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A FRAMEWORK FOR A CLOUD-BASED ELECTRONIC HEALTH RECORDS SYSTEM FOR NIGERIA

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ABSTRACT

In most countries of the developed world, one of the integral components of Health Information System (HIS) is Electronic Health Records (EHR). With advances in Information and Communications Technology (ICT) and the rise in the adoption of cloud computing approaches in the health sector of these countries by a substantial number of health institutions, cloud servers are now remote repository of EHRs. However, in Nigeria and many other developing countries, health information of patients is still predominantly paper-based medical records. This manual method is not scalable in terms of storage, prone to error, insecure, susceptible to damage and degradation over time, highly unavailable, time consuming in accessing and with no visible audit trail and version history to mention but a few. In this paper, a framework for a cloud-based electronic health records system that is capable of storage, retrieval and updating of patients' medical records for Nigeria is proposed. The framework provides for various medical stakeholders in a health institution and patients to access the EHR system via a web portal by using a variety of devices in the contextual scenario whereby the health institution is migrating from paper-based patient record documentation to an EHR system.

Keywords: *Cloud, Electronic Health Records, Framework, Patient, Service Oriented Architecture*

INTRODUCTION

One of the essentials of diagnostics in modern healthcare delivery is patient medical or heath records. A comprehensive healthcare system relies upon the capacity of the healthcare providers to promptly access a patient's test outcomes, earlier treatment notes, current medicines, to mention but a few. The absence of access to such data may postpone diagnosis and result in uncalled for treatment and in due turn, expanded expenses (Vawdrey, Sundelin, Seamons and Knutson, 2003; Shenai and Aramudhan, 2018). From another view point, health data stored over time can be a reflection of the progress of patients, resistance and adoptability of human to drugs over time and genetic links to causes of diseases in the process of time. The geographical profiling of such data can reflect a lot of information on progress of health, outbreaks and effectiveness of healthcare delivery and so on (Kester, Nana, Pascu, Gire, Eghan and Quaynor, 2015).

Habitually, medical records have comprised of information scattered among paper-based files in different sections of a healthcare delivery facility, referenced utilizing conflicting identifiers. A great part of the data in these records has a tendency to be out of date, repetitive, or garbled to the degree that it doesn't help the patient at the purpose of care (Shenai and Aramudhan, 2018). The sharing of data among various stakeholders in health institution using this manual method has generally been troublesome and tedious, regularly requiring the physical duplication of paper-based material. Furthermore, this manual method is characterized

by non-scalability in terms of storage, proneness to error, unsecured, susceptibility to damage and degradation over time, high unavailability, time consuming in accessing, no visible audit trail and version history amongst other attendant shortcomings. Considering these challenges, the advent of the applications of ICT in the health sector is a timely response.

Today, almost every facet of the human life has felt the impact of the widespread accessibility, adaptability and applications of ICT. The health sector is not an exemption. One of the developmental innovations that came by the way of ICT in the health sector is the health information system. HIS most times refers to the interaction between people, process and technology to support operations, management in delivering essential information in order to improve the quality of healthcare services. HIS are systems that process data and provide information and knowledge in healthcare environments (Haux, 2006). HIS majorly manages and maintains three categories of health and medical records which are Personal Heath Record (PHR), Electronic Medical Record (EMR) and Electronic Health Record (EHR). PHR, which contains history of the health information about individuals, is normally maintained by the patients themselves. Previously, PHR are maintained manually by individuals. Nowadays, there are host of cloud applications developed to maintain PHR. The modern day healthcare providers usually host their HIS at their private data centers, or with cloud service providers. Usually, records such as EMR and EHR are maintained by the healthcare provider's HIS. Thus, EMR and EHR of HIS hosted in these cloud applications (which could be a private, public or hybrid cloud) can be accessed from anywhere in the world by authenticated persons and can be shared with desired healthcare providers. With evolution from conventional or centralise HIS architectures to HIS on distributed network infrastructures, medical image data and other EHR can be cross-exchanged in right time facilitating a boost in the potentials of telemedicine applications ranging from teleconsulting, tele-diagnosis to mention but a few to cooperative working session and telesurgery.

In Nigeria and many other developing countries however, most healthcare institution still relies on paper-based files as the method for patients' medical record documentation. In this method, patients' medical records are stored on paper-based files and registers. If for any reason a patient needs to visit a new healthcare facility, the patient would need to provide his/her health information to the new facility without reference to the previous medical records of such a patient. Aside this limitation, this method also suffers from many attendant shortcomings earlier mentioned in this Section of the paper. Furthermore, in some few healthcare institutions that operates automated health records, various units or departments in these healthcare institutions operate as independent entities and they suffer from the inability to transfer patient health information and records amongst themselves.

In this paper, a framework for a cloud-based electronic health records system for Nigeria, that is capable of storage, retrieval and updating of patients' medical records in a healthcare institution is presented in the contextual scenario whereby the health institution is migrating from paper-based patient record documentation to an EHR system. Of utmost importance in the framework were considerations for confidentiality, authentication, and availability. The framework provides for various medical stakeholders in a health institution and patients to access the EHR system via a web portal by using a variety of devices while the database hosted in the cloud acts as an integrated data bank for patients' medical and health records.

The rest of the paper is organized into the following: Section two presents review of relevant literatures to this paper; Section three details an overview the proposed framework while Section four summarized and concludes the paper.

LITERATURE REVIEW

What are EHR Systems?

EHR systems are a documentation of health-related information about an individual with the primary aim of being a reference for consultation by medical practitioners for patient care. More technically defined, an EHR is an electronic version of a patient's medical history, that is maintained by the provider over time, and may include all the key administrative and clinical data relevant to that person's care under a particular provider, including demographics, progress notes, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports (CMMS, 2016).

The benefits of this include improved medical documentation and patient service, enhanced efficient and effective clinical workflows, improved medication management and reduced transcription and labor costs (Burk, 2010). EHR is now increasingly being deployed within healthcare institutions to improve the safety and quality of healthcare delivery. Poissant *et al.* (2005) highlighted some factors that are influencing the realization of these objectives while Zhang and Patel (2006) enumerated the major advantages EHR systems would offer if well implemented.

Overview of Cloud Computing

Cloud computing is a computing paradigm, where a large collection of systems are connected in private or public networks, to provide dynamically scalable infrastructure for application, data and file storage (Harris, 2010). From a user perspective, it is a subscription-based service where users can obtain networked storage space and computer resources (Huth and Cebula, 2011). The emergence of this technology led to a rapid decline in the cost of computation, application hosting, content storage and delivery. This computing paradigm is a pragmatic approach that comes with the advantage of direct cost benefits and also has the prospect of changing a datacenter from a capital-intensive system to a variable priced setting. The initiative of cloud computing is based on the fundamental principle of reusability of information technology capabilities. The major dissimilarity between cloud computing and other computing paradigms such as distributed computing, grid computing, autonomic computing and utility computing is that it widens scope beyond organizational boundaries.

In the health sector, the adoption of cloud computing in medical services promises enormous gains in terms of patient's quality of service on the part of patients, collaborative cooperation amongst health institutions and reduced cost of information technology on the side of healthcare institutions (Deng *et al.*, 2010). Naturally, the value of the human life is inestimable and medical and health resources are highly inadequate, hence, healthcare services adopted in cloud providers balances a cost efficient concept where patients and health institutions take advantages of this technology by bettering patients' quality of service through a distributed high integrated platform, synchronizing of medical processes as well as dipping information technology infrastructure investment/ maintenance costs which leads to an improved healthcare environment (Wang, 2010).

Information and Communications Technology (ICT) Statistical Indicators of Nigeria

ICTs have been a significant contributor to growth and socio-economic development in many sectors, countries and regions where they are well adopted and integrated (Mcnamara *et al.*, 2011). They are increasingly become a vehicle through which critical services in developing countries are

provided (Okediran, Ganiyu and Badmus, 2018). But what are ICTs precisely? ICT is any device, tool, or application that permits the exchange or collection of data through interaction or transmission (Mcnamara *et al.*, 2011). It is an umbrella term that includes all technologies for the communication of information.

In Nigeria, the increase in affordability, accessibility and adaptability of ICT has created a breeding ground for development innovations, which target key areas of economic and social impact such as agriculture, education, health and finance (Okediran, 2019). As of October, 2022, the Nigeria Communications Commission (NCC) gave the subscribers technology data (active lines) as depicted in Table 1 (NCC, 2022).

Table 1: ICT Statistical Indicators of Nigeria

Operator	Data
Mobile (GSM)	214,350,098
Mobile (CDMA)	-
Fixed Wire/Wireless	97, 961
VoIP	248,168
Total	214,696,227
Tele-density	112.47

An essential and integral component of ICTs is the internet. The internet users 'subscription in Nigeria saw a slight increase between the years 2018 and 2022, as depicted in Table 2. As of October 2022, the NCC stated that there were more than 152 million active internet users in Nigeria. Furthermore, the NCC stated the country's current broadband penetration as at June 2022 stands at 44.30% with more than eighty-four million internet subscriptions in the country.

Table 2: Internet Subscription between 2018 and 2022 in Nigeria

$\frac{Operator}{Year}$	Oct. 2022	Oct. 2021	Oct. 2020	Oct. 2019	Oct. 2018
Mobile (GSM)	152, 148,967	139,983,370	152,481,376	123,206,103	107,106,975
Mobile (CDMA)	-	-	-	-	68,793
Fixed Wire/Wireless	153,309	13,648	11,275	9578	10,170
ISP	191,426	-	-	-	-
VoIP	354,449	340,542	435,019	343,915	361,785
Total	152,710,160	140,337,560	152,927,670	123,559,596	107,547,723

Related works

Mirza and El-Masri (2005) presented a novel cloud-based integrated EHR system. The proposed EHR system applied cloud computing paradigm to evolve an all-inclusive EHR integrated environment. The system essentially consists of three many constituents namely: a central database for the cloud that houses the EHR's data repository, the unifier interface middleware and a web portal for the cloud whose responsibilities are to manages message requests and responses received from the cloud through secured network connections.

Cho *et al.* (2010) developed a standards-based interoperable EHR system which will be a component of the Korean national healthcare information system. The primary aim of the system is to provide easy access and an effective healthcare delivery anytime and anywhere.

Saif, Wani and Khan (2010) proposed a solution based on network engineering for sharing data among healthcare providers with emphasis on the protection of privacy of health records of patients

in an EHR system. A role-based and signature-based delegation was implemented by the system. To ensure the security of shared patient's data and protection of the privacy of such data, the authors proposed public key encryption techniques for access control.

Popescu *et al*. (2011) presented an eldercare EHR (EEHR) system that fuses health data with transducers and measurements of vital signs. The proposed system accords medical practitioner a wider scope of equipments for the management of chronic ailments eases the work schedule of nurses and gives way for the improvement of health context aware algorithms for health assessment prediction.

Wu, Ahn and Hu (2012) proposed a cloud based electronic health information system that ensured interoperability at a low operational cost. The authors focused more on ensuring the privacy and security of stored data in the cloud server.

El-Sappagh and El-Masri (2014) proposed a distributed and open architecture for EHR whereby every hospital on the distributed architecture will own their individual local EHR. The architecture satisfies EHRs requirements for interoperability, scalability and compatibility. Furthermore, the proposed architecture possesses a set of knowledge bases with each knowledge base having a specific specialization.

De Moor *et al*. (2014) described an Innovative Medicine Initiative (IMI) Electronic Health Record for Clinical Research (EHR4CR) project which aims to exhibit a scalable, generally acceptable and effective approach to interoperability between EHR systems and clinical research systems.

Fabian, Ermakova and Junghanns (2015) presented and implemented a novel cloud-based architecture that is germane to healthcare delivery for inter-institutional data sharing. The core aim of the architecture is on provision of a high-level security and privacy for patient data in cloud computing environment having security doubts.

Gazzarata, Gazzarata and Giacomini (2015) proposed an EHR system based on cloud infrastructure architecture. The system uses service-oriented architecture which is capable of guaranteeing the security, total provision of technical support and process and semantic interoperability.

In review of related works presented above, most of the architectures proposed by the authors are for contextual scenarios where there are no constraints in ICT resources and there exist already deployed legacy systems for different tasks within healthcare facilities. A large majority of these reviewed works proposed architectures that integrate already deployed legacy systems into an EHR system and rather than develop an EHR system from the scratch. In this paper, a framework for a cloud-based electronic health records system that is capable of automating storage, retrieval, updating and maintaining of patient's medical records from the scratch in Nigeria is proposed.

OVERVIEW OF THE PROPOSED FRAMEWORK

An essential of devising model solutions to identified problems is defining apposite research methodologies (Finkelstein, Kramer and Nuseibeh, 1994). This paper employed the Service Oriented Architecture (SOA) software development model to derive a framework for an electronic health records system that would solve a real-life problem.

A. Design Considerations

In designing the proposed framework for the EHR of this paper, of upmost importance are the considerations for:

i. *Confidentiality* that is, only the entitled users, under the defined terms, have

access to data and information on the proposed system.

ii. *Authentication* that is, a verification that the ownership of an information is actual due to the right patient and it emanated from the expected source;

iii. *Availability* that, is the capacity of proposed system to be used by the entitled users under the defined terms of access and exercise.

iv. *Multi-user:* A number of patients/ medical practitioners can use the system simultaneously;

v. *Accessibility:* The system can be accessed by patients/medical practitioners from any location via secured communication channel using computers or mobile devices;

B. Architecture of the proposed Framework

Fig. 2 depicts the architecture of the proposed framework a cloud-based EHR system presented in this paper. The framework allows at the users' side for two categories of users that include patients and medical practitioners/assistants to access the system using a variety of devices that includes Smartphone, laptops and desktop computers. A patient' request to access the system remotely will be routed through the gateway while medical practitioners/assistants accesses the system via a communication network. The cloud side consist of a set of servers that includes an application server that handles all application operations between users and the system's backend of the database; a database server that provides database services to other components of the framework; a file server which is a location for shared disk access; a web services server which provides business logic for users' requirements and a security server that ensures security of stored data and access control.

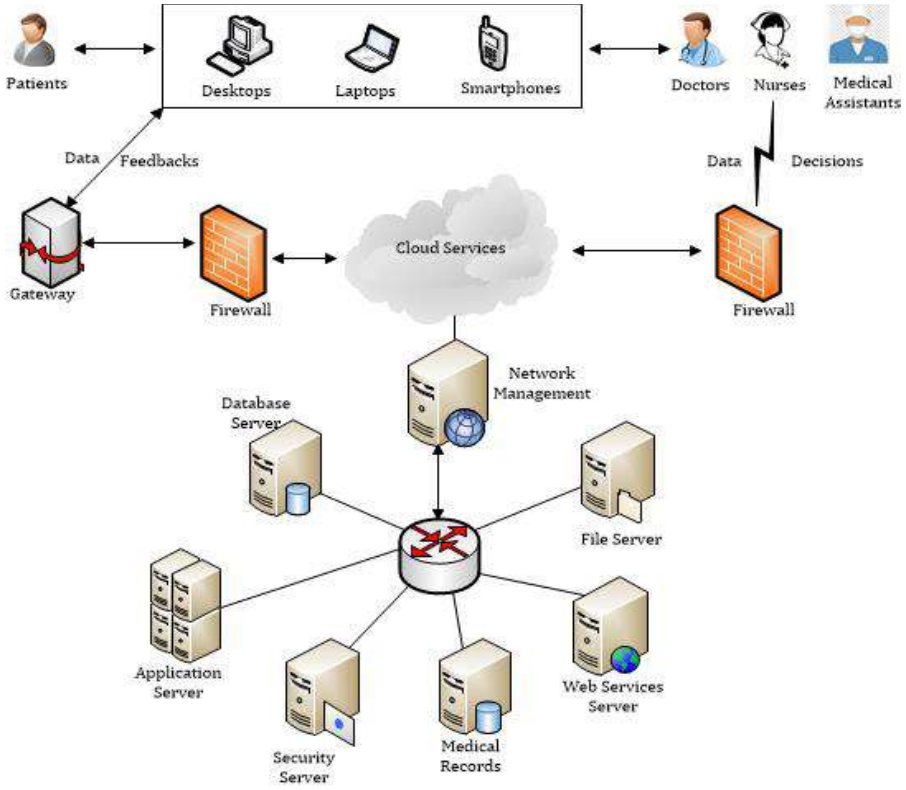

Fig 2: The Proposed Framework for a Cloud-based EHR System

The EHR system can be accessed through a web portal over a private network by patients, doctors, nurses and medical assistants with valid credentials using various devices that include Smartphones, laptop and desktop computers. The security of patient information and data is to be by a public key cryptosystem and steganography. Recorded patient's data are routinely saved and transferred to the network server via Secure File Transfer Protocol (FTPS) for future referencing. Patients' medical data accessed by medical practitioners with valid credentials can be used by them to analyze and manage patients' medical history, reaction to medication, evolution and possibly send to patients, a medical recommendation. Also, physicians can communicate with patients through the web portal while patients too can access their personal medical records.

C. Implementation View of the Proposed Framework

Fig. 3 depicts the implementation view of the proposed framework. The implementation view of the proposed framework is a multi-layered approach consisting of the Presentation, Application, Middle and Data tiers. The foremost layer is the Presentation tier which is a web portal that facilitates the exchange of information between users and the system and among various users. It is a layer that is independent of other layers underneath it since it was to be implemented for a variety of devices. Next to the Presentation tier is the Application tier. The Application tier collates users' inputs (data and information) and process them. Beneath the Application tier is the Middle tier. The Middle tier is essentially made up of services layer that handles issues bothering on integration of different applications, problems arising from disparity in data structures implemented, technical conflict in connectivity to different protocols and so on. This layer is composed by web services. The last of the layers is the Data tier. The patient data requests by the EHR application are supplied by the data tier.

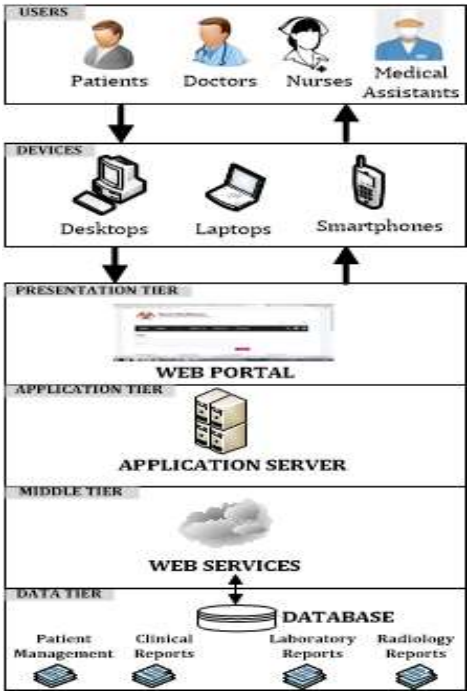

Fig. 3: Implementation View of the Proposed Framework

The algorithm for authentication of users is as stated below:

i. Start
ii. Initialize Status Flag = False
iii. Input User name and password
iv. User authentication: a search by the database for a match with the supplied user's credential
v. If there is a match in the database with the supplied credentials, change Status Flag = True
vi. Grant User login
Else
vii. Display "INVALID USER"
viii. End

The algorithm for creating and retrieving a patient's record is depicted hereunder:

Let *DB* be the database of the EHR system and in *DB,* let there exist, patients P_i for $1 \leq i \leq n$ for n

number of patients. To retrieve the health record of any patient P_i

i. Start
ii. User Authentication
iii. Join Cloud
iv. Supply Z which is the Patient's identity of Patient P_i
v. Verify if $Z \in DB$
vi. If $Z \in DB$, display patient's record
Else
vii. Display "NO MATCH FOUND IN THE DATABASE"
viii. Profile new patient
ix. Update the database DB with the new record
x. End.

CONCLUSION

In this paper, a framework for a cloud-based electronic health records system has been proposed. The proposed framework if implemented and adapted can proffered solutions to the attendant problems associated with paper-based medical records which is still predominantly used in Nigeria and many other developing countries. The expediency which such systems as this will accord patients in these countries cannot be overemphasized. Furthermore, clinical records, laboratory reports, digital medical imaging and other doctor's notes are consolidated and available in real time. This will accord researchers the prospect to be able to analyze the structured data provided in the cloud.

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