

Cloud Computing in Nigeria: Prospects, Challenges and Operation Framework

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Abstract - Cloud computing offers a promising technology paradigm for business organisations and government ministries, departments and agencies to reduce running costs, improve service delivery and generally improve national economy but in Nigeria despite these prospects, there are daunting challenges such as infrastructural deficits, data and information security issues, epileptic power supply, high cost of bandwidth and lack of broadband internet services. This paper looks closely at the prospects of this new technology and the daunting challenges confronting its full implementation in Nigeria and presents an implementation framework that will solve most of these challenges.

Keywords - Cloud, IaaS, SaaS, PaaS, Servers, Storage, Propel server and client, bandwidth, WiMAX, Wi-Fi

I. INTRODUCTION

Cloud computing is the use of computing resources (hardware and software) that are delivered as a service over a network (typically the internet). The name comes from the use of a cloud-shaped symbol as an abstraction for the complex infrastructure it contains in system diagrams [1]. Cloud computing entrusts remote services with a user's data, software and computation. It is the storing, processing and use of data on remotely located computers accessed over the Internet. This means that the users can command almost unlimited computing power on demand, that they do not have to make major capital investments to fulfill their computing needs and that they can get their data from anywhere with an internet connection. Cloud computing is an emerging new 21st century technology for efficient and effective use of Information and Communications Technology (ICT).

The definition provided by the National Institute of Standards and Technology (NIST) appears to include key common elements widely used in the cloud computing community: "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 rapidly provisioned and released with minimal management effort or service provider interaction". Fig.1 shows the NIST visual model for cloud computing. NIST defines four Cloud

deployment models (public, private, hybrid and community) [2] which describe the scope of services offered to cloud customers. NIST also defines three service models, Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS), [2,3,4] which are a Service-Oriented Architecture (SOA) that describes the type of services provided by the cloud at different levels of abstraction. In addition, NIST describes a number of essential cloud computing characteristics [2] which includes on demand self services, broad network access, resource pooling, rapid elasticity and measured services.

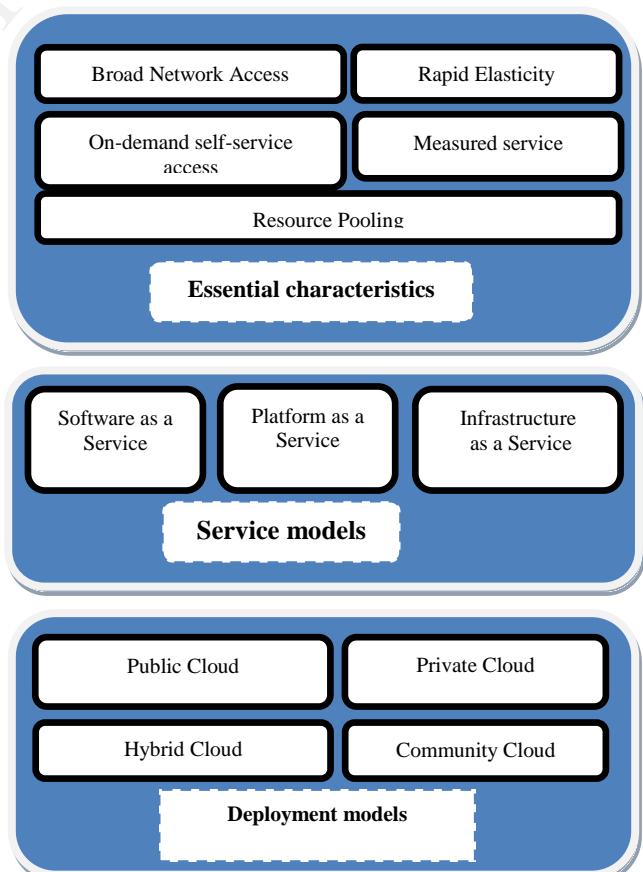


Fig. 1 NIST visual model for cloud computing[2,5]

Cloud computing is the next big step in the evolution of computing and the internet. The broadband revolution sweeping Africa and the continent's reputation for innovation add up to tremendous appetite for services that will drive this evolution. Looking ahead, the internet of everything represents the largest online trend today. As more people, things and devices connect to the internet in Africa, more data from more places will be introduced across corporate and service provider networks, which will open up new opportunities and increased demand for the Cloud. According to the report by [6], Nigeria lags substantially behind, with only 36 percent of businesses here currently using the Cloud while South Africa has about 50 percent of her small and large businesses that use cloud services, while a slightly lower proportion – 48 percent – are using the Cloud in Kenya but it is expected that Nigeria will overtake South Africa by the time the myriads of challenges, such as security and reliability, facing Nigeria's companies usage of cloud computing are addressed and users' confidence is increased. This is reasonable because Nigeria has more number of small and large companies than South Africa.

According to [7], cloud computing holds the future for sustainable socio-economic development for Nigeria if fully adopted and implemented. Author in [7] states that the benefits of cloud services from technology point of view are enormous. These benefits include replacement of data centres previously run and managed by ICT departments of public administrations, commercial banks and other private corporations using cloud computing services at far lower cost than equipping, running and maintaining data centres in Nigeria. Equipping, running and maintaining data centres in Nigeria incurs considerable amount of cost, given the fact that data centre owners run on their own generating plants and power inverters to provide 24-hour power supply and backups for disaster recovery purposes. Apart from this they have to provide 24-hour dedicated broadband internet connectivity at high cost. The unprecedented increase of data flow and processing of information over the internet being witnessed by Nigeria, there are fears that if not checked it can have significant environmental impact through energy and water consumptions and generate house gas emission. Cloud computing can mitigate these problems because of efficient use of hardware and use of low-energy data centre servers and green energy. Cloud computing can benefit private and government organisations, including public corporations to successfully replace data centres and other information in terms of reduction of running costs of the agencies. Private individuals, citizens, research institutions and schools can tap into the benefits of cloud computing to have access to arrays of sophisticated but costly software applications at far reduced cost. Business owners, once hooked up to the web, the cost of buying software licenses, purchasing servers and maintaining them is reduced because it is possible to effectively rent these applications from a third party on the cloud. In spite of these benefits and prospects of cloud computing in Nigeria, there are a lot of identifiable challenges confronting its full adoption and implementation and this has made a good number of private corporations, government Ministries Departments and Agencies (MDAs) to slow down on the adoption and implementation of cloud

computing services and technology. Cloud storage is a model of networked enterprise storage where data is stored in virtual pools, like say in the sky, hence the term "cloud storage" because your data is almost literally in the air as depicted in Fig. 2. It is a unique service model that maintains, manages and backs up data remotely and is made available to a user, and multiple users over a network regardless of the device, time-zone or location.



Fig. 2 Cloud computing model with organization's business devices connected in the air [8]

A. Cloud Services and Solutions

We have identified Cloud services and solutions to include the following:

- Backup of data/storage of data,
- Software Development Environment platform,
- Disaster recovery services,
- Provision of specialized software applications and solutions e.g. Cloud service provider can provide an integrated platform and solution for commercial banks to perform daily account reconciliations amongst the banks and these can save significant costs for the individual bank,
- Leasing of computer CPU airtime, hard disk space etc. to private individuals and organisations by cloud service providers. A typical example is hiring of computing,
- hardware (servers' hard disk space, ram, Operating System, CPU and internet 24-hour services) for running automated Forex software and robots for Forex trading clients who may not have the facilities and resources to do so,
- Leasing computer server facility,
- Website hosting services for storing of website files and documents,
- Internet and satellite services etc.

II. CLOUD COMPUTING ARCHITECTURE

According to [9], Cloud computing architecture refers to the components and subcomponents required for cloud

computing. These components typically consist of a front end platform (e.g. fat client (Personal Computer), thin client (web browser), mobile device), a back end platforms (servers, storage), a cloud based delivery or control node, and a network e.g. Internet, Intranet, Intercloud. All of which combined makes up cloud computing architecture. A typical cloud computing architecture is depicted in Fig.3. There are three (3) types of cloud models that can be adopted for cloud computing namely:

- *Public cloud,*
- *Private cloud and*
- *Hybrid cloud models [10].*

A Public cloud is a model which allows user's access to the cloud via interfaces using mainstream web browsers. It is typically based on a pay-per-use model, similar to a prepaid electricity metering system which is flexible enough to cater for spikes in demand for cloud optimisation. This helps cloud clients to better match their IT expenditure at an operational level by decreasing its capital expenditure (CAPEX) on IT infrastructure. But public clouds are less secure and are prone to all sorts of security vulnerabilities and breaches especially from cyber hackers who have moved into Nigeria cyber space en masse. Private Cloud is set up within an organization's internal enterprise data center. It is easier to align with security, compliance, and regulatory requirements and provide more enterprise control over deployment and usage. This is the type of Cloud model that is very popular in Nigeria but the cost of equipping, running and maintaining this model is very exorbitant and it is already eating deep into both capital expenditure (CAPEX) and operating expenses (OPEX) of most enterprise business organisations in Nigeria including governments'. Hybrid Cloud is a private cloud linked to one or more external cloud services, centrally managed, provisioned as a single unit, and circumscribed by a secure network [10]. It provides virtual IT solutions through a mix of both public and private clouds. Hybrid cloud provides more secure control of data and applications and allows various parties to access information over the internet. It also has an open architecture that allows interfaces with other management systems.

III. THE CHALLENGES FACING CLOUD COMPUTING IN NIGERIA

Nigeria companies and companies operating in Nigeria are increasingly becoming aware of the business value that cloud computing brings and are taking steps towards transition to the cloud. A smooth transition entails a thorough understanding of the benefits as well as challenges involved. Like any new technology, the adoption of cloud computing is not free from issues. These issues are putting fear in some of the companies to fully adopt and implement cloud computing. We have identified the most important challenges affecting the full implementation of cloud computing in Nigeria and security/privacy issues is the most daunting of all the identified challenges. These challenges are as follow:

1. *Security and privacy issues,*
2. *Lack of broadband internet connectivity,*
3. *High cost of broadband internet,*
4. *High Bandwidth costs,*
5. *Lack of high quality data centres,*
6. *Frequent power outages,*
7. *High cost of IT services,*
8. *Interoperability and compatibility challenges,*
9. *Standardisation challenges, and*
10. *Lack of enabling law or bill to protect cloud data where it is domiciled and a host of other challenges.*

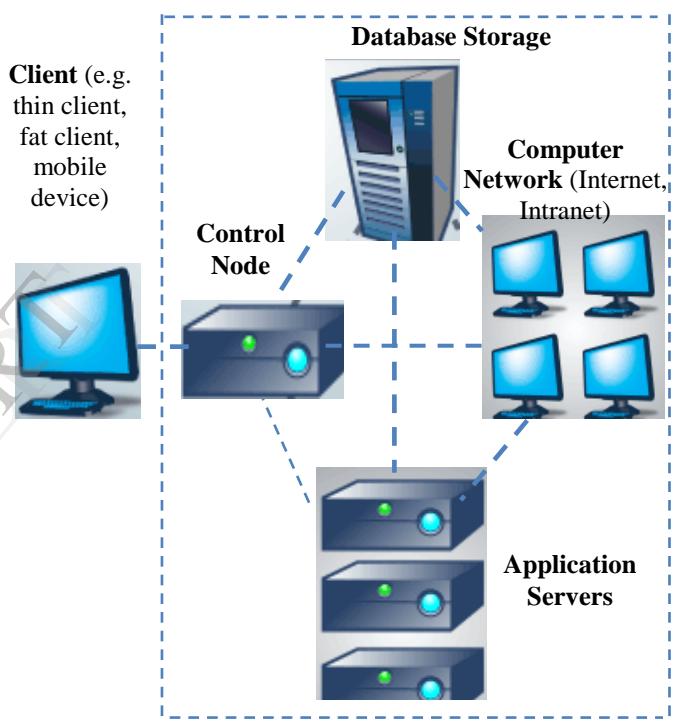


Fig. 3. A typical cloud computing architecture

IV. PROPOSED FRAMEWORK TO IMPROVE AND ACCELERATE CLOUD COMPUTING SERVICES/SOLUTIONS IN NIGERIA

Cloud computing has started attracting the interests of business communities as well as government but there is still no implementation framework in place that can address most of the daunting challenges pointed out in section 3 of this paper. So there is need for a holistic implementation framework that can tackle most of the identified challenges so that cloud computing technology will become adopted and successful in Nigeria. In this section, we present an implementation framework that can tackle the identified

challenges and this framework is sub-divided into the following:

- A. *Data and Information Security,*
- B. *Broadband Internet,*
- C. *Bandwidth cost reduction,*
- D. *Power electricity supply efficiency,*
- E. *Electronic Payment,*
- F. *Standardisation*
- G. *Interoperability/compatibility, and*
- H. *Legislation.*

A. *Data and Information Security*

Security of data and information over cloud networks, i.e., privacy, integrity and confidentiality of transactions is the biggest fear of corporate and private potential cloud customers in Nigeria. The biggest challenge in cloud computing is to successfully address the security and privacy issues associated with their deployment. In this paper we propose a data and information security model that can tackle data and information security challenge if well implemented in Nigeria. Fig.4 depicts the proposed security framework in which cloud service providers (CSPs) operating as either IaaS or PaaS or SaaS have to pass through a security zone and thereafter provide a user interface (either as IaaS, PaaS or SaaS) that is secured for connectivity by cloud customers which can be corporate or private or government. The units of this proposed security model are discussed in the following sub-sections.

1.) *Verification and Validation (V&V) Unit*

This unit is required in cloud computing not only to authenticate users but also to ensure the correctness of data and services on the cloud. The importance of this security component is due to the fact that cloud computing environment is accessible by multiple consumers and providers who wanted to use or provide several services and applications. CSPs need to prove to the users that the services and data are valid using, for instance, appropriate signature algorithms. Consequently, users will be able to verify the authenticity of the data and services made available to them through such type of digital signature. This security component can also employ techniques such as One Time Password (OTP) [2,11] and 2FA [2,12,13].

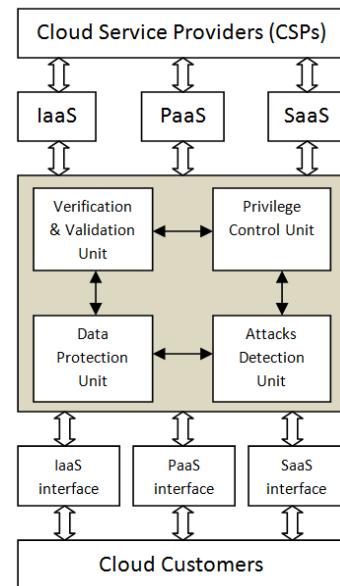


Fig. 4. A Proposed Cloud Computing Security Model [2]

2.) *Privilege Control Unit*

This security unit is necessary to control cloud usage by different individuals and organizations. It protects users' privacy and ensures data integrity and confidentiality by applying a collection of rules and policies that control who has the authority to do what on the cloud. Cloud users are granted different levels of access permissions and resource ownerships based on their account type. Only authorized users can access the authorized parts of the encrypted data through identity-based decryption algorithm. For example, in a healthcare cloud not all practitioners have the same privileges to access patients' data, this may depend on the degree to which a practitioner is involved/specialized in treatment; patients can also allow or deny sharing their information with other healthcare practitioners or hospitals [2,14]. Encryption/Decryption algorithms [15] such as AES [2,16,17] and RC4 [2,18] can be employed by this component to achieve confidentiality of information.

3.) *Data Protection Unit*

Data stored in the cloud storage resources may be very sensitive and critical, for example, clouds may host electronic healthcare records (EHR) which contain patients' private information and their health history [2, 19, 20]. They may also store critical banking information (e.g., client account numbers, balances and transactions) or national security information. A cloud security model should protect these data from loss or damage by providing secure storage servers. These servers should also secure data retrieval and removal from the cloud. Securing data storage and processing is important since cloud users have no idea about data location. Techniques for data protection such as truncation, reduction, obfuscation, and others can be used in this security component. Encryption techniques can also be employed for data security. Hash functions and Message Authentication Code (MAC) can be employed in this unit to provide data integrity.

4.) Attacks Detection/Prevention Unit

Clouds are vulnerable to many attacks and malicious behaviours that threaten both data and physical and virtual computing resources of the cloud. Basically, any set of actions that threaten the cloud security requirements (e.g., integrity, confidentiality, availability) are considered to be attacks. Attacks detection and prevention components should be installed within the cloud security system to protect cloud resources from various anomalies. For example, denial-of-service attacks should be reduced to the minimum to guarantee the maximum availability of business, governmental, health and other critical information and services. This can be achieved by deploying technologies that provide high availability such as dynamic server load balancing and active/active clustering [2]. Standard Distribution Denial of Services (DDoS) mitigation techniques such as synchronous cookies and connection limiting can also be used. Clouds should also be provided by the next generation of intrusion detection systems and firewalls in order to protect their resources from intruders, viruses and malware.

B. Broadband Internet Connectivity

The success of cloud computing depends wholly on the infrastructural availability such as broadband internet connectivity and availability. Broadband internet availability and affordability are key factors to the successfully deployment and operation of cloud computing platforms and services. In Nigeria presently, with the recent rollout of GSM 3.5G data services such as High Speed Packet Access (HSPA), cloud computing services can be more efficient but HSPA subscriptions in Nigeria currently is still unaffordable. Besides, HSPA networks are not available in the major towns and villages in Nigeria except the States' capitals. Worldwide Interoperability for Microwave Access (WiMAX), especially mobile WiMAX, and Wireless Fidelity (Wi-Fi) can be integrated with GSM so that broadband connectivity will be cheaper for subscribers in remote villages and towns. Data Service providers in Nigeria such as MTN, Globacom, Airtel and Etisalat can reduce very high tariffs currently being charged customers in Nigeria so that it will make cloud computing affordable. With the expected changes the data networks and subscription rates in Nigeria, GSM HSPA with WiMAX, Wi-Fi integrated with GSM, a new regime that can provide more efficient and affordable broadband internet connectivity to power cloud computing services all over the country will be achievable.

C. Bandwidth cost reduction

Internet bandwidth can eat up the cost of accessing and maintaining cloud-based service(s) especially where most of the cloud-based services/solutions are not optimised properly to reduce download/access bandwidths by customers over the internet or intranet. Bandwidth cost-reduction techniques can be employed by the cloud service customers to reduce their bandwidth cost. Some bandwidth reduction techniques are as follow:

- *Use of routers to manage internet bandwidth; some routers allow to bandwidth management, you could set up a lower bandwidth for the Local Area Network (LAN) and connect yourself with the WiFi if possible.*
- *Use of two network cards in one computer; one to connect to the internet and the second to connect to the Local Area Network (LAN). The computer would be sharing the internet with another cloud customer with one network card, and with software like Bandwidth manager, you should be able to control bandwidth consumption on the internet as you share the internet with another cloud customer.*
- *Use Quality of Service (QoS) to reserve bandwidth; QoS stands for quality of service. It is a bandwidth reservation mechanism that was first introduced in Windows 2000, and it's still around today. If you have applications that require a specific amount of bandwidth (such as a video conferencing application), you can configure QoS to reserve the required bandwidth for that application. The bandwidth reservation is in effect only when the application is actively being used. At other times, the bandwidth that is reserved for the application is available for other uses [21].*
- *Aggressive scan of the computer for malware to cut down their drain on internet bandwidth; Malware can rob an organization of a tremendous amount of bandwidth by turning Personal Computers (PCs) into bots.*
- *Use of hosted filtering; hosted filtering saves a great amount of bandwidth for organizations that operate their own mail servers in-house. With hosted filtering, your MX record points to a cloud server rather than to your mail server. This server receives all the mail that's destined for your organization. The server filters out any spam or messages containing malware. The remaining messages are forwarded to your organization. You can save a lot of bandwidth (and mail server resources) because your organization is no longer receiving spam [21].*
- *Use a proxy cache; a proxy cache can help limit the amount of traffic created by web browsers. The basic idea is that when a user visits a web site, the contents of the page are cached on a proxy server. The next time that person visits that web page, the content does not have to be downloaded because it already exists in the cache. Using a proxy cache not only saves bandwidth, but it can give users the illusion that your Internet connection is much faster than it really is[21].*
- *Throttling cloud backup applications; if you're backing up your data to the cloud, check to see*

whether your backup application has a throttling mechanism. An unthrottled cloud backup solution will consume as much bandwidth as it can. This might not be a big deal if you're backing up small files (such as Microsoft Office documents) throughout the day. But when you first begin backing up data to the cloud, an initial backup must be created. I have seen this process last for months, and if left unchecked, it can have a major impact on your Internet bandwidth [21].

- Blocking of access to content-streaming websites which eats up large chunks of internet bandwidth. Websites that have serves multimedia contents such as audio, video, flash animations that consume a great amount of internet bandwidth.
- Use of client-server paradigm such as the "Propel architecture" as depicted in Fig.5 can save great amount of bandwidth while using web browsers. Propel leverages a cloud-based network of content acceleration servers to dramatically reduce the amount of data required to view web pages [22]. Fig.5 depicts the components of the Propel client-server architecture, and how they interact. The Propel client server software ("Propel Client") runs in the background on the user's PC / Mac as a local proxy. The Propel Client maintains a persistent connection to the Propel Network in order to eliminate the connections that need to be established every time the browser initiates a request. The Propel client decodes and caches the content it receives from the Propel Network before sending it to the Web browser thereby cutting down on the usage of internet bandwidth.

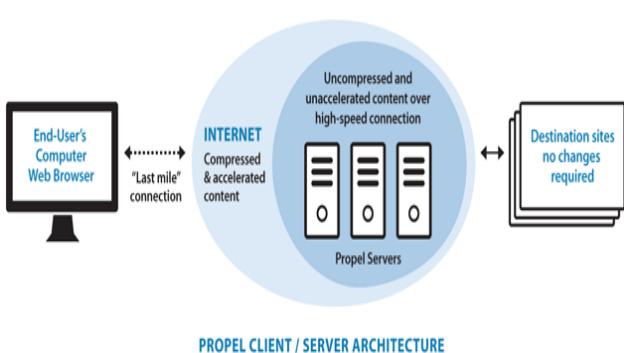


Fig.5. Propel Client Client/Server architecture[21]

D. Power electricity supply efficiency

Presently in Nigeria, efficient and uninterrupted public power supply is not available. The present government has made some efforts to solve this problem but high-level of corruption in the system has stalled the efforts from yielding visible results. We propose that for Cloud Service Providers (CSPs) in Nigeria to succeed in providing efficient and affordable cloud services to customers, they need to invest commensurately in alternative power supply systems such as

solar power systems, inverters etc; use of electricity generators to provide cloud services will make the services very expensive and unaffordable.

E. Electronic Payment

Electronic payment (Epayment) is the key towards commercialization and monetization of cloud services. Recent Electronic payment platforms in Nigeria powered by Etransact and InterSwitch can be helpful but there has been lots of security challenge posed by hackers and online criminals in the usage of these Epayment platforms in Nigeria. For electronic payment to be reliable and acceptable, we advise that the following security

F. Standardisation

Cloud Service Providers (CSPs) that must operate in Nigeria must be made to follow standard rules and regulations. This is to ensure consistent and efficient cloud services and operations where customers will have value for their money. Government should set up a regulatory agency empowered to define the standards, enforce them and penalize defaulting CSPs so as to serve as deterrent to others.

G. Interoperability/compatibility

Interoperability is defined as the ability of two or more components or architecture or infrastructure to work together (interoperate). Cloud interoperability refers to the ability for multiple cloud platforms to work together or inter-operate. A key driver of an interoperable cloud computing ecosystem is to eliminate proprietary "API Propagation" whereby each new cloud service provides their own unique set of web services and application programming interfaces. Simply, the goal of cloud interoperability is to make it easier to use multiple cloud providers who share a common set of application interfaces as well as a consensus on the terminology / taxonomies that describe them. For cloud computing to work successfully in Nigeria, each cloud service technology of a cloud service provider (CSP) should be able to interoperate with service technologies of other cloud providers (CSPs). Standardization described in section F of this paper should make cloud interoperability happen in Nigeria. Cloud compatibility means that user application and data will always work the same way regardless of the cloud service provider or platform, internally or externally, open or closed; this will guarantee smooth and seamless working experience for the cloud users or subscribers.

H. Legislation

Government should pass a legislative bill on cloud computing services in Nigeria; the bill will empower the regulatory agency to sanction and penalize defaulting CSPs and other who-would-be troublemakers. This is necessary so as to protect huge public and private investments that will come to Cloud computing and also to restore investors' confidence.

V. CONCLUSION

In this paper, we reviewed the enormous benefits cloud computing holds for Nigerian economy. We also identified and reviewed the challenges facing smooth and successful adoption and implementation of cloud computing in Nigeria of which security is of the greatest concern. We thereafter proposed implementation framework for cloud computing to take care of the enumerated problems facing cloud computing in Nigeria especially security and privacy questions with regards to deployment and operation of cloud computing platforms and services.

We believe that if these challenges are addressed holistically the benefits of cloud computing will be fully exploited by Nigeria.

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