
Keywords: Cloud Computing, Private Cloud, Public Cloud, Cloud Service Models, Cloud Characteristics

1. Introduction

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources or shared services (e.g., networks, servers, storage, applications, and IT services). The key benefits of cloud computing are costs reduction, reduced complexity, improved quality of service, and increased flexibility (Madsen, 2012).

Cloud computing is a model for delivering Information Technology (IT) platform infrastructure. It is a shift from the idea of computing platforms as hardware and software products to the idea of computing platforms as a service used by applications, just as a household appliance uses electricity as a service. This utility computing model parallels the evolution of the electric industry (Madsen, 2012).

In the early days of electricity there was no electric grid. Many small electric companies started with their own generators and wires running directly to customers, with the biggest demand being for street lights. Organizations and individuals who wanted a reliable and controlled electric supply installed their own generation equipment that was equal to their needs. Generation and transmission technology matured, going through a commoditization process. Standards developed for electricity and the electric market consolidated into a smaller number of suppliers with interconnected service. The availability of electricity as a service meant there was no longer a need for private electricity generation (Madsen, 2012).

Electricity availability as a metered service to organizations resulted in a savings in capital assets since generators and transformers were no longer needed, a savings in resources to supply the generators (coal or oil), and an equally large savings in operations and engineering labour for the people who maintained the equipment.

Cloud computing is the inevitable result of the commoditization of computer hardware and communications technologies. The combination of computing power and the ability to access it from anywhere means there is less need to buy and maintain hardware, much like universal access to electricity reduced the need for private power generation. Computing platforms have become a commodity service that can be transmitted from a remote location. This is a fundamental disruption to the IT industry, a disruption that is still at its infancy.

Public cloud computing is one of several deployment models that have been defined. A public cloud is one in which the infrastructure and other computational resources that it comprises are made available to the general public over the Internet. It is owned by a cloud provider selling cloud services and, by definition, is external to an organization. At the other end of the spectrum are private clouds. A private cloud is one in which the

computing environment is operated exclusively for an organization. It may be managed either by the organization or a third party, and may be hosted within the organization's data center or outside of it. A private cloud gives the organization greater control over the infrastructure and computational resources than does a public cloud (Leavitt, 2009; Vaquero et al, 2009; Youseff et al, 2009).

Two other deployment models that fall between public and private clouds are community clouds and hybrid clouds. A community cloud is somewhat similar to a private cloud, but the infrastructure and computational resources are shared by several organizations that have common privacy, security, and regulatory considerations, rather than for the exclusive use of a single organization. A hybrid cloud is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables interoperability (Leavitt, 2009; Vaquero et al, 2009; Youseff et al, 2009).

Today most organizations are looking at cloud computing as a way of reducing their computing costs. While cost reduction is the real benefit, there is more value in the increased speed, flexibility and ease of delivery in cloud environments. Early worries about loss of control over the environment are being outweighed by the combination of lower costs, faster deployments and simpler scalability. Though, not all deployments are moving to public cloud providers.

Many organizations are adopting private clouds for their enterprise applications because of technical, performance and regulatory reasons. There are other reasons for not using public cloud environments. Data privacy and security regulations can prevent an organization from using a public cloud. Data movement and data management between internal systems and the cloud may be enough of a challenge that it eliminates any speed or cost advantages associated with using the cloud.

Private cloud offers a solution to these challenges. A private cloud is like a single-tenant version of the public cloud. The dedicated nature of a private cloud resolves the privacy and regulatory difficulties and can resolve some of the technical challenges with public clouds (Madsen, 2012).
The rest section of this paper makes a case for the private cloud as a better platform for collaboration among Nigerian universities and further outlines a safe strategy for adopting the private cloud as a collaborative platform for Nigerian universities.

2. Cloud Computing Concept

The National Institute of Standards and Technology (NIST) defines Cloud Computing as a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or cloud provider interaction (Mel and Grance, 2011). According to the U.S. National Institute of Standards and Technology, cloud computing consists of five essential characteristics, three distinct service models, and four deployment models as shown in the table below.

Cloud Computing Concept			
	Essential Characteristics	Service Models	Deployment Models
1	On Demand Self Service	Software-as-a-Service (SaaS)	Public Cloud
2	Resource Pooling	Platform-as-a-Service (PaaS)	Private Cloud
3	Rapid Elasticity	Infrastructure-as-a-Service (IaaS)	Community Cloud
4	Measured Service		Hybrid Cloud
5	Broad Network Access		

Table 1: Representation of Cloud Computing

2.1 The Cloud Characteristics

The essential characteristics from the NIST definition for cloud computing are as described below:

- **On-demand self-service:** A consumer should be able to acquire computing resources as needed without requiring human interaction with the service provider.
- **Network accessibility:** The capabilities provided should be available over a network using standard client software that is independent of any underlying hardware.
- **Resource pooling:** The computing resources are allocated from a shared pool in a way that is transparent to the consumers of the service. The resources can be dynamically reassigned based on demand and have no strict dependence on physical location.
- **Elasticity:** Capacity should be dynamically provisioned so that it can grow or shrink on demand, and should appear as if it comes from an unlimited pool of resources.
- **Measured service:** Resources should be delivered in a "pay-for-use" model where the consumer is charged based on actual use of resources. The consumer should have the ability to monitor and control resource use, making the billing process transparent.

2.2 Cloud Deployment Models

Cloud architecture is presented as being either public or private, a public cloud is one in which the infrastructure and other computational resources that it comprises are made available to the general public over the Internet. It is owned by a cloud provider selling cloud services and, by definition, is external to an organization. At the other end of the spectrum are private clouds. A private cloud is one in which the computing environment is operated exclusively for an organization. It may be managed either by the organization or a third party, and may be hosted within the organization's data center or outside of it. A private cloud gives the organization greater control over the infrastructure and computational resources than does a public cloud (Leavitt, 2009; Vaquero et al, 2009; Youseff et al, 2009).

Two other deployment models that fall between public and private clouds are community clouds and hybrid clouds. A community cloud is somewhat similar to a private cloud, but the infrastructure and computational resources are shared by several organizations that have common privacy, security, and regulatory considerations, rather than for the exclusive use of a single organization. A hybrid cloud is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables interoperability.

2.3 Cloud Service models

Three well-known and frequently-used service models are the following (Leavitt, 2009; Vaquero et al, 2009; Youseff et al, 2009):

Software-as-a-Service. This term generally refers to applications that are delivered to end users over the Internet or broad band access. There are hundreds of SaaS providers covering a wide variety of applications. Software-as-a-Service (SaaS) is a model of software deployment whereby one or more applications and the computational resources to run them are provided for use on demand as a turnkey service. Its main purpose is to reduce the total cost of hardware and software development, maintenance, and operations. Security provisions are carried out mainly by the cloud provider. The cloud subscriber does not manage or control the underlying cloud infrastructure or individual applications, except for preference selections and limited administrative application settings.

Platform-as-a-Service. This model conveys how an application development and deployment platform can be delivered as a service to developers, allowing them to quickly build and deploy an SaaS application for end users. Platform-as-a-Service (PaaS) is a model of software deployment whereby the computing platform is provided as an on-demand service upon which applications can be developed and deployed. Its main purpose is to reduce the cost and complexity of buying, housing, and managing the underlying hardware and software components of the platform, including any needed program and database development tools. The development environment is typically special purpose, determined by the cloud provider and tailored to the design and architecture of its platform. The cloud subscriber has control over applications and application environment settings of the platform. Security provisions are splited between the cloud provider and the cloud subscriber.

Infrastructure-as-a-Service. This refers to computing hardware (servers, storage, and network) delivered as a service. This typically includes the associated software as well, including operating systems, virtualization, clustering, and so on. Infrastructure-as-a-Service (IaaS) is a model of software deployment whereby the basic computing infrastructure of servers, software, and network equipment is provided as an on-demand service upon which a platform to develop and execute applications can be established. Its main purpose is to avoid purchasing, housing, and managing the basic hardware and software infrastructure components, but instead obtain those resources as virtualized objects controllable via a service interface. The cloud subscriber generally has broad freedom to choose the operating system and development environment to be hosted. Security provisions beyond the basic infrastructure are carried out mainly by the cloud subscriber. Cloud computing model can be visually represented as show below:

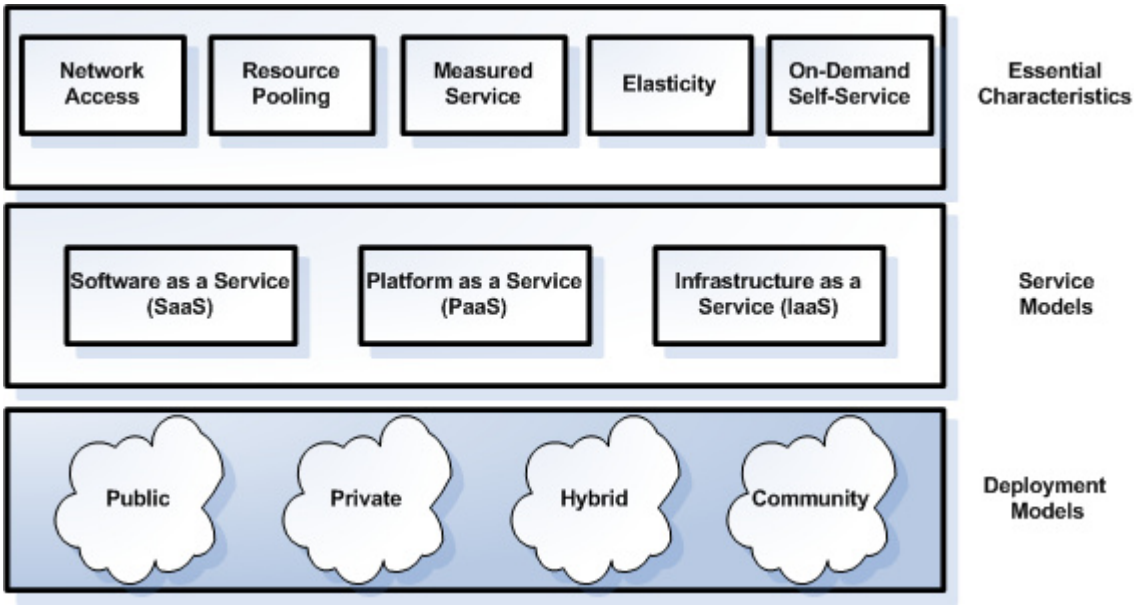

Figure 1 - NIST Visual Model of Cloud Computing Definition
Source: (NIST, 2011)

3. Motivation

Educational institutions throughout the World have become highly dependent on information technology to service their business requirements. Procuring and maintaining a wide range of hardware and software require substantial, ongoing investment and the skills to support them. The economies of scale and other features of cloud computing are likely to mean an increasing shift away from institutionally-hosted services. These services are increasingly provided using Internet technologies to staff and students and are accessed from web browsers. The services are offered cheaply or freely to education, often with much higher availability than can be provided by the educational institution. We are therefore facing a future where the majority of the educational services will be hosted in the cloud and institutions no longer host their own data centres with expensive hardware, power bills, staff salaries and computing resources which are rarely fully utilized.

Educational institutions are under increasing pressure to deliver more for less, and they need to find ways to offer rich, affordable services and tools. Cloud computing can help provide those solutions. It is a network of computing resources—located just about anywhere—that can be shared. They bring to education a range of options not found in traditional IT models.

The cloud helps to ensure that students, teachers, management and parents have on-demand access to critical information using any device from anywhere. Institutions can use the cloud to deliver better services, even as they work with fewer resources. By sharing IT services in the cloud, the institutions can outsource nonessential services, and better concentrate on offering students, teachers, faculties, and staffs the essential tools to help them succeed.

Educational institutions are entrusted with confidential information and private data. Public Cloud computing may seem risky because one cannot secure its perimeter. Institutions with sensitive information and workloads would probably never want all of their data in a public cloud. Private clouds offer better solutions. In the “private

cloud" approach, organizations develop or procure their own dedicated cloud-computing environments (either alone or in group "community clouds") rather than simply using the existing multitenant offerings of third-party providers. Universities may choose to build their own private cloud for their own consumption, and even offer hosting services to other universities for the purpose of revenue generation. The proposed private cloud for the Nigerian universities will serve as a platform for collaboration among the Nigerian universities enabling them to easily share resources, communicate easily, as well as giving them the opportunities to enjoy the cloud services under a secured platform.

4. Proposed Strategy For Successful Adoption Of The Private Cloud For Nigerian Universities

A private cloud is like a single-tenant version of a public cloud. The dedicated nature of a private cloud resolves the privacy and regulatory difficulties and can resolve some of the technical challenges with public clouds. Private cloud is the model that will serve as a platform for the proposed collaboration among the Nigerian universities as shown in figure 2:

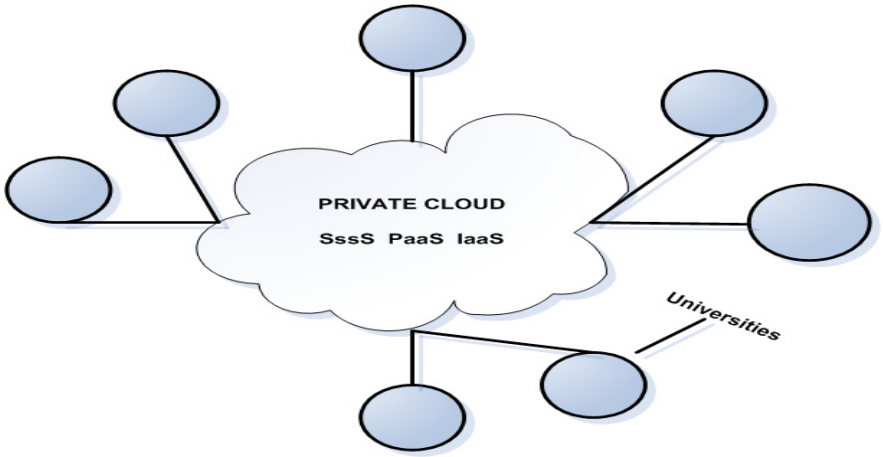

Figure 2: The proposed platform for collaboration among the Nigerian universities

The adoption of private cloud technology as a platform for collaboration among the Nigerian universities is not something to be rushed, this is because a mistake in the process will be devastating and costly thus this paper outlines a safe strategy for successful implementation of the proposed private cloud computing for the Nigerian Universities as shown in the flowchart below:

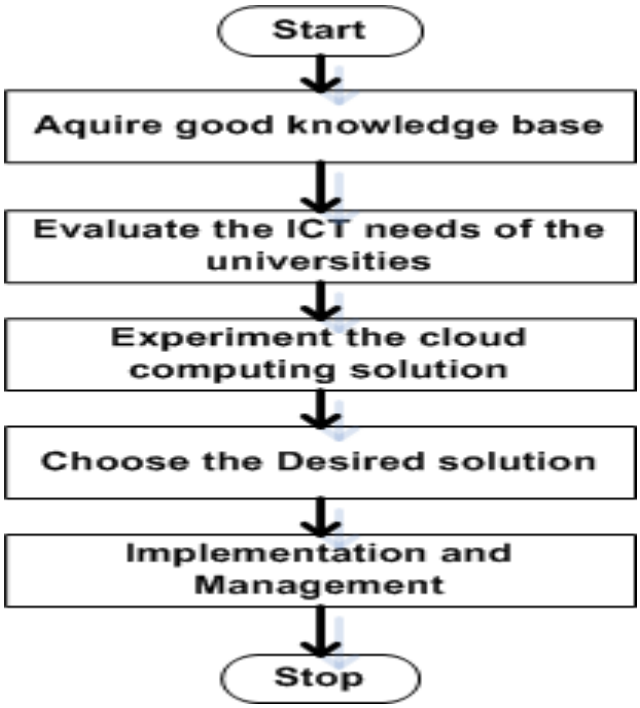

Figure 3: A flowchart for the proposed strategy for private cloud implementation for the Nigerian Universities

4.1 Acquire Knowledge base about cloud computing

Cloud computing is a new and evolving technology, so it is important to understand the concept of cloud computing before migrating into it. The knowledge can be acquired through training, workshops, seminars and conferences. Understanding the basic concepts of the technology by the various sections of the universities can lead to general acceptance of the new technology by all stake holders involved especially the authorities.

4.2 Evaluating the ICT needs of the Universities

This is involves the evaluation of the ICT infrastructures, needs and usage. This will help to determine which of the applications, data and services will be migrated to the cloud and the ones that will remain within the universities. The analysis would start with the categories of intended users of the proposed cloud and their respective needs. In carrying out the analysis of a typical university system, the user of the system will include students, lecturers, researchers, administrative and ICT staff as show in figure 4: below

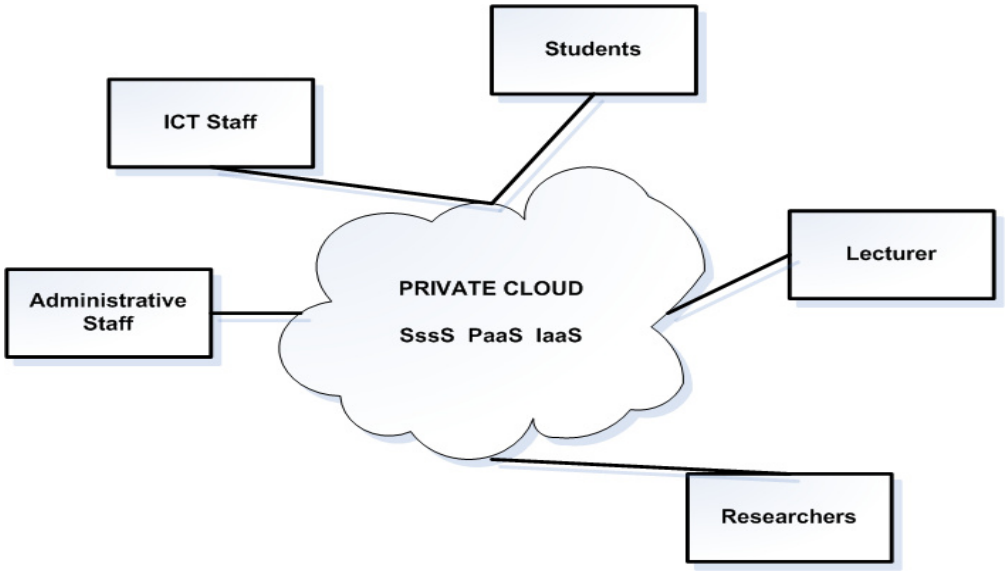

Figure 4: Anticipated users of the private cloud

The cloud computing will allow users from various universities access to the pooled cloud resources(e-mail, database, files, applications, reading and research materials etc) which will enhance learning and bridge digital divide. According to Ercan (2010) students will use many of the cloud technologies in their academic and personal life. By using the cloud models and applications the students will be able to collaborate with other students in other universities within the country. The lecturers will benefit from the cloud computing in terms of support for preparing their teaching materials such as lesson notes, assignments, write ups etc. The cloud will also support effective communication between the lecturers and students all over the nation. The researcher will also benefit from the cloud by using the latest technologies for their research work. The administrative staff will benefit equally from the cloud services by having access to the system to carry out their functions at any time and from anywhere. The ICT staff will use cloud facilities to design, develop and test applications which will be used by the university communities in the cloud (Thomas, 2009).

The evaluation would also involve the identification of various university data with regards to the categories of users of the cloud. The identified users may be categorized according to the following three main groups namely teaching, research and administration as show in figure 5:

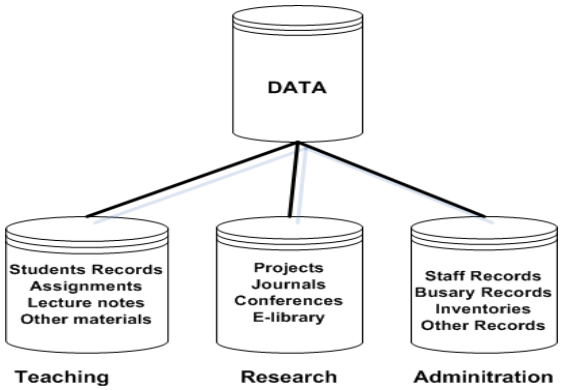

Figure 5: proposed data for deployment in the cloud

4.3 Experimenting the cloud Computing Solution

Migration to the private cloud will be gradual starting with a pilot project and then externalize the chosen application in the cloud. In doing this there is need to set necessary targets such as development and environment testing or storing of some data in the cloud. The maintenance costs and system agility must be taken into consideration. The experimentation results obtained will help the ICT department to implement and install the cloud computing framework and capability.

4.4 Choosing the Cloud Computing Solution

In choosing the appropriate cloud computing solution for the proposed private cloud computing for the Nigerian universities, we adopted an ordered layered approach as our methodology to define the proposed cloud systems. This methodology enables us to capture the inter-relationships between the different cloud components. In this methodology, each layer is developed from one or more cloud service models. Thus, the proposed system is a stack of layers. Each layer consists of one or more cloud services. Cloud services are made to belong to the same layer if they have equivalent levels of abstraction, as regards to their targeted users. For instance, all cloud software environments (a.k.a. cloud platforms) target programmers, while cloud applications target end users. Therefore, cloud software environment is classified in a different layer from the cloud applications. With this methodology, we classify one cloud layer to be higher in the cloud stack, if its services can developed from the services of the underlying layer. For instance, since cloud applications can be developed using cloud software environments, we say that cloud applications are higher in the cloud stack. Using this approach, we were able to formulate our platform for the proposed private cloud for the Nigerian universities.

The proposed private cloud computing platform has five layers: applications, software environments, software infrastructure, software kernel, and hardware as shown in figure 6 below. At the bottom of the cloud layers is the hardware layer which is the actual physical components of the system.

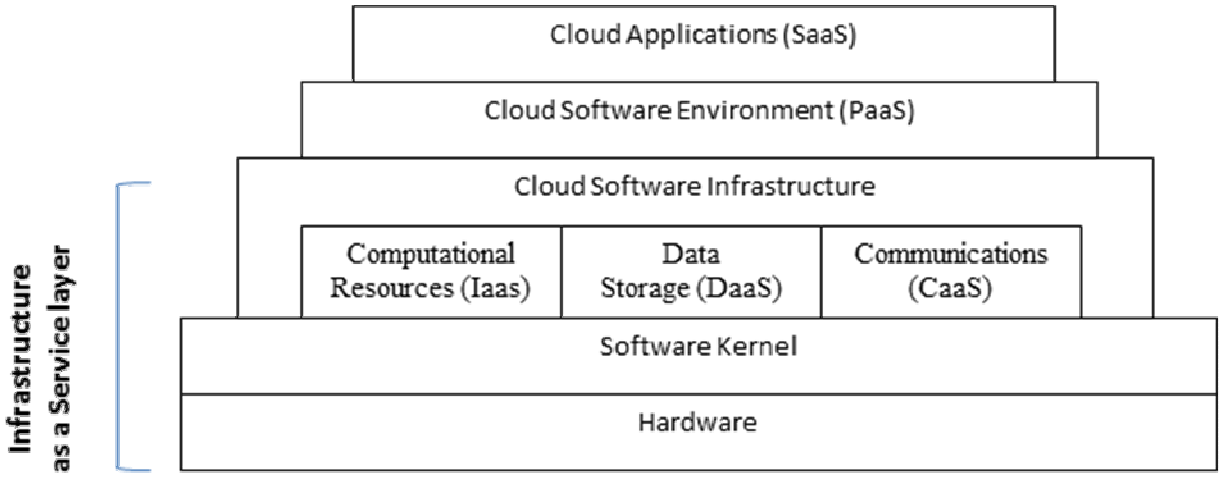

Figure 6: The adopted platform for the private cloud computing represented in five layers

The cloud application layer is the top most layers closer to the end-users of the cloud. It would be the most used layer. The users' will access the services provided by this layer through web-portals. This model has recently proven to be attractive to many users, as it alleviates the burden of software maintenance and the ongoing operation and support costs. Furthermore, it exports the computational work from the users' terminal to data centers where the cloud applications are deployed. This in turn lessens the restrictions on the hardware requirements needed at the users' end, and allows them to obtain superb performance to some of their CPU-intensive and memory-intensive workloads without necessitating huge capital investments in their local machines.

The second layer in our proposed cloud platform is the cloud software environment layer (also known as software platform layer). The users of this layer are cloud applications' developers, implementing their applications for and deploying them on the cloud. The providers of the cloud software environments supply the developers with a programming-language-level environment with a set of well-defined APIs to facilitate the interaction between the environments and the cloud applications. The service provided by the cloud providers in this layer is commonly referred to as *Platform as a Service (PaaS)*.

The third layer is the software infrastructure layer which is categorized into: computational resources, data storage, and communications. This layer provides fundamental resources to other higher-level layers, which can be used to construct new cloud software environments or cloud applications. Virtual machines (VMs) are the most common form for providing computational resources to cloud users at this layer. The service provided in this section is normally referred to as Infrastructure as a Service (IaaS). The second infrastructure resource in this layer is data storage, which allows users to store their data at remote disks and access them anytime from any place. This service is commonly known as *D*ata-Storage as a *S*ervice (*DaaS*), and it facilitates cloud applications to scale beyond their limited servers. The communication section of this layer provides some communication capability that is service oriented, configurable, schedulable, predictable, and reliable. This service is referred to as Communication as a Service (CaaS). It supports requirements such as network security, dynamic provisioning of virtual overlays for traffic isolation or dedicated bandwidth, guaranteed message delay, communication encryption, and network monitoring.

The bottom layer in our proposed private cloud platform is the physical hardware and switches that form the backbone of the platform. The users of this layer are normally big enterprises with huge IT requirements in need of subleasing *H*ardware as a *S*ervice (*HaaS*). The provider of this *HaaS* operates, manages and upgrades the hardware on behalf of its consumers, for the life-time of the sublease.

5. Conclusion

Private cloud as a platform delivers many of the benefits of the public clouds without some of the problems. Successfully adopting private cloud computing for collaboration among the Nigerian universities requires a shift in technology and methodology. A survey with organizations that are presently using the private cloud model reveals that private cloud is the better option today for gaining the scalability, elasticity, and performance management capabilities cloud computing provides.

This paper opines that the private cloud when properly implemented and installed will also offer the universities a more controlled environment than the public cloud. It should be noted that though cloud computing is still in its early stage, the benefits have been demonstrated by early adopters. It will continue to mature towards the provisioning of a very reliable and stable service. The layered approach adopted in proposed construction of the private cloud in this paper will help capture the relationships between the different cloud components for better implementation. Considering the recent financial challenges which Nigerian universities are facing, it is worth-while for the universities to adopt cloud computing as a way of saving cost, enhancing teaching and learning, better management and bridging the digital divide in the country's universities.

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