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CLOUD COMPUTING IN NIGERIA: THE CLOUD ECOSYSTEM PERSPECTIVE

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ABSTRACT
Information and Communications Technology (ICT) has gone through different phases of development, and the world is witnessing the emergence of a new technology paradigm called cloud computing. Cloud computing has pervasive access, its usage is simple and utilities are offered in pay-as-you-use. It therefore has the potential to open up ICT penetration in education, transaction, collaboration, information dissemination and in other areas of the life of a modern man. The cloud ecosystem describes the complex system of interdependent components that work together to enable cloud services provided to user. This paper presents a critical analysis of the benefits and challenges posed by the adoption and usage of cloud computing. Also presented is the relationship between important stakeholders in the cloud ecosystem. The paper further proposes methods of optimizing the benefits of cloud computing while reducing the challenges that might occur due to its adoption.

Keywords*: Cloud computing, ICT, cloud ecosystem, developing countries, Nigeria*

1. INTRODUCTION
Nigeria the most populated country in Africa with over 167 million people has being described as the largest growing market in Africa's Information and Communications Technology (ICT) market in terms of internet usage and mobile/fixed line subscriptions [1]. Electronic communication has become the standard of communication in developed countries and they are also fast approaching making e-communication the standard. This makes ICT a key factor for the much needed poverty reduction and economic growth in the developing world. The growth and penetration of Information and Communications Technology (ICT) on Nigerians can be seen in Figure 1, there is presently an internet penetration of about 30%. There is an increase in the number of mobile devices; most private and government organization now has e-presence. More people are embracing e-banking, e-commerce and e-business and other e-services and offerings. There is an increase in ICT penetration and the influence it has on the lives of the people in the country [2, 3, 4]. ICT has also been penciled down to be the key in route to the achievement of the country's millennium development goals (MDG) [5, 6]. But, despite Nigeria's large market share in the industry, ICT penetration in the country is still a far cry compared to advanced countries.

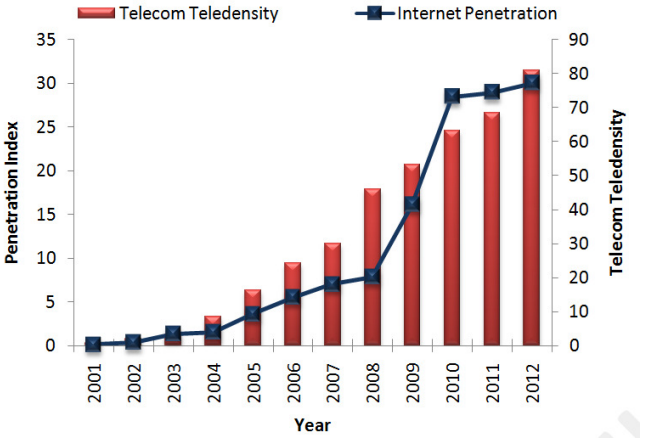

Figure 1: Nigeria's Telecom Teledensity and Internet penetration (data from [7])

This paper is a continuation of the research presented in [8]. This paper discusses the cloud ecosystem in Nigeria by investigating the relationship between major stakeholders and presenting issues that should be addressed for optimal utilization of the cloud.

1.1 The Cloud
Cloud computing is a new computing model that enables convenient, on-demand network access, to a shared pool of configurable computing resources: networks, servers, storage, applications, and services) that can be rapidly provisioned and released with

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minimal management effort or service provider interaction. The cloud evolved from many years of growth in computing technology as shown in Figure 3. Transition of Information Technology (IT) from automation to virtual businesses and then to virtual societies has changed the mode and method of communication to a global perspective.

Cloud Computing resulted from the convergence of Grid Computing, Utility Computing and Software as a Service (SaaS) [9]. A cloud is a virtualized data center geared to achieve the following objectives amongst others [10]:

Elasticity: virtual machines resources can be scaled up or down on demand

On-demand usage: computing power (CPU, memory) and storage can be increased or reduced on demand

Pay-per-use: the client only pays for what is used

Multitenancy: multiple customers have access to their servers in the data center in an isolated manner.

Services offered on the cloud are available in different service models such as: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Four deployment models were also identified for cloud architectural solutions; private cloud, community cloud, public cloud and hybrid cloud. Cloud drivers, characteristics, service models, deployment models and challenges are all summarized in Figure 3.

1.2 Service Models

Cloud computing service models are presented in more details below [9, 11, 12]:

Infrastructure as a Service (IaaS): This provides consumer with computing resources such as computations, storage, networks, and allow the consumer to deploy and run arbitrary software, which can include operating systems and applications. The consumer has control over operating systems, storage, deployed applications, and possibly limited control of select networking components. Notable commercial solutions of IaaS are the Amazon Cloud, Rackspace Cloud and GoGrid.Platform as a Service.

Platform as a Service **(PaaS):** This provides consumer with the capability to deploy onto the cloud infrastructure, consumer-created or acquired applications, produced using programming languages and tools supported by the provider. The consumer has control over the deployed applications and possibly application hosting environment configurations. Notable commercial solutions of PaaS are Heroku, Google App Engine and Microsoft Azure.

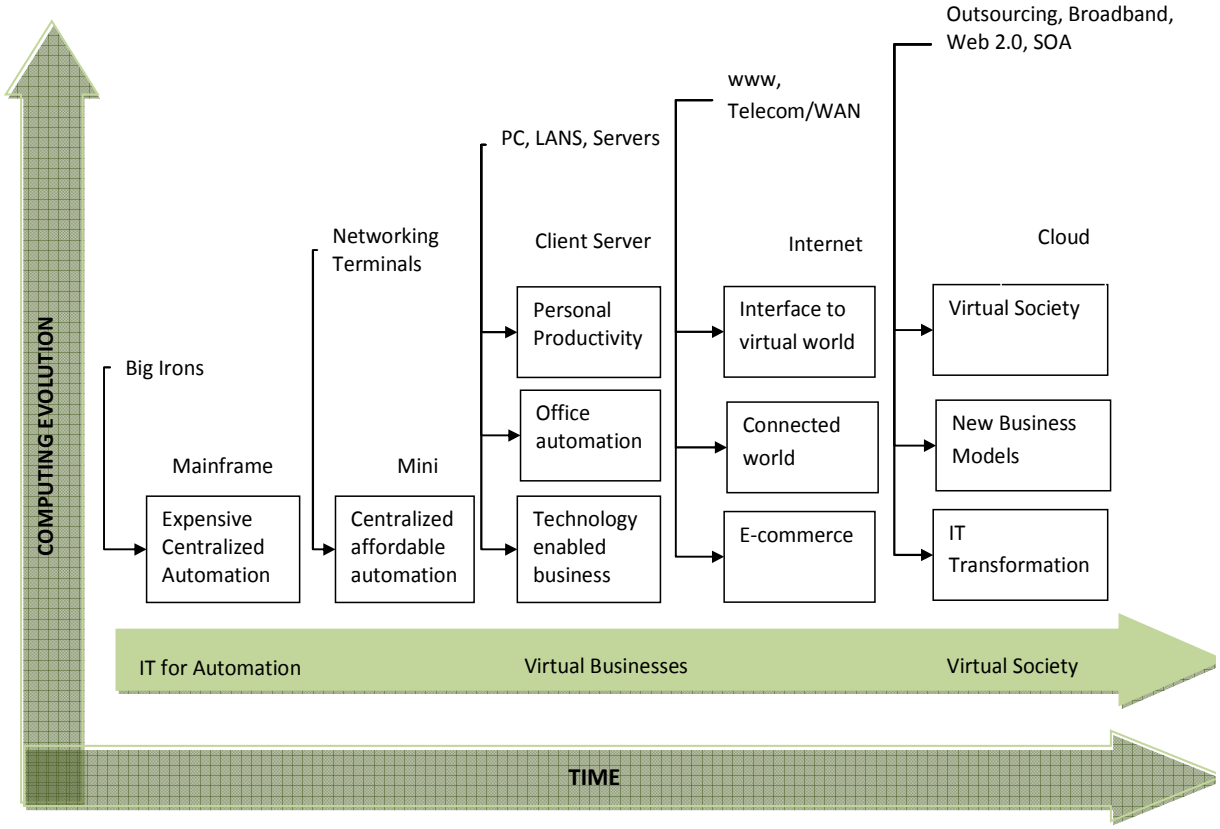

Figure 2: The Cloud: Changing the Communication Ecosystem (Adapted from [11])

Software as a Service (SaaS): This provides consumer with the capability to use the provider's applications running on a cloud infrastructure. Software as a service (SaaS) is a software delivery model in which software and associated are centrally hosted on the cloud. SaaS is typically accessed by users using a thin client via a web browser. It is a common delivery model for many business applications including office and messaging software, development software and service desk management. The consumer do not manage or control the underlying cloud infrastructure. Notable commercial solutions of SaaS are Google Apps and SalesForce.com.

1.3 Deployment Models

Four deployment models have been identified for cloud architecture solutions [9, 11, 12]:

Private cloud: The cloud infrastructure is operated for a private organization. It may be managed by the organization or a third party, and may exist on premise or off premise. Examples are Nimbus, Eucalyptus, and Xen Hypervisor.

Community cloud: The cloud infrastructure is shared by several organizations and supports a specific community that has communal concerns (e.g., mission, security requirements, government, policy, and compliance considerations). It may be managed by the organizations or a third party, and may exist on the premises or off the premises.

Public cloud: This infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.

Hybrid cloud: The cloud infrastructure consist of a combination of the above mentioned cloud types e.g. private, community and public cloud.

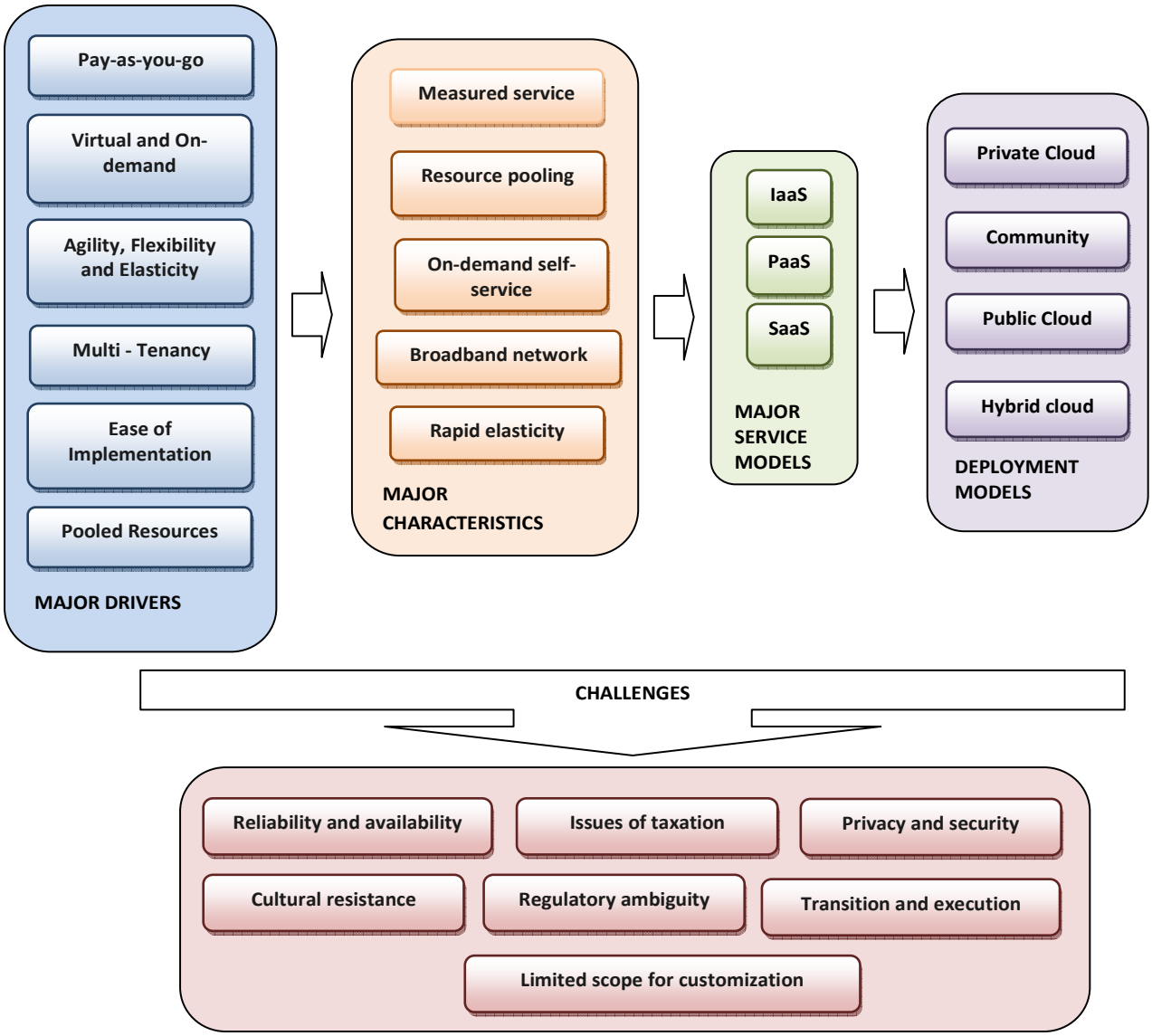

Figure 3: Cloud drivers, characteristics, service models, deployment models and challenges

2. THE CLOUD ECOSYSTEM

Ecosystem refers to a number of organisms that interact within an environment at a particular time. The cloud ecosystem describes the complex system of interdependent components that work together to enable cloud services. A rich ecosystem of cloud computing services and providers has emerged in developed countries, forming a complex environment in which Web-scale end-user applications and services are developed, tested, deployed and operated as shown in Figure 4. While this complex service environment provides many choices, at the same time it poses a great challenge to people in charge of building resilient application architectures. Cloud ecosystem describes the complex system of interdependent components that work together to enable cloud services. These interdependent components include IT infrastructures, software services, third-party vendors and consumers all of which have a bearing on the development of cloud ecosystem [13].

In developing world, the cloud ecosystem is at its infancy with most components provided by developed countries. According to [14] the rise of cloud computing ecosystem implies that classifications of popular service delivery models – infrastructure, platform, and software as a service (IaaS, PaaS, SaaS, respectively) will be less relevant. Instead of being viewed as just a platform, IT managers will now look at the technology as a broader ecosystem in which cloud services span the entire spectrum of IT capabilities

In such an ecosystem, providers and consumers of cloud services participate in common business processes. Most people are familiar with the cloud as a means of sharing information; it is now commonplace, for example, for people to share photographs using social network websites. In cloud-based business systems, this is taken to a new dimension; the cloud becomes a means by which enterprises can share business logic. Cloud ecosystems foster standards-based business exchanges between participating enterprises. This encourages optimization of products and services available in the ecosystem's marketplace [11].

2.1 Components of the Cloud Ecosystem

There are three individual components in the cloud ecosystem; the demand side, the cloud and the supply side. The demand side is mainly made up of consumers from all spheres of life and of all ages that makes use of cloud services using various cloud deployment models. The cloud provides easy access of cloud services to consumers on a pay-as-you-use basis. IT infrastructure and software resources for providing the services and managing the cloud is provided by cloud solutions/service providers on the supply side of the ecosystem. There are also cloud advisors and influencers such as third-party vendors who provide IT Solution and Services and Consulting Companies. There are also Regulatory Bodies that make sure all parties are satisfied and to guard and regulate the cloud [15].

Consumer: Individuals, groups, organizations and companies are final consumers of the cloud. Smaller businesses and individuals can reduce up-front infrastructure capital and maintenance costs by using the infrastructure (compute, memory, and storage) offered by the cloud providers.

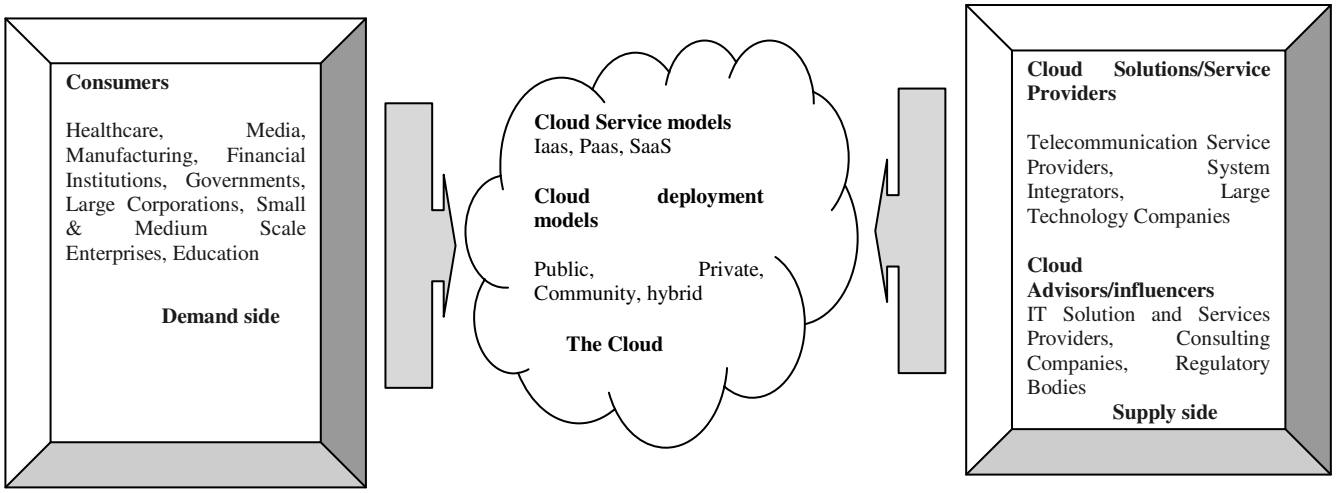

Figure 4: Cloud Ecosystem (adapted from [11])

Using cloud services also keeps physical infrastructure footprint at a minimum and easier to control. Users have virtual access to resources on the cloud as if it were in the user's premises.

Cloud computing ecosystem enables consumers to make use of cloud software services (SaaS) on pay as you go model from any cloud providers thereby making their business more convenient and provider also making money.

Cloud computing enables providers and consumers of products and services to interact much more easily, because they are freed from the drudgery of providing the necessary IT support. This encourages the creation and growth of ecosystems in which companies co-operate effectively to meet the needs of society. The benefits of cloud computing extend not just to individual businesses, but to business as a whole. Cloud computing enables interaction between consumers and IT infrastructure in the sense that consumer can make use of infrastructure as a service in the cloud for their business purposes thereby limiting the cost of infrastructure.

Cloud Solutions/Service Providers: a combined set of hardware, software, networks, data centres, facilities, storage, virtual machines is required in order to develop, test, deliver, monitor, control or support IT services. It is the backbone of the cloud and fundamentally essential for the smooth operation of the cloud. Telecommunication Service Providers, System Integrators and Large Technology Companies have these IT infrastructures and make them available to interested subscribers.

Cloud computing ecosystem helps to establish standards on infrastructures that would be provided for users so that if an application is deployed from a cloud of different provider to another there wouldn't be compatibility problem thereby enhancing the cloud services irrespective of the provider.

Cloud Advisors/influencers: They include IT Solution and Services Providers as allowed by the cloud computing ecosystem permits different vendors to produce software services on a standard basis which are also made compatible. To ensure that if one program is deployed to a cloud of different cloud providers; it will still continue to run.

Data center giants like IBM, Google, Microsoft, and Amazon that have massive infrastructure at different locations enough for their operations and extra to rent out to interested subscribers. They use technologies such as virtualization, service-oriented architecture to deliver infrastructure to individuals and small and medium Enterprises and businesses. Physical machines in the data center deliver infrastructure resources to customers through virtualization via virtual machines. Hardware virtualization is a technology that enables the creation of multiple virtual machines on the underlying physical hardware. Every virtual machine (VM) made available to users has a set of resources (CPU, memory, storage), which forms a subset of the parent physical machine resources. Third-party vendors and consulting companies serve as intermediary between some data center giants and consumers. They also assist interested cloud users with useful start-up advice, migrate to the cloud and manage their cloud infrastructure. Regulatory bodies oversee the cloud making sure that all parties obey laid down regulations.

2.2 Cloud Ecosystem in Nigeria

The emergence of cloud ecosystems is enabling vendors in Nigeria to build services on cloud and customers are able to deploy services from multiple providers with fewer complications and less risk of integration issues. A collaborative environment in cloud ecosystems enable vendors to respond to current cloud challenges, and future cloud technology will become a viable option for averagely sized firms that are yet to embrace the cloud. A rich environment in the cloud will force interplay of competition and cooperation in the technology industry, thereby enabling cloud providers to produce services catering to specialized needs. The state of Nigeria in the cloud ecosystem is further analysed in the next section.

Consumers: emerging businesses and companies who utilizes online services and database such as banks, firms and government ministries in Nigeria constitutes the cloud ecosystem's consumer that utilizes the cloud infrastructure majorly for their day to day activities. In a country with a population of more than 167 million people, the offerings can boost the productivity and provide improved services to most if not all. Some of the many things the cloud can offer to consumers in Nigeria includes;

i. Bridging the digital divide
ii. e-services such as e-finance, e-commerce, e-government, Telemedicine and e-medicine amongst many others

iii. Research and Collaborative purposes
iv. Reduction in Environmental degradation by using e-communication and e-learning
v. Disaster recovery and emergency response
vi. Storage capabilities

Infrastructure: one major challenge faced by cloud computing in the country is lack of adequate infrastructure on which the cloud runs such as electricity, fast internet connectivity, backbone networks etc. Availability of electrical power in the country is also a major problem which is why minimal data centers are being planted in the country. Most consumers and third-party vendors prefer to partner with data centres outside the country with guaranteed infrastructure than with ones within the country or at least have a backup with data centers abroad. Lack of adequate infrastructure affects the expansion and installation of data centers all over the country. The data centres within the country are concentrated in Lagos where there is a lot of backbone access due to its proximity to the sea and a landing point to backbone solution providers who provide fibre optic interconnection worldwide [16].

The backbone network presently in Nigeria is mainly made up of wireless connections which are limited and more error prone compared to wired connections. The government needs to ensure that an adequate broadband network is available and assessable to most Nigerians.

There is also insufficient internet penetration in the country. Only about 33% of Nigerians have access to internet connectivity and relatively at a higher cost. This percentage is quite low when compared to other countries in Africa such as Morocco and Egypt with penetration rates of 55%, 44% and 41% for both Tunisia and South Africa as shown in Figure 4 [17].

No hardware IT infrastructure manufacturing company is located within Nigeria, therefore every infrastructure required have to be imported into the country. When a component or device is faulty, replacement can only be sourced abroad which makes the whole process cumbersome. Engineers and skilled personnel within the country are not trained first hand but rather most are trained by other trainers. These skilled personnel are few compared to the need of a full blown cloud deployment in the country. Most of the data centres within the country are deployed and managed by expatriates.

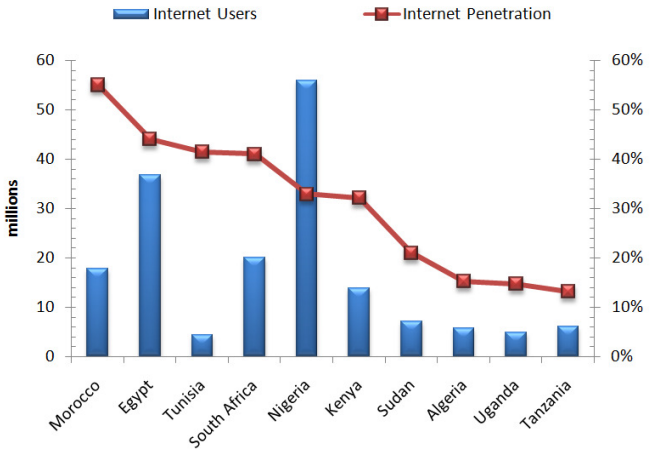

Figure 4: Internet penetration and users in some African countries (source data from [17])

Cloud Solutions/Service Providers: Cloud computing ecosystem allows interrelationship between IT infrastructures and software services through the deployment of software services on the underlying infrastructure. The software relies on the platform while the platform relies on the infrastructure thereby creating a dependency trend between the cloud services. One of the major reasons why Nigeria adopted cloud is for the purpose of Software as a Service model, where people tend to make use of different application for transaction purposes based on different scales depending on the user's request on pay-as-you-go model.

Most cloud solution and service providers in Nigeria are Third-party vendors and they serve as intermediaries between end users and the source providers of cloud services. Most of these source providers are located outside Nigeria. They ensure that the services are up at all times and are also in-charge of leasing out services to the users. They also seek after the affair of cloud facilities functionality; carry customers along with available update on cloud issues as well as cloud security etc. In Nigeria, people are conscious of the security of information on cloud so if there is bridge in the services, customer's data will be prone to hackers to tamper with. And security is one of the major reasons why most Nigerians are scared of adopting the cloud.

To ensure self reliance in the ICT ecosystem it is important that there should be skilled work force in ICT field. This might be challenging to obtain because firstly, there is huge brain drain in Nigeria, particularly amongst citizens working abroad in ICT related fields. There is poor funding of academic and research institutions and therefore poor quality of

graduates. Nigerian studying or working in ICT related fields abroad should be encouraged and mobilized to develop the ICT sector in Nigeria.

Cloud Advisors/influencers: Nigeria is a viable ICT country but due to various challenges in the country such as corruption, financial and physical insecurity, lack of adequate ICT infrastructure there are few private investors in ICT compared to ICT growth rate all over the world and this reflects cautionary expectations. With lack of reliable, affordable and dependable infrastructure, the price of providing ICT to the people is more expensive, which limits access to ICT to the people. Therefore scarce fund from both private and public investors is a major challenge to ICT growth in Nigeria especially when weighed with other pressing issues in the country such as insecurity, unemployment and corruption.

Government policies enforced through regulatory bodies are major anchors to the growth and development of any sector of the economy. Good, well implemented and monitored policies will definitely change the face of cloud development in the country.

3. SUGGESTED SOLUTIONS TO THESE CHALLENGES

3.1 Building Infrastructures

The government should make ICT one of its priorities in the area of developmental growth so that they can invest into technological growth of the country thereby improving on the availability of power supply which is the major backbone of ICT. With efficient power supply the cloud providers will implement data centers in the country with faster access rate instead of accessing it from a distance country.

One major drive for cloud is broadband network that will facilitate better service on the cloud. The government is expected to put in place a broadband network that is cheaper and affordable by everybody that wants to make use of the cloud irrespective of the scale of service so that majority if not all can benefit the advantages of cloud computing.

3.2 Availability of user devices and ICT devices

Thin and thick clients are user devices which are required tools to access the cloud and make use of the opportunities and services it is offering. The government should encourage investors to establish ICT manufacturing companies to cater for more than 100 million potential users of the cloud in the country.

3.3 Awareness to Young Scientists

Increased awareness will be required in secondary schools and most ICT institutions and colleges. Awareness can be ensured through essay competitions, quiz and other awareness campaign in a catch them young initiative.

3.4 Research and Development

Increase in research activities in cloud computing should be encouraged in research institutions by sponsoring research grants and scholarships to postgraduate students interested in the area for research. Research fellows in cloud Computing could also be sponsored to research facilities where they have established hardware infrastructure and software exposure and capabilities

Academic institutions in the country should be encouraged to have cloud network laboratory in their universities and teach it to students and all interested. Workshops and Seminars can also be organized with experts in the fields. Cloud computing is one of the major secret to en route of ICT and increase in internet penetration to rural places of the country.

3.5 Regulating bodies

There should be adequate regulatory bodies established by the Government to ensure quality of cloud services and these have to be backed by Government laws and policies. The Government has to be the major driver of cloud computing in Nigeria for it to have an established and lasting footing and for clients to take optimal advantage of cloud services.

4. CONCLUSION AND RECOMMENDATION

Cloud computing will bring a lot of development to the country especially the telecommunication sector which will affect all other sectors. For the sustainability of the cloud network, electricity, ICT manufacturing industries and ICT infrastructural backbone of the country has to be well established. The need for adequate government involvement in policy making, creating a favorable environment for foreign investors and adequate dissemination of cloud information to people are some improvements required on the side of the government.

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