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Cloud Computing in Healthcare Services in Nigeria: Applications, Opportunities, Challenges and Future directions

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Abstract:

With high growth of data produced by the healthcare services, Nigeria requires the introduction of advanced techniques and resources in terms of computational and storage capabilities regarding the managerial, administrative, and management aspects, physicians or manage patient data, analysis, diagnosis, and so on. Cloud computing has emerged as a transformative technology in the healthcare sector globally, offering innovative solutions to improve efficiency, accessibility, and patient care. In the context of Nigeria, a country facing unique healthcare challenges, the integration of cloud computing in healthcare services presents significant opportunities. This paper delves into the applications, visions, challenges, opportunities, and future directions of cloud computing in the context of Nigerian healthcare. As a country striving to overcome unique healthcare hurdles, the adoption of cloud technologies presents a promising avenue for transformative change. Healthcare industry generates lot of data (big data) in the form of Lab test results, Patient registration, and day-to-day monitoring data. Lot of storage may be required to store this data. Cloud computing environment enables to use several real-time client-server machines to fulfill the requirement of storage phenomenon. Equitable access to health services is one of the health justice criteria as proposed by World Health Organization (WHO). Several medical articles and journals from Science Direct, google scholar, academia, and Research Gate directly related to the applications of cloud computing in health system were used during the review of this paper. It was found out that, the applications of cloud computing in health system, including telemedicine, public and personal health, clinical and hospital information systems, medical decision support system, related healthcare, secondary use of health data, serve as different types of specialized software used to analyze gene sequences and archive huge biological data. Usage of cloud computing in health systems not only makes health services more affordable but helps the nation to achieve health equity among the citizens. It has eased the access of applications and data from any worldwide location from any device with internet connectivity.

Keywords: *cloud computing, healthcare services, applications, opportunities, challenges, future direction, telemedicine*

1. Introduction

The Nigerian healthcare system operates within a dynamic environment characterized by a diverse range of challenges, including but not limited to limited access to medical resources, geographical disparities, and a rapidly growing population. As the nation strives to improve healthcare outcomes and address the unique complexities of its healthcare landscape, the integration of advanced technologies becomes imperative. One such technology that holds significant promise is cloud computing. In healthcare services, the application of cloud computing have been proposed as a means for maintaining health records, monitoring patients, managing diseases and cares more efficiently and effectively, or collaborating with peers and analyzing data, The use of such technologies opens the doors to a new age for the health consisting of high computational powerful, efficient data storage, rapid data retrieval, and high interoperability (Carmelo and Roberto, 2013, and Ogirima et al., 2023).

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Fairness plays significant role in health systems and one major popular expectation from sovereign governments is to move toward equity, which according to definition of WHO, means closing the gap between socially, economically, demographically, or geographically categorized groups in term of access to resources, opportunities, and facilities. In the context of healthcare, equity is often defined with impartial access to health and hygiene resources and fairness of health determinants (World Health Organization, 2016). Some studies suggest that investments in ICT in health domain may reduce disparities in the process of care (Lee, 2015). On the other hand, others believe that ICT holds the potential to improving the quality, safety, and equity of health care, but it also has the potential to unintentionally increase disparities in health and health care (Kieschnick and Raymond, 2011).

Most ICT services in healthcare are delivered as e-health service. E-health is the response of modern technology to the health inequity, but if poorly implemented, has a potential for widening the access gap between wealthy people with great access to computers and networks or people who can use these technologies effectively and other people who fall in neither of these categories. This means that a major challenge ahead of E-health is to cross the digital divide between gender, social, geographical, age groups and reach out to people who need the E-health services the most (Eysenbach, 2001; Oh, et al; 2005) Meanwhile, the growing demands for up-to-date healthcare services, which is mainly due to increasing health-awareness of populations, and the often unsuccessful struggle of regional and national administrations to satisfy this level of demand can be alleviated by e-health solutions, but the lack of infrastructure required for such solutions limit their short and medium term potential. For example, Medical Body Area Network (MBAN), which is a good solution for real-time health monitoring, requires massive amount of scalable ICT infrastructure for data storage and real-time processing of information pertaining to millions of patients, which makes it unaffordable for most countries (Lu, et al; 2014).

It is common to describe such massive volumes of complex data with the term “big data”. This term is also closely associated with the methods required for capturing, storing, processing, and managing such massive quantities of data. In health system, the major sources of health-related to big data could be categorized as: (a) payer-provider big data consisting of electronic health records, insurance records, pharmacy prescriptions, patient feedback, responses and (b) genomics-driven big data comprising genotyping and sequencing data (Abbas, et al;2014; Barker and Stuart, 2013). One of the ICT innovations which could solve the health inequity and health big data problems is cloud computing model. The Cloud computing is not a new concept and a Cloud computing is leading to a revolutionary change in business models dated back to 1961 at the MIT Centennial when John McCarthy opined that “computation may someday be organized as a public utility” (Zhanpeng and Yu,2015, Dai, et al; 2012).

Cloud computing is a conceptual model about computer services including a set of servers with remote access to share resources like storages, networks, applications, and platform as services. This model prepares opportunities to centralize data storage and real-time access to resources and services (Mell and Grance, 2011; Wikipedia, 2016). The cloud computing model is composed of five essential characteristics, four service models, and four deployment models. The five essential characteristics are On-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. Three models as service layers of cloud are Data as a Service (DaaS), Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). And finally, four deployment models of cloud are private cloud, community cloud, public cloud, and hybrid cloud.

2. Related works

Cloud computing offers an innovative method of delivering IT services efficiently. The technology can enhance the level of services in healthcare services. This technology-enabled healthcare opportunities, issues, and applications towards medical decision-making, data security and privacy obligations of cloud service providers, health monitoring features, and innovative IT service delivery models with the aid of cloud computing (Ali et al; 2018). Cloud computing delivery is highly efficient, storage is becoming more and more current, and some groups are now altering their data from in-house records Cloud Computing Vendors' hubs that healthcare practitioner are now making use of for information sharing (Abdulkareem et al; 2022). In healthcare, cloud computing is a technology that allows dynamic and flexible computing capability and storage through the demand for healthcare delivery over the internet. With its unique properties such as rapid elasticity, on-demand self-service, and resource pooling, the cloud allows clients to rent online IT resources, platforms, and software services when necessary. Thus, cloud customers can integrate their business applications on a pay-per-use basis, store data, and process and run analytics through the Internet. The technology has wearable sensors that are used to collect a considerable number of vital signs that monitor and diagnose illness using biological data from patients. These biological data can be used in diagnosis, interpretation, and proactive action in the healthcare ecosystem (Molo, et al; 2021).

Cloud computing has been adopted in the most diverse fields and areas of health, such as telemedicine, information management, health management, and bioinformatics. The applications in the field of telemedicine have been used for the direct provision of health care, such as the prescription and treatment of patients, their monitoring, diagnosis, and education. In the area of information management, the access, use, storage, and sharing of electronic medical records or interdisciplinary information repositories stands out. The management of business processes, such as billing or payment of patients, and the assessment of the quality of healthcare against existing standards or regulations are the applications most cited by the studies analyzed in the area of health management. Digital image processing, research, and molecular modeling correspond to the most common

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applications of cloud computing in the field of bioinformatics (Moraisa, et al; 2022).

There are lots of challenges in deploying cloud computing in eHealth due to lack of security, maintenance, culture, infrastructure, and legal laws (Nermeen and Kesmat, 2021). The Challenges of cloud computing in the healthcare sector also includes technological (security, privacy, and interoperability of data, systems data integrity, volatility or even current connectivity infrastructure), human (refer to the lack of skills and technical knowledge of the staff, the resistance and inertia of the various partners, and staff satisfaction with the service provided or used), organizational (culture, lack of leadership, the added value of the service, or its impact on the business model), and environmental (to compliance issues with legal aspects, such as standards, laws, and policies of different jurisdictions) (Moraisa, et al; 2022). Cloud computing in healthcare adoption is slowed down by security and privacy concerns along with legal matters and trust by different stakeholders (Narkhede, et al; 2020).

There are three services provided by cloud computing that are Software as a Service (SaaS), the way of carrying application as a service on the internet is known as software as a service. In place of installing the software on his computer, the user can simply access it via the Internet,

Platform as a Service (PaaS), a development environment or platform is given to the consumers as a service in PaaS, upon which user can deploy their own software and coding. The customer has the liberty to construct his own applications that can run on the provider's infrastructure and Infrastructure as a Service (IaaS), many computing resources are provided by the IaaS in the form of storage, network, operating system, hardware, and storage devices on demand. IaaS users can access the services using a wide area network, such as the internet Figure 1 and 2. The basic examples of cloud computing which are used by general people in daily life are Facebook, YouTube, Dropbox, and Gmail etc. It offers scalability, flexibility, agility, and simplicity that's why its use is rapidly increasing in the enterprises (Srivastava and Khan, 2018).

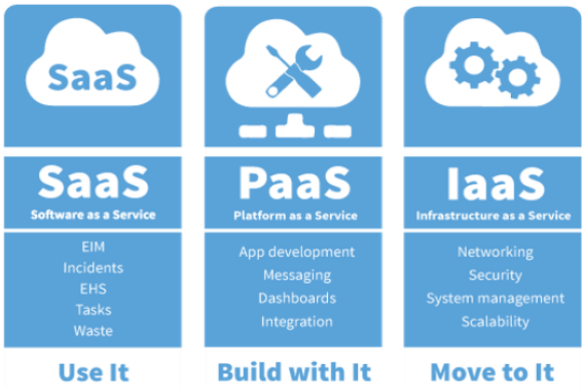

Figure 1: Cloud Computing Services (Srivastava and Khan, 2018)

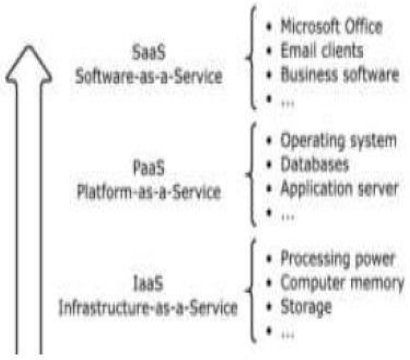

Figure 2: Service Models in a Cloud Computing Environment (Srivastava and Khan, 2018)

Cloud computing layered model was used in various aspects of health system. The notable one in health systems is E-health services capabilities of cloud can alleviate some restriction induced by ICT infrastructure on realization of broader E-health services (Kuo, 2011). Electronic health services are provided in many areas some of which include: Health information system, telemedicine services, personal health record, electronic medical record, and electronic health record (Comyn, 2009). The service layer model of e-health cloud includes:

- Data as a Service: presents data
- Software as a Service: provides software in cloud (clinical Information systems) where consumers such as healthcare providers get access to the software in the cloud.
- Platform as a Service: extends the basic infrastructure with High-level integrated environment to design, build, test, deploy, and update online healthcare applications.
- Infrastructure as a Service: presents physical processing and storage resources.

Broad spectrum of recipients of services from cloud computing in health systems could be: patients, healthcare gjhs.ccsenet.org Global Journal of Health Science Vol. 9, No. 6; 2017 35 organizations, insurance companies, researchers, epidemiologists, etc. (Dai et al., 2012; Kuo, 2011). In the following sections, some of the applications of cloud computing in health systems are presented.

3. Method

Several reviewed articles, numerous research papers from different resources, such as MEDLINE, IEEE, and Science direct, goggle scholar, academia, Research Gate, and even university teaching hospital across Nigeria were consulted. Study was conducted based on the applications of cloud computing in health system. The reviewed study was done to present some important concepts about cloud computing services in Nigeria.

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4. Healthcare Information System as a Service

Apart from the benefits of healthcare information system for healthcare organizations, software and hardware cost, complexity and inflexibility issues of healthcare system have raised a lot. So, the development of low cost technology is essential to reduce the charges. Cloud computing helps to develop and solve various healthcare issues, including the costs. Cloud computing brings significant benefits to healthcare information systems. It can solve various healthcare issues, such as data storage, data transmission, high setup cost, software maintenance, and optimizing resources (Masrom and Rahimli, 2014). For example, in 2012, Yoo et al. managed to combine virtualization technology, a virtual desktop infrastructure, and 400 virtual machines to a construct a cloud within Bundang Hospital of Seoul National University (Korea) to allow managed but easy and pervasive access to hospital information from mobile devices throughout the hospital (Yoo, Kim, Baek, Suh, Chung, and Hwang, 2012). Another example is a work carried out in 2011 by Yao et al. The community cloud-based medical service delivery framework (CMSDF) developed in that work allowed resource exchange between a large general hospital and its affiliated healthcare institutions. They also tested a prototype CMSDF, where a cloud-based virtual desktop infrastructure (VDI) of a large hospital was allowed to share its medical software (as SaaS) with its affiliated healthcare institutions (Yao, et al; 2014).

4.1 Telemedicine in healthcare service

Nowadays, cloud computing is used as ICT infrastructure for telemedicine projects. Telemedicine and cloud computing allows health services to be provided with a lower cost and thus greater availability. In a study in India, researchers studied the implementation of a telemedicine project and reported a number of bugs in the form of low bandwidth or high cost. They developed a cloud-based solution to address these issues (Matlani and Londhe, 2013). In a project in Australia concerning cloud-based telemedicine, the cloud was combined with multiple concepts such as e-appointment, e-consulting, telemedicine, and e-Prescription to enable patients to use the internet for maintaining remote connection with their physicians and discussing their health-related problems. The resulting system allowed the physician to easily access the patient's medical history, files, and medical test results. This system also provided the physician with data regarding the patient's physiological status through body sensor networks. In that work, telemedicine design was implemented as a hybrid system composed of various communication techniques and hardware including web camera for video feed, Microsoft Expression Encoder 4, and also Windows Azure virtual machine as the server, since it allows adequate video or audio processing through live streaming media server (Lu, et al; 2014). Cloud computing offers transparent service, good scalability, and elasticity, support for the pay-as-you-go service model, omni-accessibility, and other features. This paradigm not only lets users enjoy convenient, versatile, efficient services but also relieves them of maintenance. Integrated with smart mobile devices, the telemedicine cloud is a promising approach to pervasive and cost-effective health services. Although many telemedicine systems use advanced cloud computing features, Figure 3 shows, the telemedicine cloud is far from mature.

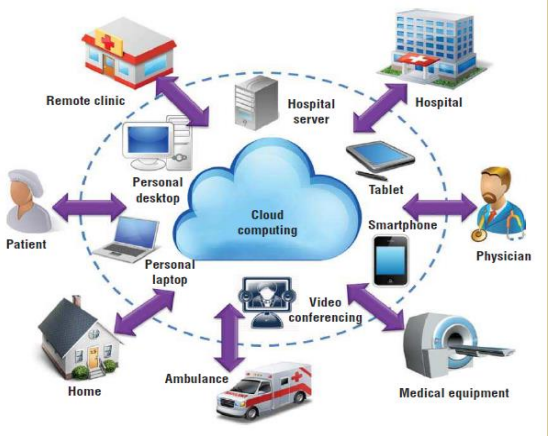

Figure 8: Diverse telemedicine applications based on the cloud computing ecosystem, where all stakeholders can be connected and can take advantage of the shared infrastructure through various means (Lu, et al; 2014).

Cloud computing in healthcare services offers substantial scalability, elasticity, agility, and cost advantages, making it ideally suited for delivering healthcare IT services. In cloud-based electronic health records systems (EHRs), a Web application lets individuals access, manage, and share health information according to their authorization and authentication levels, without any specialized infrastructure. Various patients' information, such as personal details, medical history, living behaviors, lab exams, diagnostic results, and prescriptions, can be effectively and efficiently maintained. Nevertheless, with the sensitive nature of the data involved, EHR applications will impose stringent requirements on the cloud-based solutions, such as securely and efficiently sharing the data among multiple parties.

4.2 Personal Health Record (PHR) in healthcare service

Another high-potential application for the cloud in E-health is to manage access to personal health records (PHR) and Electronic Health Records (EHR). The MyPHRmachines system developed in the Eindhoven University of technology is a combination PHR system and cloud technology, which allows users to access raw PHR database via specialized software and share and analyze the PHR data made available. In the architecture of this system, data and software components are separate but software sharing measures allowing joint use of health-related data

are predicted. Another advantage of this architecture is its ability to delegate access to different users with more flexibility but also adequate security. For example, patients using MyPHRMachines can share selective health information with a physician without needing to worry about improper storage by physician or any third party, as shared data cannot be stored beyond a time limit, and unshared data is securely

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out of reach of third-party software components, services, and specialists (Van Gorp and Comuzzi, 2012). Another cloud-based platform allowing convenient PHR management is the Microsoft HealthVault. This architecture allows patients to store, manage, and share their PHR by providing them with convenient means of importing their health data from a wide range of medical devices into the HealthVault without any need to intermediary tools and software. Once imported, medical data can be easily monitored, managed, and shared through a GUI. This program also possesses advanced sharing features allowing different level of control over shared data, multi-profile sharing, and sharing with designated health organizations, devices, or software applications, all under supervision of data owner. HealthVault can also be embedded into or developed with desktop and mobile applications, as it is based on standard sharing protocols like SOAP, CCR/CCD, and XML and is equipped with programmer APIs (Sunyaev, et al; 2010).

4.3 Clinical Decision Support System (CDSS) as a Service

E-health services and cloud technology can be used as a supplement to Clinical Decision Support system (CDSS). For example, a decision support system can be developed and tested a cloud-based CDSS on a latest information management and sharing framework among medical practitioners for the repository for clinical purpose. This repository may consist of data concerning medical-related diseases and is based on a community cloud hosted by Medical Council of Nigeria for healthcare services. In the framework, the cloud hosts a CDSS rule engine that will enable it to store a limited data set pertaining to primary care patients and preventive care notification to practitioners and other health workers.

4.4 Biological Software as a Service

Some biologic subject areas such as genomics and proteomics have already been overwhelmed with big data. Wining DNA sequencing throughput, in the race between computer speed and DNA sequencing is the evidence. Nowadays cloud computing model solves the problem of big data in biological software. As an example of big data in biology, we can mention the Gen-Bank (NCBI, 2016). The size of data in this repository is over 150 billion nucleotide bases in more than 162 million sequences in 2013 (Schatz, et al; 2010). Using a cloud computing to solve this problem is called “bioinformatics cloud” in some studies. This cloud model delivers a large variety of services from data storage, data acquisition, to data analysis, which in general fall into four categories which are known as DaaS, SaaS, PaaS, IaaS (Dai et al., 2012). Operational samples of each layer are presented in Table1, Including services AWS Public Datasets (Amazon organization, 2016), Eoulsan (Jourdren, et al; 2016), CloVR (National Human Research Institute, 2016). Another example of using cloud in bioinformatics is Azure Blast. Another potential for cloud-based development is in optimization of the BLAST life science algorithm and other data intensive scientific tools in the field of bioinformatics. In case of the BLAST algorithm, pairwise alignments can be carried out independently so parallelization of algorithm is not difficult but rather unaffordable because of large-scale of resources required. With the cloud technology however, there is a better chance for achieving a more readily available large-scale alignment search. One example of this approach is the Azure Blast, which can combine the computing power of thousands of Azure instances running on different machines (Lu, et al; 2010).

4.5 Considerations for Healthcare Facilities before Moving to the Cloud

Healthcare organization have been dealing with growing amounts of electronic records and digital images, would seem a good fit for cloud storage services. Among the reasons for this sudden interest in cloud-based computing and communications are the need for collaboration among the increasing number of remote and mobile workers, several office locations, a desire to improve patient quality of service, and the ever-present goals of improving operational excellence while driving down technology equipment and healthcare management costs.

To help healthcare organizations decide whether they ready to move to the cloud there are a few important points need to consider.

- **Organization Facilities**: Depending on how the health organization operates - whether their information technology infrastructures are distributed between their medical facilities or in a data center, moving to the cloud would help communications, applications, and collaboration between the health organizations. These approaches reduce the need for information technology staff in each facility satellite station, as well as to reduce information technology budget.
- **Infrastructural Preparation**: Most of the current networks at healthcare facilities and their multiple office locations were built years ago. Adopting cloud-based systems, an inadequate infrastructure can quickly collapse due the high network traffic by up-tick in voice, video, and data traffic applications deal with.

4.6 Applications of Healthcare Services of Cloud Computing in Nigeria

Application of Cloud Computing in Healthcare Services in Nigeria has help greatly in technology functionalities such as information processing, availability, and monitoring tools

Opportunities in Healthcare Services in Cloud Computing in Nigeria

The implementation of Cloud Computing in Healthcare Services in Nigeria is beneficial and categories in the following ways:

- **Management gains**: Availability of computing resources on demand has help in quality of service, efficiency, and improvement in decision taking by the stakeholders of the healthcare services in terms of lower cost of new information technology infrastructure when needed.

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- **Security**: More resources available for data protection, replication of data in multiple locations increasing data security and dynamically scaled defensive resources strengthening resilience.
- **Technology**: Reduction of information technology maintenance burdens, scalability, and flexibility of IT infrastructure and advantage for green computing.
- **Legal and ethical issues**: Fostering of regulations by government for data and privacy protection, development of guidelines and technologies to enable the construction of trusted platforms by not-for-profit organizations, and Provider's commitments to protect customer's privacy. Liability of cloud service provider, legal policy, data preservation policy, has been finalized in the initial planning stage.
- **Privacy**: Patient data is highly personal that needs inter-organisational sharing by authoralized practitioners by taking patient consent, authorization through GUI.
- **Reliability**: Healthcare information network has to be ensuring service when demanded without any hardware or software failure with an alternative backup system for emergency applications.
- **Efficiency**: For real-time accessibility, the effectiveness of system has to be properly be addressed to improve resource optimisation.
- **Illiteracy of patient**: Communication barrier between patients and healthcare practitioners particularly in remote areas of developing or undeveloped cities is a major concern. More so, patients with difficulty in the using mobile devices need to the application.
- **Data format:** Patient data at various sections of the hospitals has different formats. Therefore, storing and retrieval issues in a cloud database are reduced.
- **Database management**: Data analysis, data search need to be ensured properly for usability and avoidance of data traffic.
- **Trust:** There must be trust amongst users' and top management regulations to support in adoption of the application of cloud computing healthcare services which enhance user acceptability.
- **Interoperability**: There various university teaching hospitals across the country that manages its own capabilities with independent policies and decisions. Each has formats in primary care and specialty care therefore interoperability needs to be ensured.
- **Energy consumption**: To have a sustainable of cloud computing applications in healthcare services there need to have 24 hours electricity with less carbon footprint.
- **Feasibility evaluation**: There should be an expertise to evaluate its feasibility of the application adoption of cloud computing in healthcare at initial planning stage in other to have a successful usage.
- **Quality**: Patient rush or flow to healthcare services centres as result of quality of service and quality of expectancy which that need to be consider to make the applications user-friendly with less complexity.
- **Availability of resources**: There should be provision of infrastructure, power supply, and internet facilities before the adoption of cloud computing healthcare service.

4.7 Challenges Facing Cloud Computing in Healthcare Services in Nigeria

There are many challenges facing cloud computing in healthcare services growth. The slow adoption of the Cloud Computing model in the health field is mostly due to the following under listed issues below which need to be addressed in order to overcome doubts when moving to cloud and taking advantage of all the solutions and improvements it brings. These include:

- **Storage**: In cloud-based systems, data is often stored in multitier storage media in a distributed manner. A multitier storage system helps to relieve the financial burden by moving data that is less frequently used to a lower, and typically cheaper, tier. However, the lower tier often implies reduced performance or security. As the amount of data grows exponentially, it isn't feasible for administrators to manually move data among tiers. Instead, scalability and availability have necessitated Non uniform I/O speed, and storage capabilities among different tiers pose extra challenges in inter-tier data transmission.
- **Security**: Security has been identified as the top concern when data and computing tasks are outsourced to cloud. Although the telemedicine cloud has the same information assurance and system security as general cloud computing platforms, it must meet stricter security requirements because of the unique nature of medical and health applications. In particular, widely deployed smart mobile devices, such as sensors and monitors attached to the human body, face tighter constraints in developing security solutions. Because of their limited resources, deploying computation-intensive security solutions on such devices is unfavorable.
- **Privacy and Authentication**: Privacy is recognized as one of the most important requirements in eHealth systems. In the cloud paradigm, loss of physical control, heterogeneous environments, and highly diversified applications make the preservation of user information privacy even more difficult. Cryptography-based solutions are insufficient. The most challenging issue lies in the inherent conflict between privacy and usability. To receive the service conveniently no matter where the patient goes, user data must be timely and accessible, and medical service providers must be able to share the information across the network.

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The user data will be manipulated on various platforms and transferred among different networks. The risk of data being exposed to unauthorized parties is high. Meanwhile, accurate patient location information is mandatory, particularly in emergency situations; however, this information can violate privacy requirements by revealing the patients' daily activity routines. Balancing service efficiency and privacy protection is still an open challenge.

- **Regulatory Issues**: In Nigeria, medical practices, like e-health or telemedicine is subject to regulatory oversight through restrictive licensure laws. The goal of such licensure is to ensure that practitioners comply with various standards and regulations across lines of medical practice.
- **Hybrid Mobile Telemedicine Cloud Architecture**: Although mobile cloud computing promises ubiquity, richer applications on mobile terminals, and lower costs for using powerful computing resources, in the context of a mobile telemedicine cloud, it's unclear how it can balance the benefits of mobile devices (convenience, versatility, and efficiency) with powerful cloud services. Although mobile devices are obviously not designed for data or computation-intensive tasks, outsourcing all raw data to remote cloud servers isn't always optimal. Not only is the communication expensive in terms of energy consumption, but transmission delays can be a concern in real-time applications. Instead of a pure cloud-based paradigm, therefore, we need an architecture that can partition and distribute the workload into multiple execution points.
- **Data Interoperability**: Establishing telemedicine in the cloud has gone drastically beyond the deployment of an individual medical device. A cloud-based telemedicine system will consist of highly intricate networks of diverse medical devices, diagnostic equipment, communication tools, network ICT infrastructure, and computer systems, all cooperating to provide high-quality care to patients. It has to meet International Telecommunications Union (ITU) set of standards has facilitated wide-scale videoconferencing interoperability.
- **Risk management**: The main challenges include lack of trust in data security and privacy by users, organizational inertia, loss of governance, and uncertain provider's compliance. Trust is at the heart of the resistance that many customers have to the cloud. Concerns arise when their sensitive data and mission-critical applications move to a cloud computing paradigm where providers cannot guarantee the effectiveness of their security and privacy controls.
- **Lack of knowledge**: This affect the deployment of cloud computing when the personel involved do not have enough knowledge to deploy the necessary infrastructure
- **Cultural resistance, religious beliefs, and values**: Medical industries to share data and change traditional ways of working is a common management challenge to adopting cloud computing. Medical practitioners need to consider patients' cultures, religion, and other related values on attitude toward application of cloud computing in healthcare Services. For example, religious leaders preach against the usage of technology for the diagnosis and treatment of patients for fear of hacking their private information.

5. Discussion

Based on a study about the translational biomedical informatics in the cloud, the applications are categorized in 4 segments as follows: Bioinformatics; Imaging informatics; Clinical informatics; and Public health informatics (Chen, et al; 2013). The application of cloud in the healthcare scope is divided into six categories referred to as: Telemedicine/tele consultation; Medical imaging; Public health and patients' self-management; Hospital management/clinical information systems; Therapy; and Secondary use of data (Griebel, et al; 2015). The use of cloud computing in the healthcare system can be classified in two subject areas which include e-health services, and bioinformatics services. Software researches this days are in the form of total systems are mainly implemented as web application (Tabatabaei and Sadighi, 2008). The opportunities provided by the cloud technology in healthcare systems include better utilization of ICT resources and thus better quality of healthcare services, provision of pay-as-you-go pricing models allowing reduced need for initial capital investments in the ICT infrastructure, and provision of efficient and scalable tools for sharing and management of massive volumes of medical information such as EHR and medical files distributed across E-health systems (Lu, et al; 2014). The challenges of a modern e-health system (such as scalability, agility, cost-effectiveness, and ubiquitous availability of medical information) requires extensive collaboration among multiple domains of healthcare and informatics, which according to Researchers or experts, can be achieved through innovative cloud-based solutions, and thereby bring about significant changes in the quality and availability of health care services, and speed, universality and ease of health care research (Abbas et al., 2014; Kuo, 2011 and Ogirima et al., 2023). However, the cloud computing services in Nigeria face a lot of challenges such data security, privacy, and management.

6. Findings

The findings from the exploration of cloud computing in healthcare services in Nigeria reveal a multifaceted landscape with both opportunities and challenges. The findings in terms of opportunities are facilitating the remote accessibility to healthcare services; efficient data management by allowing healthcare providers to securely store and retrieve patient information; telemedicine advancements in enabling virtual consultations; enhanced collaboration among healthcare

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professionals by providing real-time access to shared resources and patient data; and data analytics for public health insights on analyzing large datasets, tracking disease outbreaks, and formulate targeted interventions to improve overall public health. Findings in terms of challenges include data security concerns revolves around data security and privacy; infrastructure limitations; regulatory compliance; digital literacy and industry may face resistance to change.

7. Conclusions and future directions

Application of cloud computing in healthcare services has play significant opportunities to revolutionize healthcare services in Nigeria by improving accessibility, efficiency, and collaboration, addressing challenges related to data security, infrastructure, and regulatory compliance is imperative. Strategic planning, continuous training, and a commitment to ethical practices are essential for realizing the full potential of cloud-based healthcare solutions in Nigeria. Applications of cloud computing in any kind of E-health services will be efficacious when we need qualitative parameters including On-demand self-service, broad network access, ICT resource pooling, rapid elasticity in ICT, and measured services. Various applications are developed based on the nature of the service which provides sharing resources in four levels (DaaS, SaaS, PaaS, and IaaS). This does not mean that the use of cloud computing in health systems makes health services more affordable, but helps nations to achieve health equity so that by 2035, internet-based applications will be used by the majority of people in Nigeria. Smartphone with a high-resolution camera, GPS, and embedded sensors are making cloud computing as an attractive solution for healthcare services.

Competing Interests Statement

The authors declare that there is no conflict of interests regarding the publication of this paper.

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