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IoT-BASED TELEMEDICINE SYSTEM TO ADDRESS HEALTHCARE ACCESS CHALLENGES IN NIGERIA

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ABSTRACT

The Internet of Things (IoT) integrates sensors, software, and connectivity to enable real-time data exchange between devices and systems, playing a transformative role in modern telemedicine. This study presents an IoT-based telemedicine system developed to address healthcare access challenges in Nigeria, especially in rural and underserved areas. The system includes an Android mobile application that uses the smartphone's camera to capture pulse readings, enabling preliminary assessment of patients' cardiac health. In parallel, a web-based administrative platform allows healthcare administrators to register medical practitioners, assign doctors to patients, schedule consultations, and manage cloud-based patient records. To protect sensitive health data, the system implements the Advanced Encryption Standard (AES) for secure data encryption and decryption. Developed using Flutter SDK, Dart programming language, Visual Studio Code, and Firebase, the application—referred to as the Rim360 Health App—demonstrates how IoT can facilitate real-time, encrypted patient monitoring and doctor-patient interaction. The system holds potential to significantly enhance telemedicine adoption in Nigeria by providing accessible, secure, and scalable healthcare solutions for remote populations.

Keywords: Android, Cloud-Computing, Diagnosis, Internet of Things, Telemedicine

INTRODUCTION

Nigeria, with a population exceeding 200 million—over half residing in rural areas—faces significant challenges in delivering accessible and quality healthcare. The integration of Internet of Things (IoT) technologies into telemedicine presents a transformative opportunity to bridge healthcare gaps, especially in underserved regions (Statista, 2024).

Internet of things (IoTs) has evolved to become one of the most promising technologies in the industry and academics for innovation. The IoT devices will play a significant role in monitoring the health of patients. Telemedicine services are still in a developing stage in Nigeria. The remote diagnosis and treatment of patients by means of telecommunications technology has proven effective since its abduction into the healthcare system. Due to the lack of adequate/good doctors in rural and urban areas, healthcare services are not as good as it should be for consulting and monitoring of patient's health (Rolim et al., 2010). Therefore, the need of telemedicine sets in to cope with the situation. In the year 2020, the population of Nigerians living in rural areas reported at 48.04%. Due to lack of adequate/good doctors and lack of finance by the settlers in rural areas, death may become the fate of a patient suffering from an ailment.

For the proposed system, encryption and decryption operations will be carried by symmetric key cryptographic techniques Advanced Encryption Standard (AES). Services offered by Cloud Providers are classified into three groups including Software as a Service (SaaS),

Infrastructure as a Service (IaaS) and Platform as a Service (PaaS) (Bhandari, & Mishra, 2013).

Medical records are made readily available anywhere at all time since the emergence of cloud computing. Telemedicine services are cheaper than face-to-face consulting the doctors. It is not possible to save all the consultation and test reports (hard copies) of patients in libraries in well maintained and safe house. Internet provides cloud storage, which is accessible by the doctor and the patient at anytime from anywhere in the world through cloud computing (Rai & Anand, 2017). Cloud computing has its advantages and disadvantages. These disadvantages include security of data, complete control over the cloud infrastructure, network latency issues and full access of the cloud environment. Many organizations prefer storing mission-critical data in their own infrastructure. To manage some of these challenges, data encryption is use to ensure data security. Numerous researches in both cloud data access systems as well as storage system where conducted. Khan and Sakamura (2012) proposed a Discretionary Access Control (DAC) framework that protects healthcare organizations against security attacks and ascertains confidentiality of patient data.

Android application to render telemedicine services has offered easy access to information, better user interaction; convenient interface based on user habits, offline user mode and using device features such as accessing other built-in functions of the smartphone and connected peripheral devices.

On the other hand, in the urban areas, developed or in developing phase, where Internet services are readily available, many healthcare portals are accessible where Internet of Things (IoT) devices are supportive in healthcare services (Rolim et al., 2010).

A doctor using sensors and IoTs devices can monitor the health condition of a patient.

Nigeria faces significant healthcare delivery challenges, particularly in rural and remote communities where access to qualified medical personnel, diagnostic tools, and timely consultations is limited. The uneven distribution of healthcare infrastructure, combined with a shortage of medical professionals and the high cost of transportation, often prevents early diagnosis and effective treatment of critical health conditions. While telemedicine presents a viable solution to bridge these gaps, its full potential remains underutilized due to infrastructural, technological, and security-related constraints.

Additionally, existing telemedicine platforms in Nigeria often lack real-time diagnostic capabilities and robust data protection mechanisms, making them unreliable for critical care and sensitive health data management. The absence of integrated systems that combine real-time monitoring, secure communication, and automated patient-doctor interaction further impedes the adoption of telemedicine in the country. Telemedicine (or telehealth) represents a revolutionary patient management approach combining various forms of information communication technology (ICT) to remotely deliver care, consultation, medical education, specific healthcare and clinical services, and for monitoring patients' parameters at distance. It is a promising tool for improving access to care, empowering patients, influencing their attitudes and behaviors, and ultimately enhancing their medical conditions. (Omboni et al., 2020)

Therefore, there is a pressing need for an IoT-enabled telemedicine solution that can provide real-time vital sign monitoring, secure data exchange, and efficient remote consultations. This research addresses the problem by developing an integrated mobile and web-based system that enhances patient care through real-time pulse monitoring, secure cloud-based data storage, and streamlined doctor-patient engagement—ultimately aiming to improve healthcare accessibility and quality in underserved Nigerian communities. The objectives of the study is to; Design the model for the

MATERIALS AND METHODS

The technique used to design the Android based Telemedicine Application is Object Oriented Analysis and Design (OOAD) Model. The Object Oriented Analysis Design Model is a standardized modeling language consisting of an integrated set of diagrams, developed to help system and software developers for specifying, visualizing, constructing, and documenting the Information Technology (IT) Artifacts of Software Systems.

Object Oriented Analysis and Design in the Software Development Life Cycle (SDLC)

The software life cycle is typically divided up into stages going from abstract descriptions of the problem to designs then to code and testing and finally to deployment. The water fall stages of the SDLC are shown in figure 1.

Research Tools

PHP, Flutter, Dart Programming Language iv., MySQLi

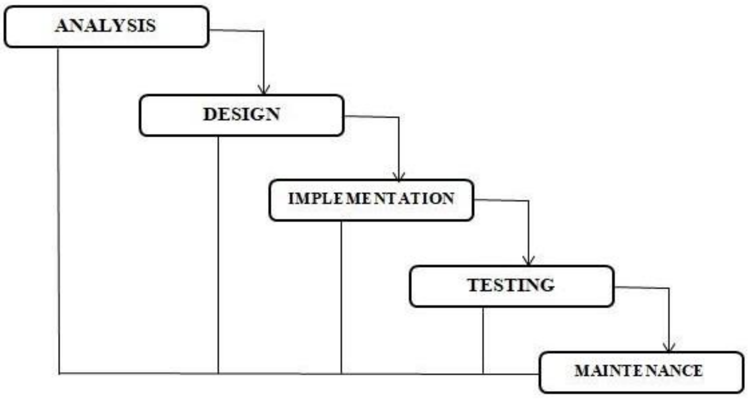

Figure 1: Waterfall Model

The Proposed System

The proposed system will make use of a standalone (Android) application to carryout telemedicine practices. The system will grant easy and fast access to information needed by either the doctor or patient, send instant notifications to its users, create a convenient user interface, provide an offline user mode and most especially ensure data security through data encryption. System model of the proposed system can be found in figure 2.

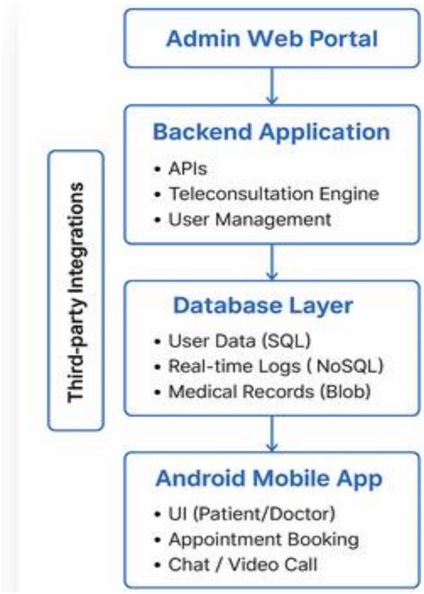

Figure 2: Model for Android-based Telemedicine Services

Based on figure 2: telemedicine services can be explained as follows:

Android Mobile Application Layer

This layer represents the primary user interface for both patients and doctors. The mobile application, developed using the Flutter Software Development Kit (SDK), serves as the front-end interface for:

Pulse reading through smartphone sensors or connected IoT devices.

Appointment booking with registered doctors, Real-time communication via chat or video call functionalities.

It ensures ease of use and accessibility, especially for patients in rural areas, and supports the secure exchange of information between users and the backend system.

Backend Application Layer

This layer acts as the core logic and communication engine of the system. It includes:

i. *Application Programming Interfaces (APIs)* to manage data flow between the mobile app, admin portal, and external systems.
ii. *Teleconsultation Engine* responsible for managing secure video conferencing and chat sessions between patients and healthcare providers.
iii. *User Management Module* to authenticate and authorize users, assign roles (e.g., doctor, patient, admin), and manage profiles.

The backend is built using a scalable architecture that supports both synchronous and asynchronous communication patterns to handle real-time interactions efficiently.

Database Layer

The database layer is responsible for persistent data storage and is divided into three key components:

i. *Structured Data (SQL)* for storing user details, appointment records, and role assignments.
ii. *Unstructured Logs (NoSQL)* for storing real-time activity logs and session data.
iii. *Medical Records (Blob Storage)* to handle binary files such as scanned prescriptions, diagnostic images, and encrypted patient documents.

This layered data architecture ensures optimal performance, security, and data accessibility for different system functions.

Admin Web Portal

This module provides system administrators with a centralized web interface to manage the platform. Key functionalities include, Registration and verification of doctors.

Assigning doctors to patients based on specialization or availability. Scheduling and monitoring teleconsultation sessions. Managing access to cloud-based medical data and logs.

The web portal enhances system transparency, governance, and operational control.

Third-party Integrations

To expand functionality, the system architecture supports seamless integration with third-party services such as, Health monitoring IoT devices (e.g., pulse sensors, BP monitors). Payment gateways for service billing.National health registries and insurance verification systems.

These integrations allow the system to remain flexible and future-ready, accommodating the evolving landscape of digital health in Nigeria.

Use-case Diagram

Use case diagram at its simplest is a representation of a users' interaction with the system and depicting the specifications of a use-case. A use case diagram can portray the different types of users of a system. This use case diagram depicts the three users of the proposed system and various types of functions that can be carried out by each of the users. The use case diagram of the system can be seen in figure 3.4.

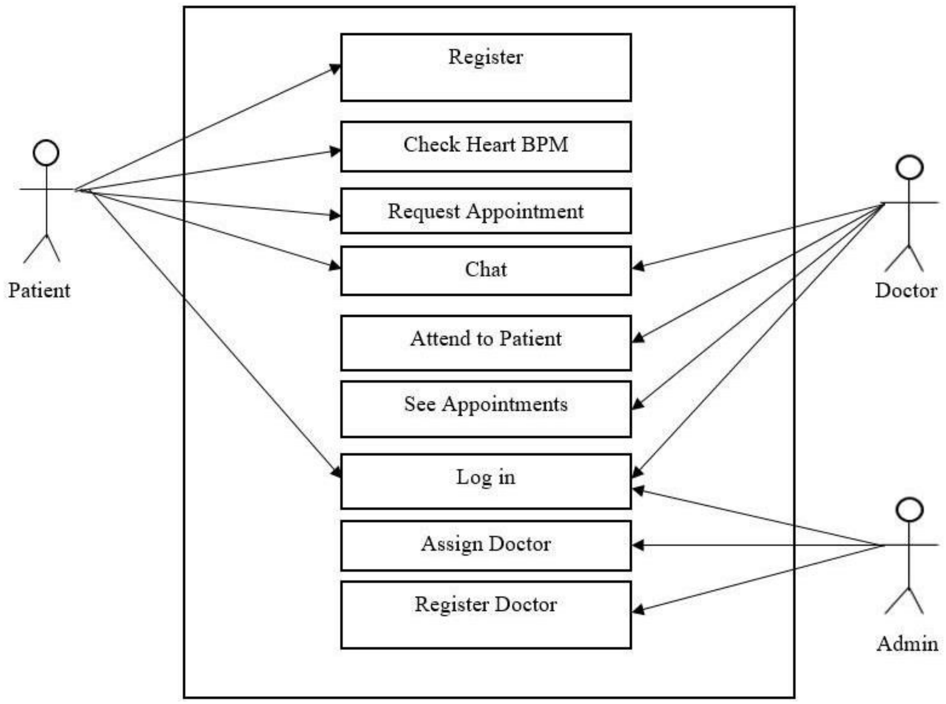

Figure 3: Use-case Diagram of the Proposed System

Activity Diagram

An activity diagram is a variation of a state machine in which the states represent the performance of actions or sub activities and the transitions are triggered by the completion of the actions or sub activities. Activity diagram for registration can be seen in Figure 3.5.

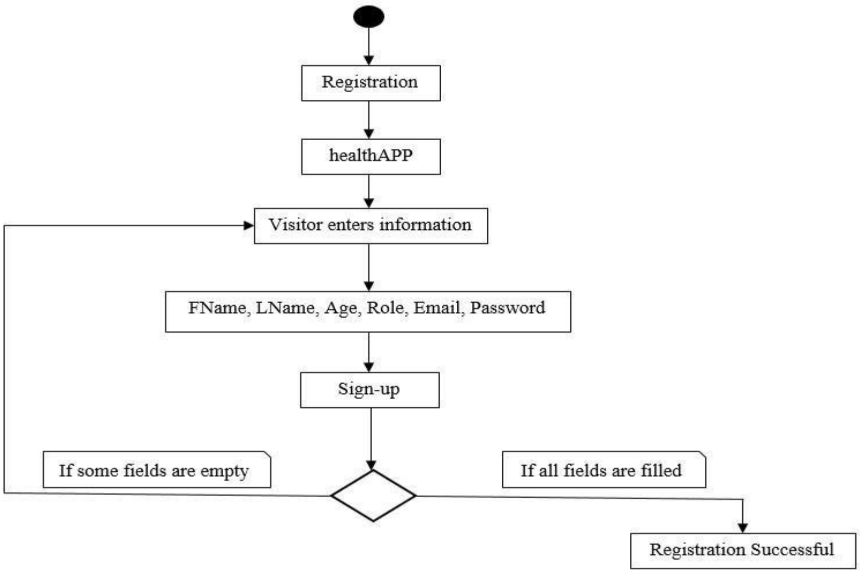

Figure 4: Activity Diagram – Registration

The activity diagram of user registration (patient) is shown in figure 3.5 and it depicts the actions a visitor will undergo in being registered on the system. The process of registration entails the visitor having access to the system's android application and then clicking on register now button on the app's home page. The next step is filling in the required information and then click on register. Immediately, the new user's information will be added to the system's database.

Sequence Diagram (SD)

A sequence diagram sometimes referred to as an event diagram or an event scenario, shows the order in which objects interacts. This way, you can visually represent simple runtime scenarios.

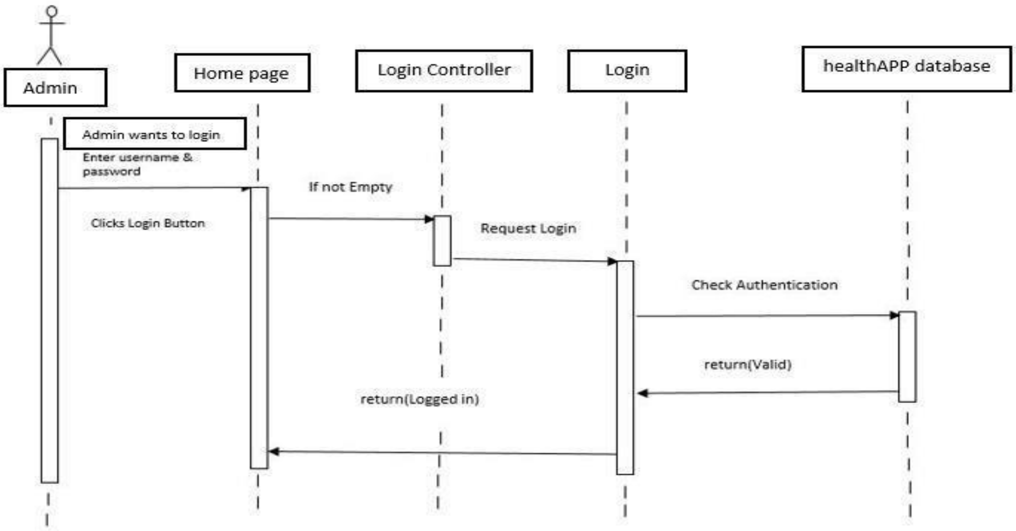

Figure 5: Sequence Diagram – Admin Login

For the administrator of the system to have access into the system, login credentials must be provided. The credentials will be entered in the login portal located on the home page interface. If the provisions provided for the credentials are not empty, the login controller sends a login request. The system checks to confirm the authenticity of the credentials provided from the system database. If they are valid, then access is granted and if otherwise, access is denied. The sequence diagram of the administrator login can be seen in figure 5.

Class Diagram

Class diagram is static in nature. This diagram depicts the static view of an application. Class diagram purpose is not just for visualizing, describing and documenting different aspects of a system but also for constructing executable codes of the software application. The class diagram of the system can be seen in figure 6.

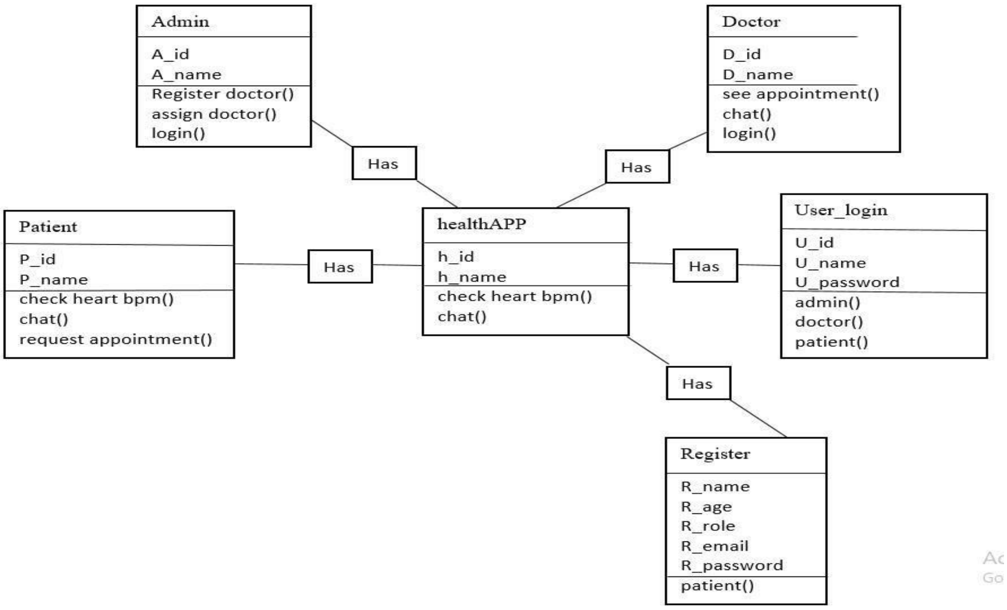

Figure 6: Class Diagram – Health APP

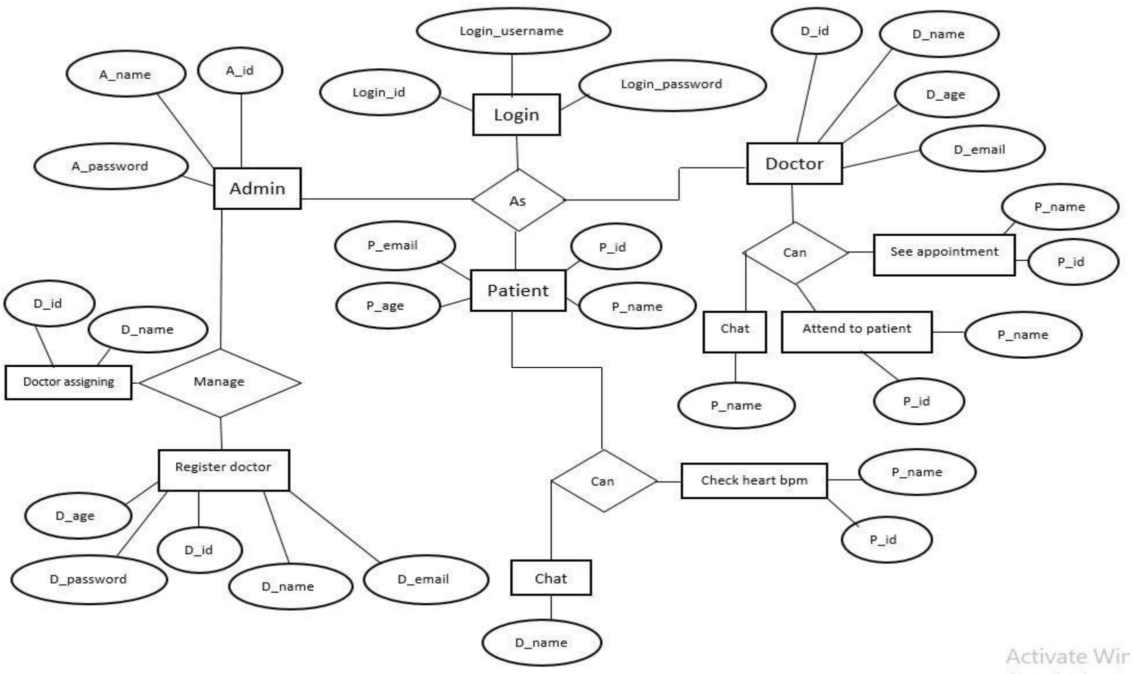

Figure 7: Entity Relationship Diagram

IPPG Instrumentation

The key part of an IPPG system is the camera, which collects the reflected or transmitted photons from the skin. The camera's characteristics significantly influence the recorded images and, consequently, the physiological parameters. Making use of the cellphone based IPPG system, the embedded digital camera for image videoing mode and white LED (the flashlight) as the light source positioned photoplethysmography instrumentation setup serves as our instrument.

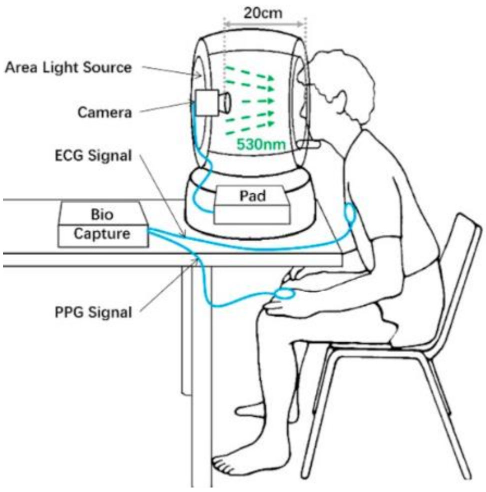

Figure 8: Imaging Photoplethysmography Instrumentation Setup

RESULTS AND DISCUSSION

Main Menu

This primary menu contains different modules of the android application "Rim360 Health App". The modules comprise of the following:

i. Home Page
ii. Login Module
iii. Register Page

Home Page

This is the first page that pops up when a patient, doctor or administrator logs into their account. The page contains several links to other pages. The figures below shows the home page of the three different users of the system. Figure A shows the home page of a patient, B shows that of a doctor and C of the administrator.

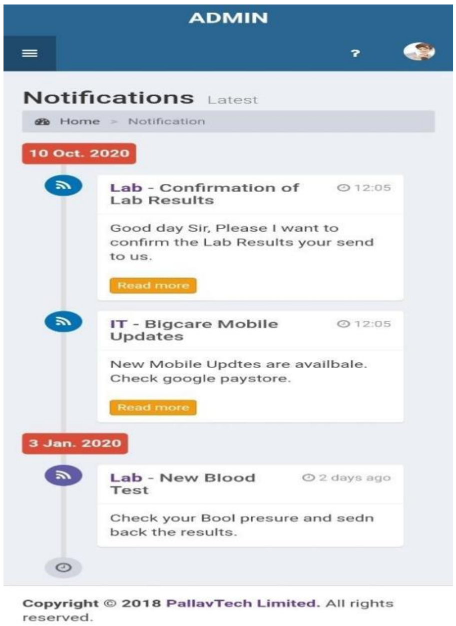

Figure 9: System Home Pages

Register Page

On this page, a patient registers before getting access to a username and a password. During the registration process, the visitor makes use of a valid email address as a username and chooses a pin.

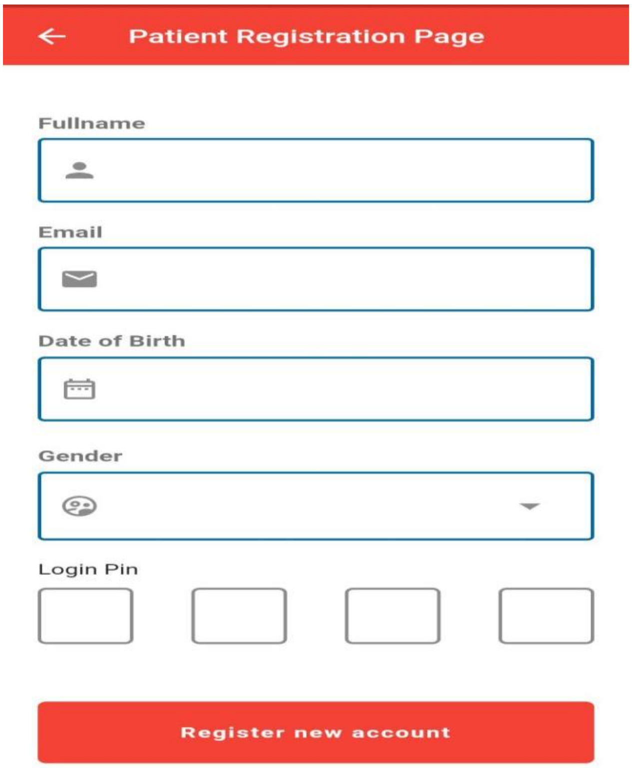

Figure 10: Register Page

Login Module
This is a module in the system where a patient, doctor or an administrator provides the log in credentials in order to have access in to the system. The figures labelled a, b and c shows the patient, doctor and administrator log in interface respectively.

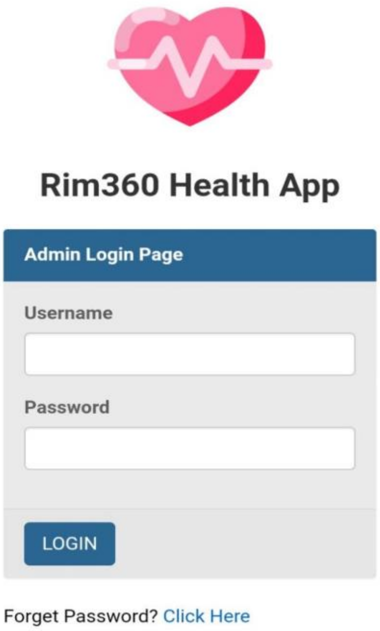

Figure 11: Login Pages

Submenus
A submenu also known as a cascading menu is a secondary menu displayed on demand from within a menu.

Patient Dashboard
This is the personal dashboard of a patient where the patient can consult a doctor. Under this module, a patient can measure heart beat rate, view appointment time and get to chat with doctor assigned during the consultation session. The patient can get to view his/her profile.

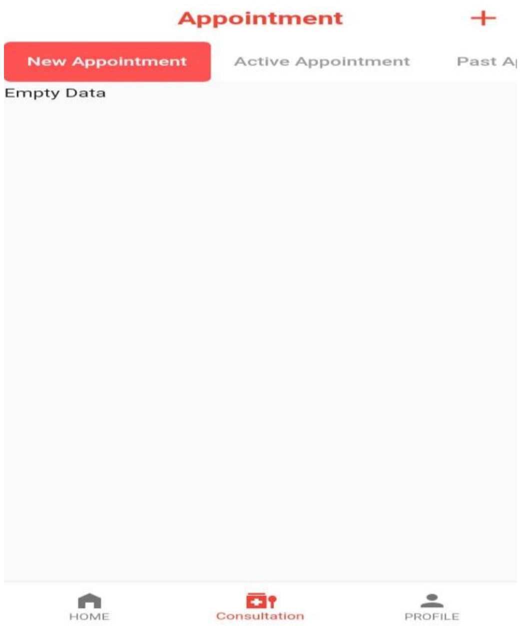

Figure 12: Patient Dashboard

Doctor Dashboard
This is the personal dashboard of a doctor where the doctor can know the patient(s) assigned to him/her, chat (communicate) with a patient during the consultation session, view new, active and past appointments and lastly, the doctor can get to view the profile of the patient.

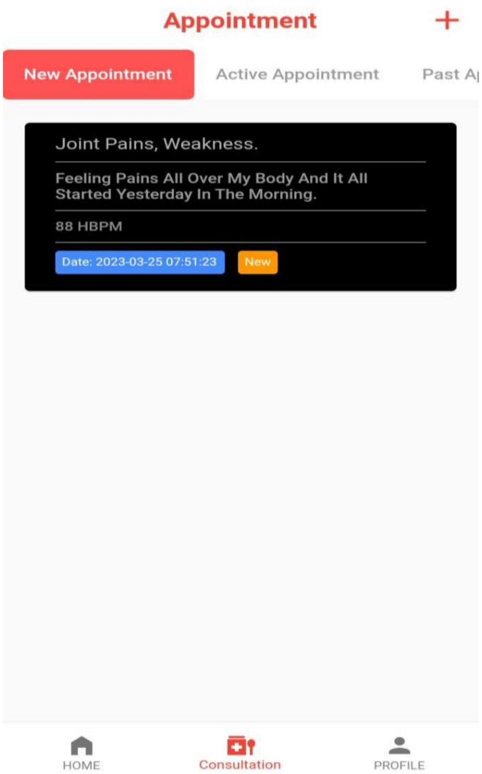

Figure 13: Doctor Dashboard

Admin Dashboard
This is the personal dashboard of an admin (i.e the hospital) where the admin can also create user (doctor), assign doctor to a patient, set time for appointment and view the profile of any doctor or patient registered in the system.

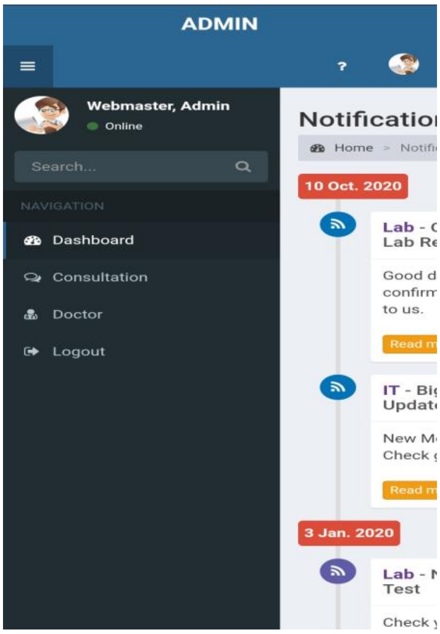

Figure 14: Admin Dashboard

CONCLUSION

The integration of Internet of Things (IoT) technologies into telemedicine presents a transformative opportunity for improving healthcare delivery in Nigeria, particularly in rural and underserved regions. The developed system, featuring a mobile application for pulse monitoring and a secure web-based platform for administrative and clinical interactions, demonstrates the potential of digital health solutions to bridge the gap between patients and healthcare providers. By leveraging real-time data collection, cloud-based storage, and strong encryption protocols like AES, the system ensures both accessibility and data security. Furthermore, the use of Flutter SDK and Firebase provides a scalable, cross-platform solution capable of supporting Nigeria's growing digital health ecosystem. This innovation addresses critical challenges such as doctor shortages, geographical barriers, and patient data confidentiality. With the proper infrastructure, policy support, and public awareness, IoT-driven telemedicine systems like the Rim360 Health App can significantly enhance the reach, efficiency, and quality of healthcare services across Nigeria.

Ultimately, this study underscores the urgent need for nationwide adoption of smart health technologies, backed by robust ICT frameworks, to meet the rising demand for accessible and affordable healthcare in the country.

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