CloudeMR: A Cloud Based Electronic Medical Record System

Olutayo Boyinbode and Gbenga Toriola

Department of Computer Science,
Federal University of Technology, Akure, Nigeria
okboyinbode@gmail.com

Abstract

The utilization of modern information technology in the delivery of healthcare is to enhance the availability and reliability of improved healthcare services to patients at a reduced cost. The alternative in this context is to outsource the computing storage resources with the help of cloud infrastructure. The drastic reduction in the cost of healthcare services, utilization of resources, maintainability and the adoption of new technologies are some of the benefits that healthcare centers in rural areas can get from cloud-based medical information system. Also, new prospects such as easy and ever-present access to medical records and the chances to make use of services of physicians that are not readily available in the rural areas are some of the opportunities offered by a cloud-based medical information system. This paper proposes and implements a cloud-based electronic medical record (CloudeMR) system to improve the delivery of healthcare system in the rural communities of Nigeria.

Keywords: Cloud computing, Electronic medical record, HealthCare Information Systems, ICT

1. Introduction

The healthcare industry in Nigeria has not been able to tap into the full potential of modern information technology to improve on healthcare delivery [7]. Accesses to patients’ longitudinal records are often times difficult and cumbersome. The lack of proper access has cost the healthcare industry a huge fortune every year due to duplication and waste [7]. This is just one of the many challenges facing the healthcare industry. Cloud computing technology has received tremendous attention in recent years. In simplest terms, cloud computing can be defined as a form of computing where shared resources, software, infrastructures and information are delivered to computers and other devices through network or an internet. The accesses to information or network shared resources are not limited by the user’s physical location. Therefore, vital resources and people are connected irrespective of where they are around the world, provided there is network connectivity [3, 4].

The ability of cloud computing to facilitate the exchange of medical information between the healthcare stakeholders such as the pharmacist, doctors and all other healthcare institutions that are geographically isolated can help to modernize healthcare services [9]. Privacy, confidentiality, security and regulation problems have however curtailed the immediate adoption and implementation of cloud computing in the management of healthcare system. One of the reasons for the slow adoption rate is the inability to guarantee if the data are fully secured. Kuo [9] and Malin [10] stated that societal stigmatization and isolation may for instance cause some HIV and mental health patients to want their medical information to be strictly confidential.

Healthcare industry has recorded a significant improvement in the last two decades through advancement in information technology. Despite all success recorded, there are still concerns in many areas that affect almost every individual in the industry, and
especially the patients who are direct beneficiary of all the successes also bear the brunt of lapses in the system. Some of the problems can be classified as lack of access to patient’s medical records [7], limited medical personals in rural areas, high mortality rate [1]. The goal of this paper is to design and implement a cloud-based electronic medical record system that can be used to effectively manage the sharing of medical information.

2. Related Works

The utilization of modern information technology in the delivery of healthcare is to enhance the availability and reliability of improved healthcare services to patients at a reduced cost. There exists a handful of published research that uses the adoption of cloud computing as a dependent variable to explore healthcare industry characteristics that are associated with the implementation of these technologies.

Padhy, et al. [14] designed and presented the implementation of a cloud-based healthcare information system model for rural communities; this system makes use of a cloud central server that accepts virtual machines as tenants. The tenants are secure facilities that store information in different healthcare centers. The configuration and connectivity of the system is based on the cloud data center location and the policy of the service provider. The internet is the main link of communication between the rural healthcare center and the service provider. It also maintains the network traffic between the physical resources and the cloud. The authentication server uses the authentication and authorization mechanisms. The system can be used by other applications and across various devices to share information in near real-time situation effortlessly. However, there is no fail-safe mechanism in the model to ensure system reliability and availability.

Also, small hospitals and private physicians do not have the IT requirements to support the technologies deployed in the system.

Saif, Wani, & Khan [17] proposed a system of engineering network solution for data sharing solution across healthcare providers for protecting patients’ health information in an Electronic Health Record (HER) system. This system was implemented on a role-based and signature-based delegation. The signature-based delegation provides a secure avenue for basic delegation and revocation, while the role based delegation yields dynamics in the face of delegates’ status, availability and change. In addition to this, basic access control based on public key encryption techniques was also implemented. This ensures the sharing of data and also that the privacy of patients’ data is protected across all collaborating healthcare centers but the introduction of proxy sign-in in the system exposes it to another high security risk.

An approach based on utility computing and Wireless Sensor Networks (WSN) was proposed by [16]. Wireless Sensor Networks (WSN) uses sensors that can be worn to gather vital indications that enable the easy collection and distribution of information to and from any mobile device. These two computing features were combined to develop a system that automates the collection, input and analyses patients’ critical information through network of sensors connected to installed medical devices, which in turn deliver the records to the health center’s cloud for storage, processing, and distribution. Medical specialists can use the information collected to monitor and observe patients anywhere through the internet (on a computer or mobile devices). The system makes use of micro controllers to evaluate data collected. However, there was no provision made for the confidentiality, integrity and privacy of patient data in this system. Also, the design has a complex architecture which may be difficult to implement in developing societies due to lack of infrastructural facilities.

Another mechanism designed to ensure a trusted communication between different health information systems was presented by [15]. This system uses an advanced cross platform model which incorporates national and regional security domains via an inter-domain zone. Interoperability service and a common security service are offered by this
zone to all the connected domains. The function of the platform is to provide security services that are centrally managed for a cross-organizational predefined communication. The fundamental security services of this cross-platform domain are to bridge security policies, identification and authentication of users crossing the domain, certification services, auditing services and management of static privileges. Public Key Infrastructure (PKI) services were used on the platform to enable external users from the public to gain access to any of the EHRs inside the connected domains. However, this mechanism lacks harmonized legal and ethical framework, common security standards and trans-border communication security services.

However, all these previous researches either lack legal, security and privacy of patient’s data or the system is too complex to implement. Also the reliability and availability of the system cannot be guaranteed. This study differs to every other works considered by taking into account all the lapses to design a robust, yet simple and effective electronic medical record (EMR) system that will ensure security, privacy, reliability and availability of patient’s records. This system can easily be implemented in small hospitals and by private physicians, without running afoul of the existing healthcare legislation and regulations.

3. Healthcare Information System (HIS) – A Nigerian Case Study

Advancements in technology made in the world especially in the last two decades have altered the entire scenario in every sector of the economy. As the healthcare sector continues to be one of the most expensive and crucial sectors in the economy, Health care system in Nigeria is currently in a comatose state, there is a high rate of preventable and curable diseases such as maternal mortality, diabetes, high blood pressure and other controllable diseases. The Nigerian government is yet to improve the health care delivery through the use of technology [1, 2].

According to Okeke [12], a lot of Nigerian patients seeking medical treatments are being forced to patronize the traditional medical practitioners and patent dealers of medicine due to the lack of access and high cost of modern healthcare facilities. The rich and wealthy in the society rather embark on medical tourism abroad to get medical services, because of scarcity of experienced medical personnel [11].

Ayeni, et al. [1], also pointed out that there is Zero level of significance in EMR based hospitals because only less than 10% of Nigerians can afford it and most of these EMRs are remotely located in hospital’s infrastructure rather than moving it to the cloud. There is need for (EMR) Electronic Medical Records to be moved to the cloud to allow Nigerians have easy access to health care delivery.


The workflow among the various healthcare entities is improved upon by the healthcare information system and also, patient’s access to healthcare increases [13, 19]. The communication between organizations and stakeholders is facilitated by the application information and communication technologies. ICT helps to improve on the seamless workflow among people and the organization; effective processes can also be achieved through efficient and effective interactions [21]. Weiner [23] stated that network effectively among themselves with the use of electronic health technology, by allowing the review of patient’s treatment online and to accurately prescribe the necessary drugs.

Keenan et al. [8] discovers that the care given to patients is enhanced and also the daily work of the physician has improved: (a) the turn-around times of medication fell from 5:28 hours to 1:51 hours; (b) the procedure completion times of radiology fell from 7:37 hours to 4:21 hours; and (c) the reporting times of lab results fell from 31:3 minutes to 23:4 minutes. In the same study, errors in orders due to transcription declined, and the length of stay in hospital decreased. The online monitoring of vital signs, improved
physicians’ collaboration in patient care and multi-site review of patients records are the other benefits of electronic medical records systems. EMR speed up the access to medication administration records easily, and the ease by which consultation reports are shared, the decreased time taken to transmit test results are parts of the benefits of healthcare information system [8].

The errors recorded in diagnosis and the administration of drugs decline with the introduction of electronic healthcare information system. Fuji and Galt [5] opined that in the United States, over 1.5 million residents suffer injuries that are related to error in prescription and other medical complacencies yearly, the authors suggested that the figure could as well be a fraction of the total patients that suffers adverse medical errors, especially when patient’s own mix-up is considered. They deduced that some parts of the healthcare information systems increase participation of patients in the care process, thereby reducing all forms of medical and prescription errors.

Healthcare facilities are accessed between the urban and the rural communities with great disparity due to the heterogeneous nature of the Nigerian society. The introduction of healthcare information system can help to bridge the gap [13]. Also, the clinical data captured by clinical information system helps to improve on the clinical decision making of the physician on patients care [22, 24]. Policy makers in healthcare that seeks ways to improve the quality of healthcare at some reduced cost can also leverage on the healthcare information system to deliver the inexpensive healthcare [18, 20].

Woodside [25] agrees that electronic exchange of patient’s records between physician and pharmacist can help to protect the patient by detecting the prescription of drugs combinations that are not compatible, stating potential allergens to patients. One very important benefit of the electronic exchange is Insurance verification. Lots of healthcare providers do not have means of verifying insurance claims by patients; some just provide care without getting assurance from the patient’s insurance company. All these issues are solved with the use of electronic exchange between the healthcare entities. Delays in approval process and healthcare services are reduced.

Clinical time optimization as a result of effective communication and also the increased level of compliance with guidelines are some of the other benefits of healthcare information system [6]. Medical students and resident doctors can benefits from the effective educational tools provided by the EMR system, the healthcare information technology also offers a very strong potential in clinical protocols and research development [8].

5. System Design and Implementation

5.1. Design Methodology

This section introduces the design methodology of the cloud based electronic medical record system.

Design Considerations
i. Cloud-based EMR: To pool different healthcare IT resources into large clouds so as to be able to share records easily.
   ii. Authentication: Security is achieved through the use of username and passwords.

5.2. Architecture of the System

The architecture of the cloud-based electronic medical record system is presented in Figure 1. The system consists of two major components which are: the cloud-based system and the e-health web portal.
5.3. The Cloud-Based System

This system consists of (a) a Central Database Server, (b) a Unifier Interface Middleware (UIM) and (c) an Authentication Server.

(a) The Central Database Server

This server acts as the unifying data repository for all the collaborating hospitals. The cloud datacenter holds the central database server as the information bank which stores electronic medical records and also retrieves patient information. The data is stored in a unified standard layout which can be retrieved from the collaborating hospitals’ Web Portal system through the Unifier Interface Middleware (UIM).

(b) Middleware

This part of the cloud provides a common platform for all the EMR systems of the collaborating hospitals. The middleware has an interface that covers the heterogeneity of all the collaborating hospitals EMR standards, to ease the communication process between the Central Database and hospitals’ systems. The middleware remains in the cloud and recognizes any type of EMR standard it interacts with. It communicates with each collaborating hospitals via network connections. Therefore, each hospital does not need to have its own separate interface mask in order to benefit from the cloud; all it needs is just an interface.

(c) Authentication Server

This part of the system handles authentication and authorization. The authentication verifies if an entity using the system has the right to perform the intended action such as (updating, retrieving, transferring, etc.) on the medical information provided. It grants access to authorized users and denies unauthorized users access to the records or resources on the system. The system generates usernames and passwords for doctors (or other members of staff) of the sharing hospitals that will serve as part of the admin. All
the members of the admin are expected to log in to the system with their username and password. The system compares the username and password with those in the local database and grants access to the user if they match, otherwise, the user is denied access.

5.4. The E-Health Web Portal

The e-health web portal is the front end of the whole cloud system, and the part of the cloud (top layer) that provides the application - Software as a service (SaaS) for the EMR system. The proposed cloud system presents a web portal configured for end users (authorized doctors, clinicians and the hospitals administrators who serves as the cloud administrator) to navigate through the central database and the whole EMR system. The web portal communicates by sending messages and receiving response messages between the middleware and the hospital system. For each sharing hospital in the cloud, the web portal provides the user two ways to access the database, one for accessing the hospital’s local EMR system, and the other for joining the cloud central database.

Every authorized user (cloud administrator) can retrieve, update and receive medical information from the cloud’s central database through this web page with some degree of restrictions which depends on the end user’s privileges. The web portal also shows where the information of a particular patient from a specific hospital resides, whether in the cloud or on the target hospital system and can decide to view medical information about the patient or even copy the information into its local database from the collaborating hospitals connected to the cloud.

Each collaborating hospitals allow its administrator and doctors to have different view of the patient’s record in the database. The administrator can see the number of doctors and patients in the hospital and can also view their details. Only the bio-data of the patients will be displayed to the administrator and not the result of the different diagnosis and doctor’s report, this will ensure some level of privacy to the patients. Such information can be viewed only by the doctors.

The application was developed with macromedia Dreamweaver and Wamp server technology, HTML, JavaScript, PHP and CSS and MySQL for data storage.

6. Implementation and Results

The implementation and testing of the system was carried out using five personal computers and one server with internet facilities meeting the minimum software and hardware requirements. The five computers represent five different hospitals collaborating on the use of resources and sharing information. When the application is launched by the administrator, the administrator login page or authorization interface comes on. The hospital’s administrator seeking authorization enters his username and password in their respective columns in order to gain access into the system; it compares the details with those of the administrator in the database and the system grants access to administrator, the login interface is shown in Figure 2.
If access is granted for an authorized user (administrator), it leads to another interface that displays the summary of doctors and patients in the hospital as shown in figure 3, the administrator also have the option of adding a new patient to the database or to add a new doctor, to view details (bio-data) of existing patients and doctors.

However, if an unauthorized user attempt to gain access into the system by entering incorrect details (i.e. incorrect username and password); the system denies such user the access as shown in Figure 4.

A cloud administrator can also copy records of patients not in the local database from the cloud into their system. Patients find themselves in different hospitals at any time for
different reasons, they can tell the administrator to get a copy of their record that resides in database of their last or former hospital from the cloud. Figures 5 and 6 shows the interface where the cloud administrator copies record from the former hospital.

![Figure 5. Cloud Administrator Interface to Copy Patients Record](image1)

![Figure 6. Patients Record Transfer Section Interface](image2)

When the application is launched by the doctor, the doctor’s login or authorization interface comes on. The doctor seeking authorization enters his username and password in their respective columns in order to gain access into the system; it compares the details with those of the doctor in the database and the system grants access to doctor, the login interface is shown in Figure 7.

![Figure 7. Login Interface for Doctors](image3)
If access is granted to the authorized user (doctor), it leads to another interface that welcomes the doctor and provides tab to view patients in the hospital’s record as shown in figure 8, if the doctor clicks on the “view patient” tab, a page comes on that displays the list of all the existing patients in hospital’s database. Against each patient’s name are two tabs; “diagnose patient” and “view full details”. The “view full details” tab allow doctors the view of only the bio-data of the patient, however, the “diagnose patient” tab displays both the bio-data and the result of previous diagnosis of the patient. Also, there are columns where laboratory, radiology and pharmacy information can be entered to generate a new diagnosis report as shown in Figures 10 and 11.
7. Conclusion

In this paper, a complete, robust and efficient cloud-based EMR system has been designed and implemented. Cloud computing has been identified generally as the next big deal in computing infrastructure and it offers some benefits by allowing the use of infrastructures like networks, storages, and servers, software such as application programs and platforms like operating systems and middleware services. Adapting the cloud technology to medical record management, reduces the cost of healthcare delivery through reduce administrative bottlenecks. The convenience this kind of system will give to physicians, patients and hospital administrator especially in developing world cannot be quantified. With time, it is hoped that hospitals, health care regulatory bodies and the Health ministries in Nigeria will take advantage of innovations that are becoming available through internet solutions to improve healthcare system. It is also hoped that synergy among health care stakeholders will produce results expected from health care organizations.

References


Authors

Olutayo Boyinbode, PhD, is a Senior Lecturer in the Computer Science Department at the Federal University of Technology, Akure, Nigeria. Her research interests are in Mobile Learning, Ubiquitous Learning, Cloud Computing and Mobile Networks. She is a professional member of ACM and IEEE.

Gbemga Toriola, is a Postgraduate student in the Computer Science Department at the Federal University of Technology, Akure, Nigeria.