



## **CLOUD COMPUTING IN THE DEVELOPING COUNTRIES: ARCHITECTURE, CHALLENGES, SECURITY, BENEFITS AND PROSPECT.**

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### **Abstract**

*Cloud computing comes into focus only when you think about what it always needs: a way to increase capacity or add capabilities on the fly without investing in new infrastructure, training new personnel, or licensing new software. Cloud computing encompasses any subscription-based or pay-per-use service that is in real time over the internet which extends its existing capabilities. In this paper, the general benefits of cloud computing are discussed. Then the challenges in general perspective and the challenges in Nigeria. The way forward to the challenges of cloud computing in Nigeria and the recommendations were finally discussed.*

**Keywords:** *Cloud computing, challenges, security, Infrastructure-as-a-Service, Platform-as-a-Service, Software-as-a-Service*

### **INTRODUCTION**

Access to eLearning and other learning resources is fast increasing among inquisitive learners around the globe, but this is made possible if these resources were placed in a location that can easily and affordably be accessible to the user. Cloud computing seems to address these challenges where storage locations were virtually made available to the users.

Offering increasing access to a wider range of learners in a country like India is usually considered one of the main benefits provided by e-learning systems (Mell & Grance, 2009). The National Institute of Standard and Technology (NSIT) defines cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable

computing resources such as Servers, Network, Storages, applications, and services that can be accessible with minimum management effort or service providers interaction, (NIST, 2009).

Many authors define cloud computing in a different but all scaled down to similar concept and understanding; some of which are:

**Cloud computing** involves the dynamic provisioning of IT capabilities (hardware, software, or services) from third parties over a network (Knorr, 2021).

**Cloud computing** as an IT infrastructure which evolved as a successful utility computing paradigm for Information and Communication Technology (ICT) resources delivery as a service over the Internet. The adoption of cloud computing spans across industry, government, and academia alike. (Shroff, 2010).

**Cloud computing** as the use of off-site systems to help computers store, manage, process, and/or communicate information. These off-site systems are hosted on the cloud (or the internet) instead of on your computer or other local storage. They can encompass anything from email servers to software programs, data storage, or even increasing your computer's processing power. (netcov.com, 2021)

On general note, the word "cloud" is a term that simply means "the internet." Computing involves the infrastructures and systems that allow a computer to run and build, deploy, or interact with information. In cloud computing, this implies that instead of hosting infrastructure, systems, or applications on your hard drive or an on-site server, you're hosting it on virtual/online servers that connect to your computer through secure networks.

Simply we can define cloud computing as the delivery of computing services: including servers, storage, databases, networking, software, analytics, and intelligence over the Internet ("the cloud") to offer faster innovation, flexible resources, and economies of scale.

## **Methodology**

Researchers have reviewed different literatures on cloud computing as well as factors militating against its use in the developing countries especially Nigeria from published journals and studies by looking at the three (3) service models of cloud computing..

## **OVERVIEW OF CLOUD COMPUTING**

As discussed above cloud computing is the off-site use of hardware and software which is accessed using internet for computing needs.



Figure 1: Cloud computing view

Cloud computing offers **platform independency**, as the software is not required to be installed locally on the PC. Hence, the Cloud Computing is making our business applications **mobile** and **collaborative**.

### **Basic Concept of Cloud Computing:**

Cloud computing, according to Mathias and Baldreck (2011), have specific models that are working behind the scene that makes the cloud computing feasible and accessible to the user. The following are the working models:

1. Service Models
2. Deployment Models

**Service Model:** Cloud computing is based on service models. These are categorized into three basic service models which are -

- a) Infrastructure-as-a-Service (IaaS)
- b) Platform-as-a-Service (PaaS)
- c) Software-as-a-Service (SaaS)

**Anything-as-a-Service (XaaS)** is yet another service model, which includes Network-as-a-Service, Business-as-a-Service, Identity-as-a-Service, Database-as-a-Service or Strategy-as-a-Service.

The **Infrastructure-as-a-Service (IaaS)** is the most basic level of service. Each of the service models inherit the security and management mechanism from the underlying model, as shown in the following diagram:

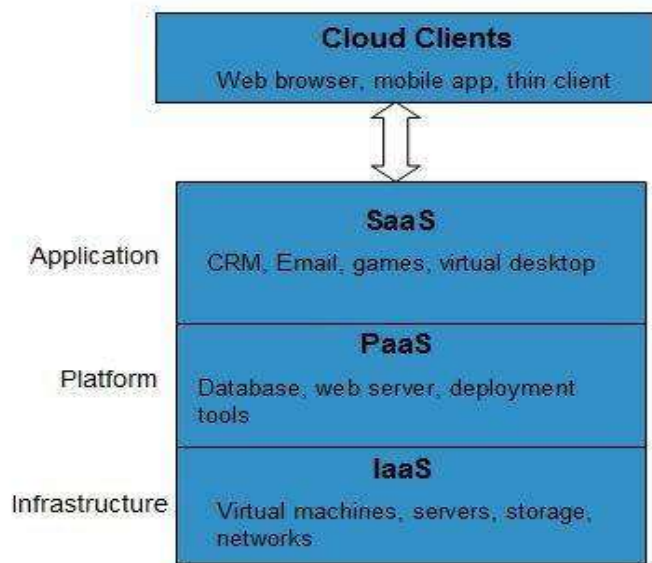


Figure 2: Cloud Service Model

### **Infrastructure-as-a-Service (IaaS)**

**IaaS** provides access to fundamental resources such as physical machines, virtual machines, virtual storage, etc.

### **Platform-as-a-Service (PaaS)**

**PaaS** provides the runtime environment for applications, development and deployment tools, etc.

### **Software-as-a-Service (SaaS)**

**SaaS** model allows to use software applications as a service to end-users.

**Deployment Model:** You build and manage the cloud deployment model. The cloud deployment model represents the exact category of cloud environment based on proprietorship, size, and access and also describes the nature and purpose of the cloud. Cloud have four types of access:

- a) Public cloud
- b) Private cloud
- c) Hybrid Cloud
- d) Community Cloud

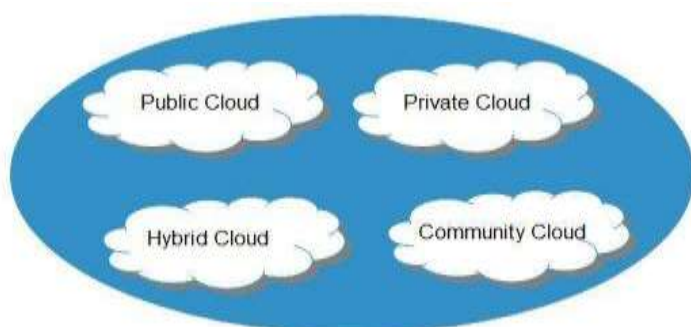


Figure 3: Cloud Deployment Model

### **Public Cloud**

The **public cloud** allows systems and services to be easily accessible to the general public. Public cloud may be less secure because of its openness.

### **Private Cloud**

The **private cloud** allows systems and services to be accessible within an organization. It is more secured because of its private nature.

### **Community Cloud**

The **community cloud** allows group or organization to access systems and services.

### **Hybrid Cloud**

The **hybrid cloud** is a mixture of public and private cloud, in which the critical activities are performed using private cloud while the non-critical activities are performed using public cloud.

## **BENEFITS OF CLOUD COMPUTING**

Cloud Computing has unlimited benefits (Mell & Grance, 2009), which include:

1. Reduce Local Storage:

One can dynamically allocate storage space on demand, access data anywhere through the Internet and no need to care about data consistency between computers or about data loss due to hardware damage since it is independent of local storage.

2. Variety for end user devices:

User can easily access cloud service through small devices with unlimited computing power anywhere which are intelligently managed through cloud.

3. Performance:

Using the cloud, PaaS supports the capabilities, distributes jobs to idle resources, remove jobs from the overloading resources and distributes data to storage system with load balancing

4. Security:

Authorization can be used to control the user's access right and reject malicious requests, establishes or confirms something or someone as authentic and limits the malicious behaviors when detected.

5. Scalability:

Provide scale-out compute/storage capability of handling very large amounts of application/data.

6. Availability:

Provide the ability of failure tolerance such that application or service would not stop on failure.

7. Manageability:

This lets applications run continuously while minimizing the administrative effort required. In particular, customers do not worry about Windows patches

8. Performance:

Provide load balancing to spread request across Web role instances and support parallel processing with Worker role instances.

9. Accessibility and Portability:

Cloud controls and monitors running instances through the web portal or the programming APIs and allows access to services using any devices, anywhere, continuously with mobility support and dynamic adaptation to resource variations

## **CHALLENGES OF CLOUD COMPUTING IN GENERAL PERSPECTIVES**

A growing technology like Cloud Computing, should be expected to have lots of challenges before it fully matures. These challenges can be viewed in African as well as Nigerian context.

### **Cloud Challenges in Africa**

Mathias and Baldreck (2019) considered the following as the African Cloud Issues:

1. Security and Privacy issues:

The cost-effectiveness offered by cloud computing has led to a growth in cloud interest, but data security and privacy remain the main concern in various parts of African countries like South Africa, Tanzania and Nigeria.

2. Infrastructure:

Most rural communities in developing countries lack basic infrastructure such as roads, telecommunications, electricity, and water which are the backbone of any development initiatives.

3. Devices:

Most households in developing countries do not possess a personal computer and they rely on mobile devices to access the internet.

4. Internet coverage

Internet coverage in developing countries, like Nigeria, is still a challenge due to lack of infrastructure or dwindling services offered by the network operators. This causes a digital divide in African countries.

### **Challenges of cloud computing in Nigeria**

Hindrances to the success of cloud computing as an alternative for the provision of computing services lie primarily in issues facing consumers of cloud (Ekundayo & Ajayi, 2015). These challenges are often related to cloud interoperability, security and trust, and contractual complexities.

The following provides a summary of the key challenges that must be addressed in Nigeria:

1. **Transitioning existing software and data to the cloud may be too expensive and technically challenging to undertake** - this is particularly true in situations that involve legacy or non-standard software systems and data stores. Transition to the cloud in some of these cases may require replacing the software with a modern cloud-ready design and extracting the data into a cloud based data store.

2. **Lack of cloud Interoperability and contractual ‘lock-in’** - Cloud interoperability issues arise when a software application and related data that are hosted in a cloud need to be moved to a different cloud provider (e.g., to reduce cost, improve service they provide, reduce security and availability risks).



**3. Data security and trust is a major concern** - Companies and consumers often do not want to store their data in the cloud due to a lack of trust and the risk of exposing their data in an un-trusted environment. In addition, companies and government agencies are often bound by data sovereignty concerns to host their application and/or data within specific geographic boundaries.

**4. Quality of Service (QoS) is difficult to monitor and maintain** - Existing software systems typically consist of different parts and subsystems, such as Web frontend, rich client application, business services, workflows, database layer or message queuing. Such systems often have rigid *QoS requirements* in terms of performance, dependability, security and trust. *Monitoring and enforcing* those QoS requirements is a key challenge to fulfil Service Level Agreements (SLA) between the cloud application owner and the customer.

**5. Frequent (re)assessment is required to keep maximizing cloud benefits** - Different cloud providers offer similar services at different prices; also, often these prices are subject to frequent change. While one provider might be cheap for offering terabytes of storage, renting powerful VMs might be expensive. Therefore, a key challenge will be to *optimize this trade-off* by maximizing the SLA fulfilment while minimizing the cost.

### **The way forward to challenges of cloud computing in Nigeria**

The cloud has indeed become a compelling adventure and good news for start-ups and small business, particularly business in developing countries like Nigeria.

Experts identified and emphasized several challenges, opportunities, risks and benefits in cloud computing that will significantly impact on the operations of government, its services to the citizenry, regulatory bodies, businesses, Software practitioners, Education sector, and the young population and generate an overall effect on the Nigerian Economy in the educational sector in the very near future.

1. Stakeholders identified that Cloud Computing will grossly impact on and advised on the strategic importance of reviewing ICT Curriculum at all levels and organizing special certification training for ICT Lecturers and Teachers and support services at all level in the Education sector.
2. Government is advised and severally encouraged to facilitate the building of massive ICT Knowledge capacities and capabilities and explore the



windows of opportunities presented by Cloud Computing, ensuring that Nigeria leverages on Cloud Computing Infrastructure as a service(IaaS), Platform as a service(PaaS) and also, Software as a service(SaaS). In particular, Software developers should focus on the Mobile-web market.

3. It should be noted that Cloud Computing offers great opportunity to Software entrepreneurs because it is easy to scale, it does not require investment in massive infrastructure, it offers a global market reach great opportunity for the youths and young population of Nigeria to become entrepreneurs and leverage the global opportunity it offers, emulating examples like founders of Facebook, Google and Instagram. There is need therefore to establish Software Knowledge Parks and Entrepreneur Incubation Centres in strategic locations in the country.

4. The future of and opportunities in the Entertainment Industry with particular reference to the Film and New Multimedia sector has a very huge potential for Nigeria. In this regard, Stakeholders recognized and unanimously agree that Software and Local Content should constitute a strategic part of the emerging entertainment and Film industry such as Nollywood.

5. All States of the Federal Republic of Nigeria should be encouraged to establish a State Framework for Cloud computing to ensure the democratization of tools and knowledge and enable everyone to have easy access and right to knowledge and expertise needed.

6. The conference identified major benefactors in the cloud computing business enterprise as Platform owners, Service Implementers or Sustainers and the Content creators. Experts therefore advised that, if Nigeria really wants to benefit from the cloud services, they should strategically consider where they want to play either as services providers, Implementers or content creators levels. In this regards, the Nigeria Software industry was encouraged to study carefully the new model that cloud computing offers and leverage the opportunities in the 21st century.

7. Some of the challenges and concerns of Cloud Computing in Nigeria include but not limited to: ownership and security of data and information on the cloud, Policy implications arising from implementing cloud services, Litigations on Data ownership in the cloud and infringement rights, Interoperability and International Legislation.

8. Then, IT Experts, Community and Stakeholders called on government through Technology Implementing organs such as NITDA and Communication Technology Ministry, and regulatory bodies (CPN) at the conference agreed that the existing policy regimes may be incapable of resolving the imperatives for cloud computing and should therefore be carefully re-considered, reviewed and adopt the best functional, effective, practical and sustainable solutions for implementation.

9. Good infrastructure, Access and availability of broadband to all, access to computer, Education of the youths in the area of software development and the reflection of educational and academic curriculum to reflect practical software development skills are major requirements and critical drivers of cloud computing and its future in Nigeria.

10. The Conference commended the initiatives of the Minister of Communication Technology on the computer-in-school ownership scheme launched by the FG, the proposed connectivity of the Nigerian Universities and Research centres to Research Education Network (NREN) and the building of Technology Incubation Hubs in all the geo political zones of the country as some of the Ministries initiatives that will drive cloud computing in Nigeria.

11. Finally, Experts agreed that the future of Software in Nigeria and the implementation of Cloud services in Nigeria lie in the young Nigerian population who should be encouraged to embrace cloud computing at the early stage of their life, so as to become the nation's code warriors.

### **Recommendations**

1. That there is need to proactively launch a national consciousness awareness initiative on cloud computing as a new and revolutionary concept in Information Technology which, if intelligently applied with strategic vision, it is capable of taking Nigeria to its pride of place among the global knowledge giants in the technology ecosystem.

2. Government is called upon to establish a national Cloud Strategic Framework, ensuring that the pursuit of Cloud Computing initiative is classified as a significant national ICT asset and project that will guarantee the survivability of the Nigerian nation and make her globally competitive. Government is advised and severally encouraged to facilitate the building of massive ICT Knowledge capacities and capabilities and explore the windows of opportunities presented by Cloud Computing, ensuring that Nigeria leverages on Cloud Computing Infrastructure as a service (IaaS), Platform as a service

(PaaS) and also, Software as a service (SaaS). In particular, Software developers should focus on the Mobile-web market (Armbrust, M. & Armando, F., 2009)

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7. Given our plans for e-Government and the increased use of ICT by government Ministries, Departments and Agencies (MDAs), this is an unsustainable practice that must be managed. A Government cloud will provide some economic savings, In view of this, Galaxy Backbone is building a major cloud computing infrastructure with the aim of bringing significant cost savings to the running of the federal government. The government cloud, according to the CommTech Minister is expected to not only to improve cost savings but drive efficiency and productivity across all its MDAs (businessdayonline.com, 2020).

## **CONCLUSION**

The major problems and milestones of Cloud Computing in Nigeria are; the pioneers and key players, infrastructure and investment, awareness, jobs, patronage, security, connectivity and cost analyses.

Cloud computing offers worldwide access to virtually unlimited processing power, new storage capabilities and capabilities that are being used to create virtual web platforms, where humanity today and in the future will live out large parts of their everyday lives, educating, working, shopping and talking to private networks of friends and relatives (Creeger, M., 2009).

Cloud computing technology is still relatively young in terms of maturity and adoption. The expectation is that it will undergo several changes in the future, in terms of resources, issues, risks, and ultimately best practices and standards. However, there are some sought of great advantages it can potentially provide value for institutions of higher education. On-demand services can reverberate positively with the current university tight budgets across the nation and other parts of the world.

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