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Patient-Centric Cloud-Based EHR System for Government Hospitals in Developing Countries

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Abstract: *The increased cost and difficulty experienced by government hospitals in developing countries as a result of maintaining patient health records manually on paper files and the lack of easy access to patients' previous health history across hospitals for continuity of treatment, especially in the case of transfer or the relocation of a patient, causes a lot of setbacks in the health sector such as delay in the delivery of healthcare, fragmentation of health records of patients and probably the loss of patient health records. Again, maintaining independent hospital information systems with individual storages by the few hospitals already automating their work processes leads to increased cost of maintenance and wastage of resources. The aim of the research is to automate the paper health records mostly in existence and use cloud computing technology to make the electronic health records accessible anywhere and anytime at reduced cost by authorized health personnel across different government hospitals in developing country such as Nigeria. The system was designed with Object-Oriented Analysis and Design Methodology (OOADM) and implemented using Adobe Dreamweaver on a Microsoft Windows operating system using PHP, HTML, CSS and MYSQL technologies. The result of the work is that a unified view of the electronic health record that can be accessed anywhere and at anytime using cloud computing by different hospitals together with the patients was provided and also patients were allowed to be treated accurately in any hospital in order to reduce redundancy.*

Key Word*: EHR; Cloud Computing; Patient-Centric; Unified EHR; HIS.*

I. Introduction

Most developing countries are faced with the challenge of not utilizing fully the contemporary information technology especially in the health sector, to make healthcare delivery faster, better and easier. Large funds are spent each year as a result of the difficulty and cumbersomeness of not properly accessing a patient's health records causing duplication and waste [1]. Majority of government hospitals in developing countries currently operate and maintain health records of patients manually whereas, the very few private hospitals that use electronic health records to make reference to the previous health history of patients have independent hospital information systems with separate patient health records and doctors rest on the health staff to coordinate and manage patient's health data. The inability to share patient's health records so as to enable the patient obtain proper health care in any hospital whether within or outside the location registered for NHIS (national health insurance scheme) hinders effective healthcare delivery[2], [3]. Another fact about paper patient health records is that as the number of patients' health records increases, the storage requirements for them consequently becomes a challenge [2]. Importantly, a patient's health record, as created by healthcare professionals is the confidential legal documentation of the facts concerning a patient's health history, including all past and present health conditions, illnesses and treatments, putting more considerations on the specific events affecting the patient during current incidence of healthcare for the purpose of providing care and continuity of treatment[4]. Moreover, the electronic health record (EHR), also known as Hospital information System (HIS) is a patient-centric model of a digitalized record of health information of an individual which is generated, updated and maintained over the lifetime of a patient by healthcare professionals during one or more encounters in any health care delivery setting, such as hospital and used to provide high quality health care [5][6].

The need to make the EHR of patients easily and readily accessible to health maintenance organizations (HMO) such as hospitals, promote interoperability among these HMOs for the purpose of resource sharing, and reduction in the cost of healthcare delivery cannot be overemphasized in the health sector. A necessity is, for a technology that could allow different hospitals to easily share and remotely access patient's EHR. Cloud computing technology has been a great tool for researchers and is equally applied in virtually all fields presently and in the past few years, health sector not being an exception, because of the numerous benefits it offers. The National Institutes of Standards and Technology (NIST)[7] simply defines cloud computing as a utility (pay as you use) model that enables ubiquitous, convenient, on demand network access to a shared pool of configurable computing resources such as storage, applications, services, which can be quickly delivered and

released with minimum management effort or service provider interaction. The cloud service models include: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Cloud Services can also be deployed in various ways which are private cloud, public cloud, community cloud and hybrid cloud. Adopting cloud computing in healthcare provides an enabling environment for patient health record to be remotely accessed by healthcare stakeholders such as the doctors, pharmacists, etc. which invariably, improves healthcare delivery. Therefore, this paper aims to examine the existing methods used to bring about the interoperability of hospitals so as to share a single view of the EHR of patients and provide a cloud-based solution that enables patients to receive adequate healthcare with reference made to their electronic health records and without limitations of place and time.

The rest of the research paper is organized as follows: section 2 describes the related works, section 3 explains the research methodology, section 4 explains the design of the proposed system, section 5 is about the implementation of the system, and section 6 concludes the research.

II. Related Works

The inability of patients in developing nations to access adequate healthcare in government hospitals when health physicians make reference to a single consistent EHR of a patient regardless of the location that the patient felt ill or the time has been a major challenge in healthcare delivery. In order to make a patient's data accessible to different federal government hospitals and also provide the support to medical professionals in circumstances when a health expert is not available, an approach based on artificial Intelligence (expert system) and distributed database was proposed in [8] to diagnose and prescribe drugs for diabetic patients. However, in the system, because of the use of distributed database, the sharing of patient record across hospitals could be limited to only the areas across which the database was physically distributed, could cause degradation in the availability, maintenance, reliability and performance of the system if the complexity as a result of replication of health record is not properly handled, and could lead to increased processing and communication cost of ensuring data.

A unified patient information management (UPIM) platform was proposed in [9] to ensure better access, mobility and transfer of patient medical data when needed across various hospitals as well as improve management by giving a singular complete view of a patient's data gotten through gathering information from health service providers, physicians, health insurances and so on. UPIM is a centralized, real time and patient-centric information management system that works by integrating health related IT applications and service provider office workflows which allow the transfer of patient information as well as make available patient's records. The author however, did not consider the scalability of the workloads of hospitals and also, the system may not be suitable to small hospitals because of the complex technologies it needs before it could be implemented. Moreover, the system is not a pay as you use and may bill users for utilities they did not use.

A cloud solution that minimized loss of hospital data, allowed different government hospitals of the third (3^{rd}) world nations to access and share the health information of patients stored in the cloud storage, and also reduced cost and wastage of resources due to government hospitals maintaining separate and autonomous Hospital Information System (HIS) was proposed in [2]. The system used only hybrid cloud to ensure security of the EHR in the cloud, however, that may not be enough to convince health professionals to adopt the system. Additional means such as authentication and authorization may be needed.

Another system that provided grassroots health institutions with inexpensive, consistent and shareable health care was presented in [10]. The paper proposed cost-effective hospital information as a service (HIaaS) that ensures patient information sharing across grassroots healthcare institutions by using cloud-based virtual desktop infrastructure as a server such that each individual grassroots healthcare institution uses a virtual machine that runs on the same platform. However, the system has the likelihood of being slow because of the use of virtual desktops, which affects its overall performance and reliability.

The authors in [1] demonstrated the use of cloud computing technology to facilitate the effective delivery of healthcare to rural communities of Nigeria by ensuring that patients medical records are made ready when needed anytime and at anywhere and also serving as a support to areas where medical practitioners are limited. The system however, had to copy the health records of the patients when it is needed by a hospital from either the patient's previous hospital's database or the cloud. Having the health records stored in local systems may not be very ideal because of security issues and moreover, each hospital having a separate HIS of which their heterogeneity have to be hidden in order to connect to the cloud may be complex and resource wasting.

This paper considered the design of a transparent, uncomplicated, secured and effective system that considered most of the problems in the researches to make patient health records easily accessible by authorized health personnel and improve healthcare management through the use of a central database hosted in the clouds for the health records of patients and providing a customizable EHR system as software-as-a service in order to enable the patients to be treated in any hospital. The health records are not stored in the local systems because of security issues neither are they copied from one hospital to the other.

III. System Analysis and Design

This section presents the analysis and design of the Patient-Centric Cloud-Based EHR (PC-CBEHR) System.

System Analysis

The proposed system eliminated the manual method of keeping patient's medical records and created a unified health record system (cloud-based solution) that will be accessed by different hospitals anywhere and anytime. This system provides software as a service (SaaS) to authorized users of the system to be able to access the unified cloud storage of the patient health records and runs on the cloud infrastructure offered as a service by the cloud provider. There is no need for hospitals to maintain their different hospital information systems which is masked in order for them to access the cloud. The SaaS application is hosted on the cloud. The system is accessible from any device through a web browser. The users of the system need internet connection in order to access the software provisioned. The unified cloud storage for the health records, provided by the cloud provider, resides in the cloud data center (Infrastructure as a Service, IaaS). The proposed system deployed a hybrid cloud model which is a composition of community cloud and public cloud that are bound together but remain unique entities, offering the benefits of multiple deployments. Basically, for this system, there are four users- Administrator, Doctors, Nurses and Patients who must login in order to make use of the system and also as a form of authentication. There are different functionalities that the users of the system can use and perform, in other words, the various authorization levels of the users. Figure 1 is the use case diagram of the system while figure 2 shows the activity diagram for the treatment of a patient by a doctor.

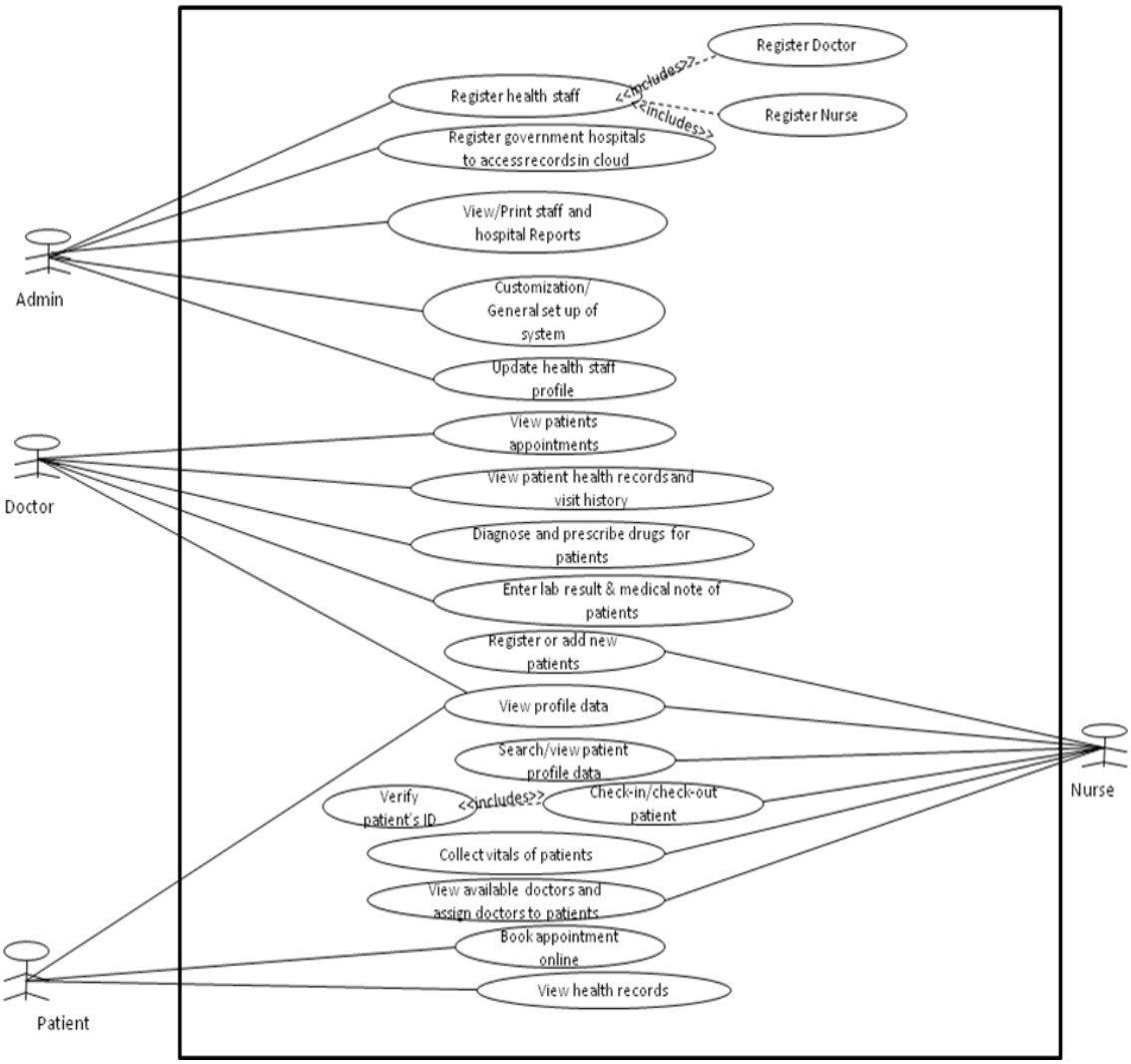

Figure 1: The Use Case Diagram of the System

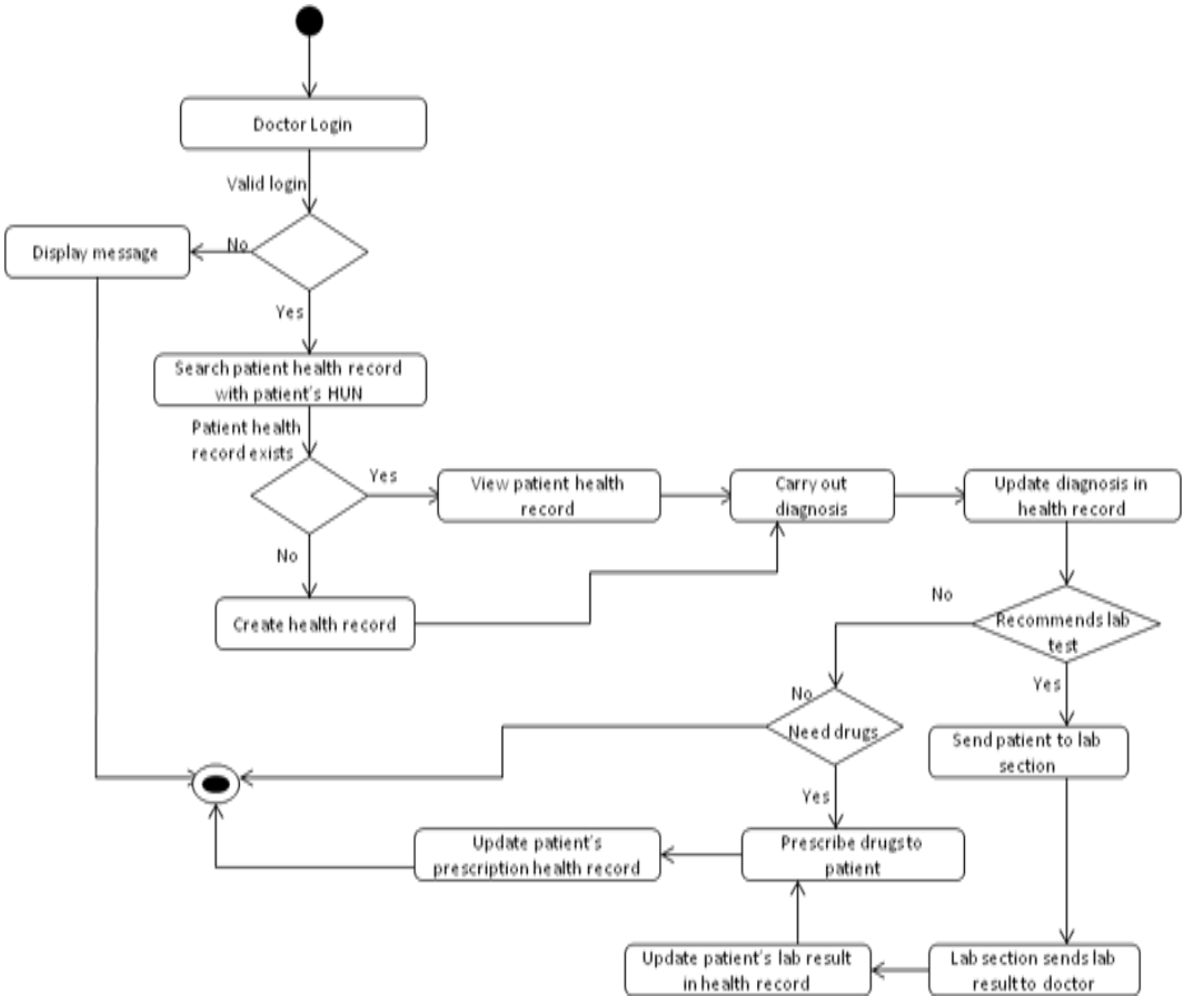

Figure 2: The Activity Diagram for the Treatment of a patient by a doctor.

System Design

Various components made up the system modules/ sub modules and are linked together. Figure 3 shows the architecture of the patient centric cloud-based EHR (PC-CBEHR) system. The system architecture is made up of two important components: the cloud system serviced by the cloud provider and the customizable hospital application serving as SaaS to various hospitals and accessed through the internet.

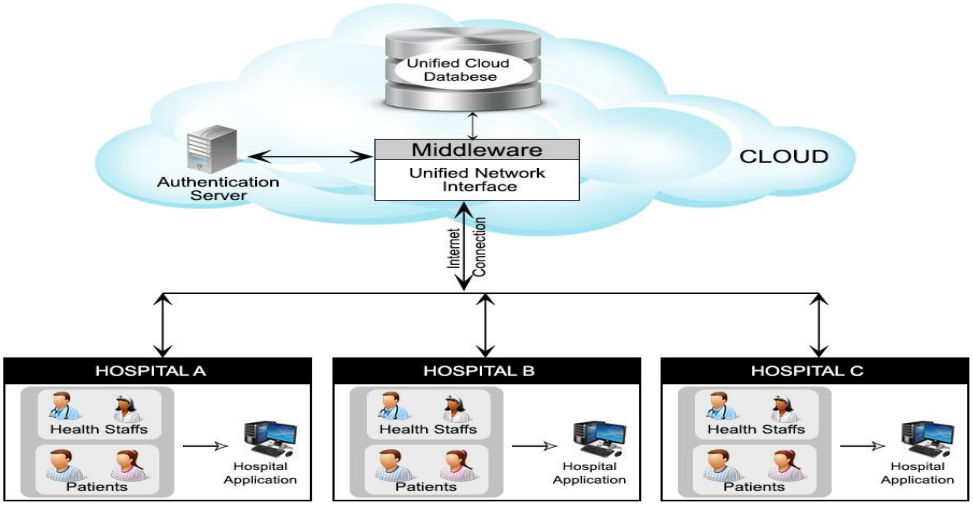

Figure 3: The Architecture of the PC-CBEHR System

The customizable hospital application serves as the front-end of the system and is shown to the users of the system to enable him move to the unified cloud storage. The SaaS application which delivers the electronic health record system as a service to users is required to access the cloud system. The application communicates by sending results to the web browser on a client platform such as a computer, and to the cloud system. It equally serves as a way of accessing the unified cloud storage by the different government hospitals. Moreover, the back-end of the system which is the cloud system is made up of the following: the authentication server, the Unified Network interface middleware (UNIM) and the unified cloud storage. The Authentication Server is the part of the cloud system that handles the authentication and authorization of the users of the system. When users are establishing a dialogue with the proposed system, they must be authenticated. The PC-CBEHR system performs authentication of every user to ensure that the user has rights into the system and is authorized. A central cloud server administers the system, monitoring traffic and client demands to ensure everything runs smoothly. It uses virtualization technique in which multiple virtual servers with their different operating systems run on the same physical server in order to reduce the need for physical servers, space and make more efficient use of the CPU. It follows a set of rules called protocols and uses a special kind of software called middleware. The web application runs on these virtual servers. The Unified Network Interface Middleware (UNIM) allows networked computers to communicate with each other. The cloud system uses the middleware to provide communication services and serve the purpose of a messenger so that the web application can send and receive messages to/from the cloud storage. The middleware is required in order to connect to the cloud storage. The main work of the middleware is to allow networked computers to smoothly communicate with each other. The middleware used in the system is application server. The Unified Cloud Storage is the data tier of the PC-CBEHR system. It serves as the central database for all the registered government hospitals. It stores the electronic health record of patients which can be retrieved and updated. The information in the unified cloud storage adopts a particular form and is retrieved from the hospital application through the network interface middleware. MYSQL is the program that manages, reads and writes access to the cloud storage.

Additionally, the objects in the system together with the static structure were represented using the class diagram. The classes within this system are shown and they have attributes (member variables), behaviour (member functions) and relationships with other classes identified. Figure 3.3 depicts the class diagram of the system proposed.

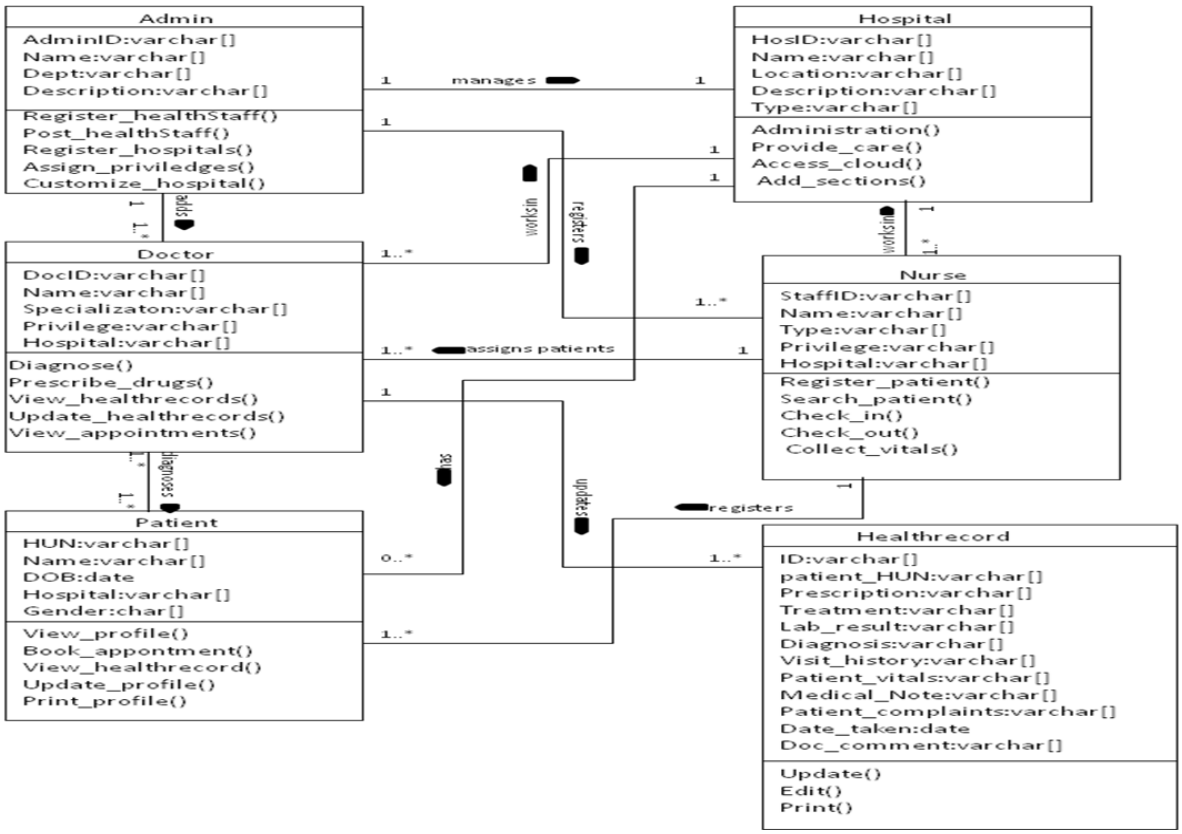

Figure 3.2: Class Diagram of the proposed system

IV. System Implementation

The system was implemented with PHP scripting language and MYSQL database. After the system was hosted in the cloud and the application launched from a web browser in any computer system that has internet connection, the home page of the system is shown figure 5. It is through this home page that a user can access his/her page. The page contains the main menus such as Home, About, Services and Contact. On the extreme top right are some icons representing tools that are important in the system. One of which is the open padlock icon that is for logging in and out of the system. On clicking this button by the user, the login page is opened. It is after a user logs into the system, that he/she can properly make use of the system.

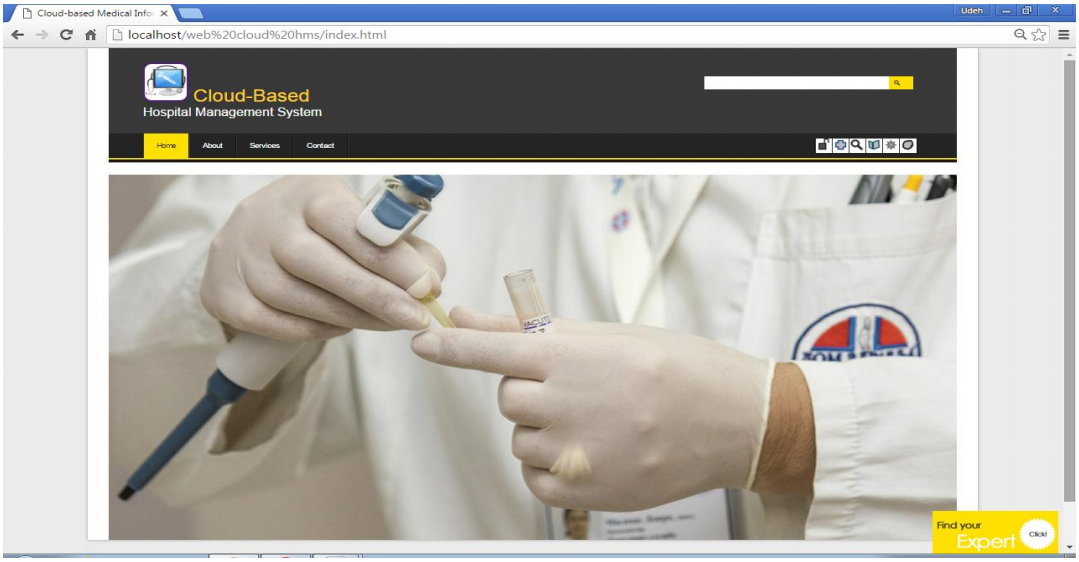

Figure 5: Home Page of the CB-PCES

The login interface for all the users of the system is shown in figure 6. In the figure, the administrator of a hospital, under the directives of the Ministry of Health, first attempts to log in with his username and password. If the password is correct, he gains access into the system to be able to customize the hospital's portal in the settings, register hospitals, register staff, view or print staff report, view or print hospital report, update staff profile etc. Once, a user logs into the system, the user's page is opened to him/her to access the functions that are due to him/her.

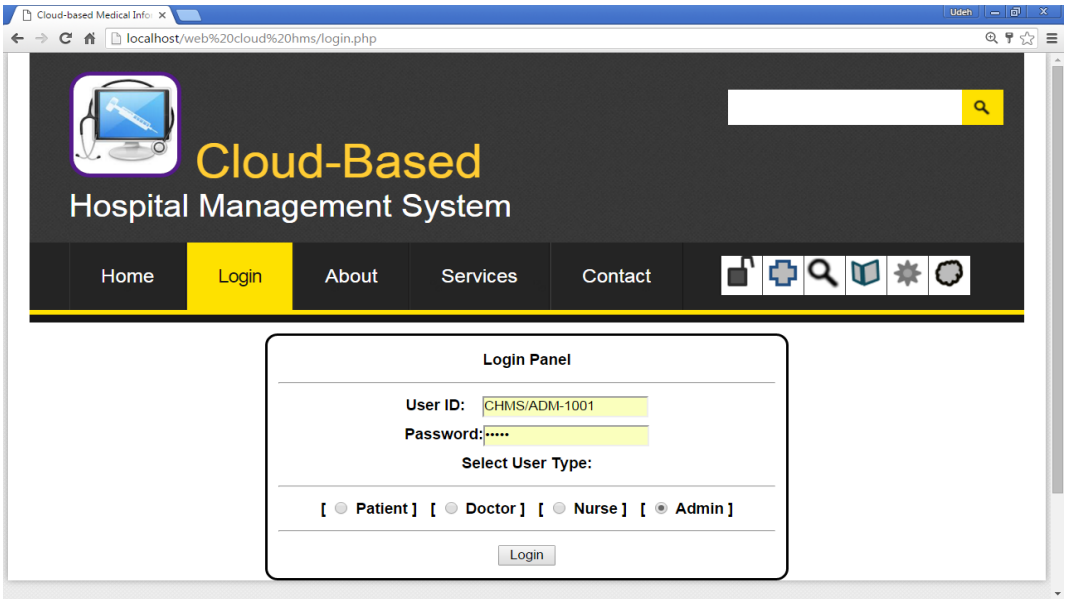

Figure 6: The Login Interface of the System

The administrator can modify a hospital's name, slogan, address, header colour and body colour to suit their need in the hospital's setting through the Admin Control Panel as depicted in figure 7. He can also register

a hospital; register staff of the hospital to use the system, view or print staff and hospital reports, post staff to hospitals by the authority of the Ministry of Health, update a staff's profile data etc. The roles of the administrator are important in the sense that he is the first user to customize a hospital before other users can use the system.

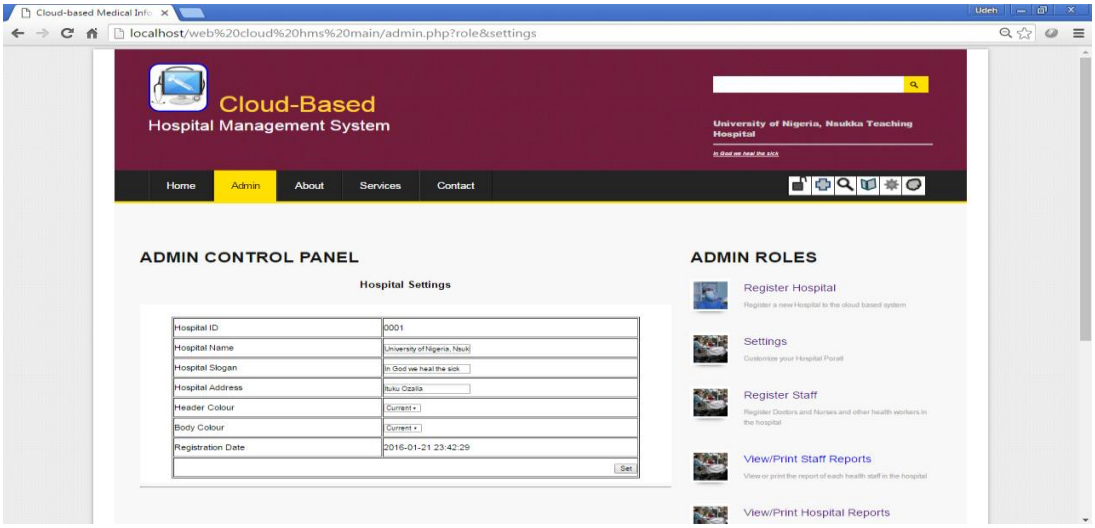

Figure 7: Administrator's Control Panel for Customizing the Hospital's Web Application

When a doctor, as a user of the system, successfully logs into the system as an authenticated user, he first of all sees the data protection right page that he has to accept in order to access the functions that are due to him. If he does not accept it, in other words, he rejects the right to patient data protection; he is taken back to the login page and would not have access to a patient's health record. Figure 8 shows the patient data protection right page that a doctor must accept in order to gain entrance to his own view of the system. This page is peculiar to doctors because they are the users that can view a patient's health records before commencing treatment apart from the patients themselves.

The data protection rights of a patient when accepted by a doctor, opens the doctor's page as seen in figure 9 is shown. The doctor can view a patient's existing health record, diagnose patients, prescribe drugs for the patients, enter lab results, fill medical note, view appointments he has with patients, enter visit history of patient, and view his own profile.

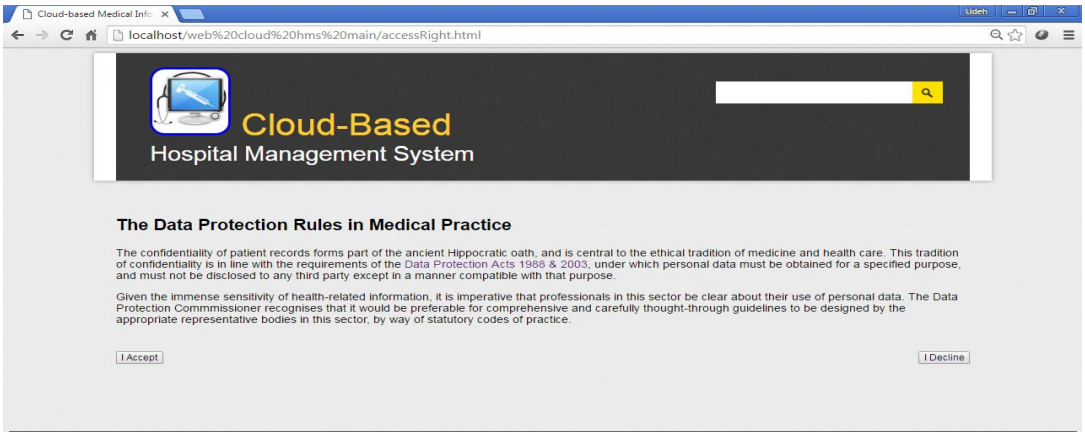

Figure 8: Patient data protection right page to be accepted or rejected by a doctor.

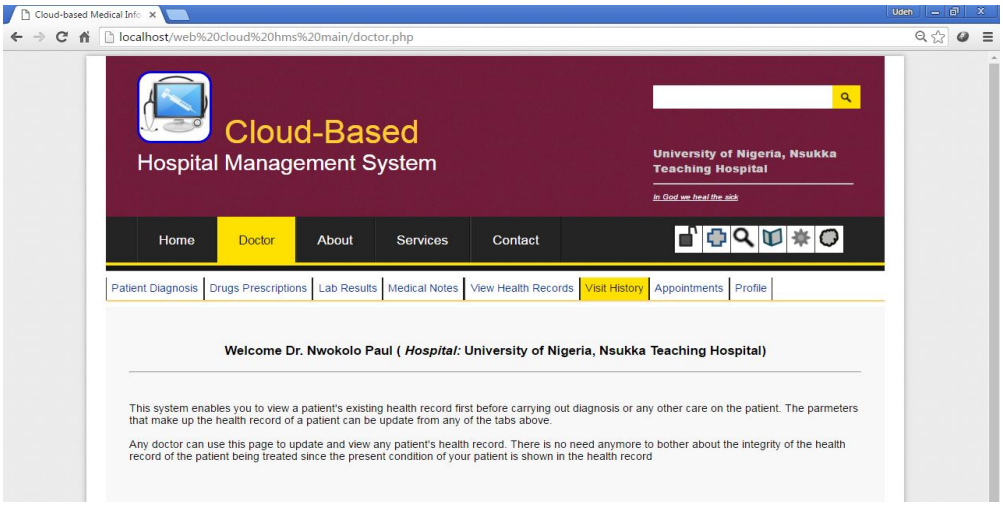

Figure 9: The Doctor's Page

The doctor could view the previous health record of a patient he is treating. He/she types in the patient's ID to be able to see the previous health record displayed in figure 10.

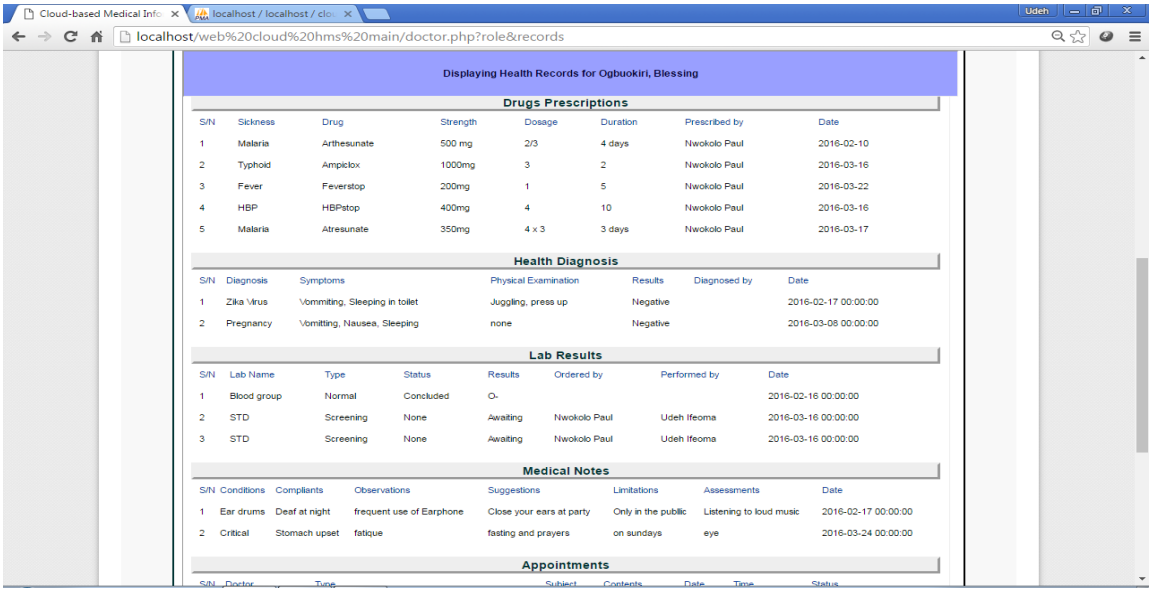

Figure 10: The existing health record of a patient

V. Conclusion and Recommendation

Cloud computing is one key technology that has a wide application in health sector. The technology facilitates and improves the quality of healthcare delivery to patients. It is a promising way for different hospitals to pool their resources together in order to achieve easy and faster health record sharing, decision making and reduced cost of healthcare management.

This paper has in essence, described how cloud computing can be used to improve healthcare delivery and enable patients get quality care from any registered hospital in any location because adequate reference is made to an electronic health record created for the patients. It also solved most of the problems encountered in the manual approach of keeping health record by developing an automated system that can be employed by different hospitals. Furthermore, a centralized database for keeping all patients' records together with the software that can be customized to suit the needs of the hospitals was created and developed respectively.

Moreover, it is recommended that a secured internet connection and constant electricity supply be provided so that the system can be effectively used. Also, favourable government policies for the adoption of the cloud-based electronic health records system in developing countries should be put in place.

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