Development of an Android Based Medication Reminder and Adherence System

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ABSTRACT
Android based medication reminder and adherence system is a system in which an alarm and notification system is implemented and also provides a platform for doctors, healthcare givers and patients' interaction. Patients can set a customized alarm tone in their local language or select from a list of default tones. The application allows specialists to automatically see the list of patients connected to them and their chat messages. Specialist can send health tips and other broadcast messages to his entire patients or fix an appointment date with any of their patients at will.
Agile software engineering process was used for the development of the system. The front end was implemented using android studio and the back end was designed using firebase frame work. The android based application runs on mobile devices, such as smart phones, tablet computers and PDAs. The application was implemented and tested on the mobile phones of several patients, healthcare givers and Computer programmers, it was found to be very helpful in care management and easing travelling stress and fatigue and the reminder system assisted in medication adherence. Survey results shows 100% likes for the system's reminder and notification module, 80% likes for the chart module, another 80% likes for the search for specialist module while 70% likes were recorded for broadcast messages.
This paper presents the development of the reminder and adherence system. The application is light weight, very easy to use and support medication adherence. The application will assist patients with chronic illness like Cancer, Diabetes, Asthma and HIV/AIDS, to get notifications from medical personnel about the availability of drugs and also served as a reminder system, thereby promoting adherence.

Keywords: Automatic Alarm, Chronic Ailment, Medication Adherence, Notification System.

1. INTRODUCTION

The use of mobile devices such as handsets, Personal Digital Assistants (PDAs) and tablet computers has increased in the past few years that it has become a must have, in fact mobile phones and other devices has become human companion almost impossible to live without. All professions make use of mobile device in one form or the other and the inclusion of web services within the device has further encouraged its usage. Thus, developers are regularly developing applications that will run on mobile phones. These applications are designed and programmed to meet specific needs and also to run on specific platform.
Mobile phone platforms are important as it predetermines the type of applications and software that will eventually run on it. Phone manufacturers are creating phones that supports two platforms and convergence is something that is been advocated for within the industry.

This paper presents a mobile phone based medication reminder and adherence system which runs on Android platform which is a stable Linux-based operating system, and implements an alarm and a reminder, sending and receiving of chat and broadcast messages to promote medication adherence among patients. The application can be incorporated into already existing health management system through which patients can use their mobile phones to obtain required information.

2.0 LITERATURE REVIEW

Several Medication reminder systems have been developed to run on different mobile phone platforms ranging from Java, Symbian, Windows, Apple and Android. MediHealth, (Slagle et al, 2011) is a medication reminder system for children that run on mobile devices and it provides user interfaces for setting medication schedules and user alerts for reminding users about the time and type of medication schedules.

However, some systems use sensors, radio frequency identification (RFID) or motion detection technologies to ensure that patients actually take their medications, Becker et al 2009, Ammouri, and Bilodeau (2008) and Prasad (2013). Medicine reminder pro is a free application which supports up to 15 reminders. Users can select them in non-repeating or in a repeating order Batz, et al (2005). Time interval can be selected on hourly basis from the minimum of one hour at the scheduled time; application will produce a notification with an alarm, vibration or LED indication. Batz, et al (2005). Wedjet is another smart phone application running on windows operating system which was developed to avoid medicine administration error (Zao et al 2010). Moreover, review and analysis result shows that there are more than 328 mobile applications for medication management Tabi et al 2019.

Mobile health system refers to the use of mobile applications for health care services in the medical domain. The term is most commonly used in reference to using mobile communication devices, such as mobile phones, tablet computers and PDAs, and wearable devices such as smart watches, for health services, information, and data collection.

The Mobile Health field has emerged as a sub-segment of eHealth, the use of information and communication technology (ICT), such as computers, mobile phones, communications satellite, patient monitors, etc., for health services and information. Mobile Health applications include the use of mobile devices in collecting community and clinical health data, delivery of healthcare information to practitioners, researchers and patients, real-time monitoring of patient vital signs, the direct provision of care (via mobile telemedicine) as well as training and collaboration of health workers Christine et al 2011.

3.0 METHODOLOGY

This work was designed using the integration of a real-time mobile-based communication among multiple users on a single platform. It is strictly developed to run on android powered smart phones. The front end is designed using android studio and the back end is designed using firebase frame work.

The software engineering methodology used for this work is the agile approach. Agile methodology is a practice that promotes continuous iteration of development and testing throughout the software development lifecycle of the project. Both development and testing activities are concurrent unlike the Waterfall model. (**Software Development Methodologies** 2019), The Agile Process differs from waterfall model in ways like: instead of having big projects, it attempts to break projects into small increments in a cyclic manner and it allows future updates to software applications. The Figure 1 is the agile software process.

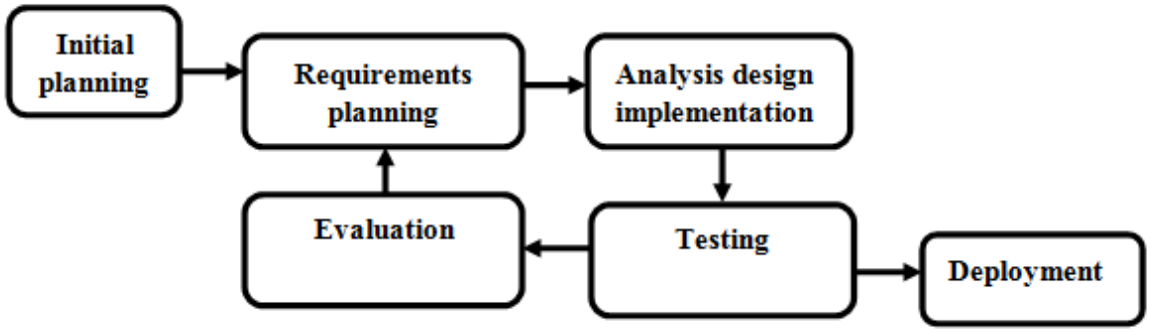

Figure 1: The Agile process

Source: https://www.visual-paradigm.com/scrum/what-is-agile-software-development/

Android is a Linux-based operating system designed primarily for touch screen mobile devices such as smart phones and tablet computers, developed by Google in conjunction with the Open Handset Alliance. The system is specified on android operating system only because android phones are more commonly available and affordable by most people in Nigeria. Android also comes with an application development

framework (ADF), which provides an API for application development and includes services for building GUI applications, data access, and other component types. The framework is designed to simplify the reuse and integration of components. Android apps are built using a mandatory XML manifest file. The manifest file values are bound to the application at compile time. This file provides essential information to an Android platform for managing the life cycle of an application. Examples of the kinds of information included in a manifest file are descriptions of the app's components among other architectural and configuration properties. Components can be one of the following types: Activities, Services, Broadcast Receivers, and Content Providers, Mahmood, Mirzaei, and Malek, (2014)

Firebase provides a real time database and backend as a service. The service provides application developers an API that allows application data to be synchronized across client's and stored on Firebase's cloud Farr (2013), Marshall (2013). The company provides client libraries that enable integration with Android, iOS, JavaScript, Java, Objective-C, Swift and Node.js applications. The database is also accessible through a REST API and bindings for several JavaScript frameworks such as Angular JS, React, Ember.js and Backbone.js (Firebase Real Time Database, 2016) The REST API uses the Server-Sent Events protocol, which is an API for creating HTTP connections for receiving push notifications from a server. Developers using the real time database can secure their data by using the company's server-side-enforced security rules, Darrow (2012) , Firebase (2019).

The application was developed as a client-server based application with two client interface called the specialist application and the patient interface called the consultation application. The Specialists' application was named LTH Specialist and the patients' application was named LTH Consult arbitrarily respectively. The patient application user interface is slightly different from that of specialist's application. For example, Patients need to register first and login subsequently in order to gain full access into the application and there is no limit to the number of patients who can register while four specialists has been added to the backend of the system (hiv-aids@specialist.lth.com, cancer@specialist.lth.com, asthma@specialist.lth.com and diabetes@specialist.lth.com) and their login passwords will be given to them by the administration. Patients can retrieve their password if forgotten through their valid email addresses.

The firebase client server helps to connect the patient's application with the specialist's application and it serves as a repository for storing the broadcast and conversation messages between a patient and the specialist. The major advantage of it is that users can easily gain access to vital information after a successful login, it doesn't consume the smart phone's internal storage memory and it prevents loss of information since everything is on the firebase cloud.

Firebase provides a real time database and backend as a service. Figure 2 is the diagrammatic illustration of the firebase integration. The service provides application developers an API that allows application data to be synchronized across client's and stored on Firebase's cloud. (Firebase Real Time Database, 2016), Darrow (2012). The company provides client libraries that enable integration with Android, iOS, JavaScript, Java, Objective-C, Swift and Node.js applications. The database is also accessible through a REST API and bindings for several JavaScript frameworks such as Angular JS, React, Ember.js and Backbone.js Firebase (2019). The REST API uses the Server-Sent Events protocol, which is an API for creating HTTP connections for receiving push notifications from a server. Developers using the real time database can secure their data by using the company's server-side-enforced security rules. [16].

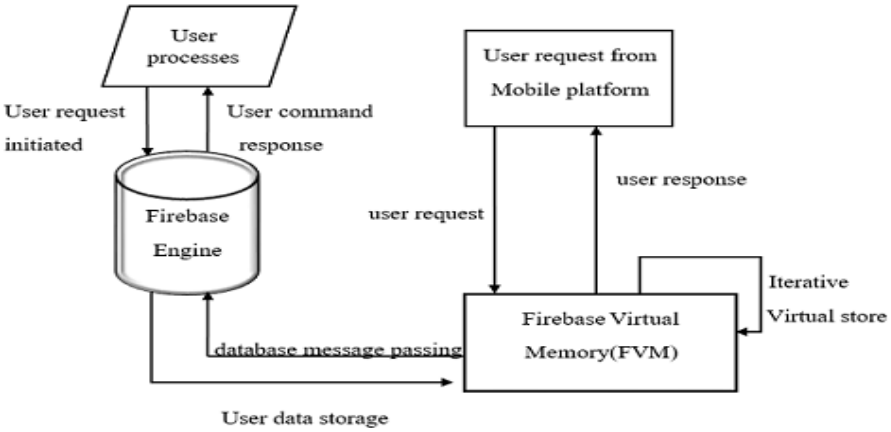

Figure 2: Firebase Integration

4.0 Requirement Analysis

In this stage of the software development process, potential requirements of the application were identified and defined in terms what the application should do and not how it works.

The following are some of the functional requirements of the android based medication reminder and adherence application:

i. It should allow a patient/doctor to sign up and login thereafter
ii. It should notify the users about the incoming messages
iii. It should allow a user to chat with a medical personnel
iv. It should allow a user to set a reminder and a notification message.
v. It should allow medical personnel to send out broadcast messages to all his patients.

5.0 Design Analysis

This phase provided the analyzed system in order to properly generate the models that were used in the application. It shows sequentially how the application works.

i. Users could launch the application.
ii. Users need to choose between sign in (after previous sign up) or sign up (for a new user).
iii. If sign in option was selected
iv. The authentication of users would be verified for true identity
v. Users could chat with medical personnel and set a single or multiple reminders.
vi. Users could receive broadcast messages.

Figure 3A and Figure 3B shows the flow of the steps mentioned above.

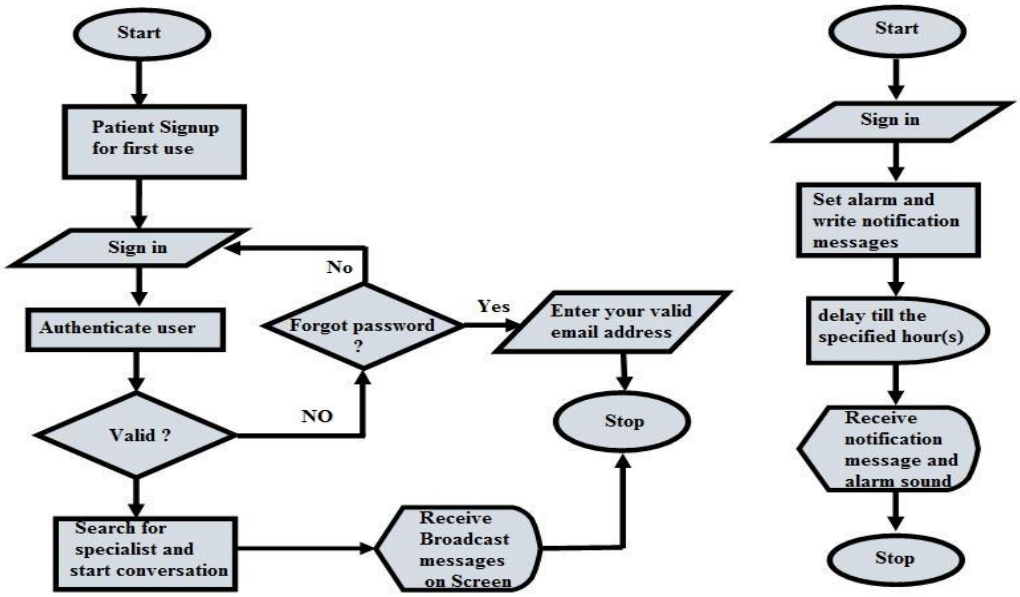

Figure 3A and Figure 3B: Flow Chat of patient's activities using the mobile application

While on the other end, the doctors would be able to perform the following activities.

i. Doctors would launch the application

ii. Doctors would need to choose between sign in (after previous sign up) or sign up (for a new user) option

iii. Sign in option was selected

iv. The authentication of the users would be verified for true identity

v. The medical personnel could then chat with his patients privately and send broadcast messages to all his patients.

Figure 4 shows the flow of activities of the steps mentioned above

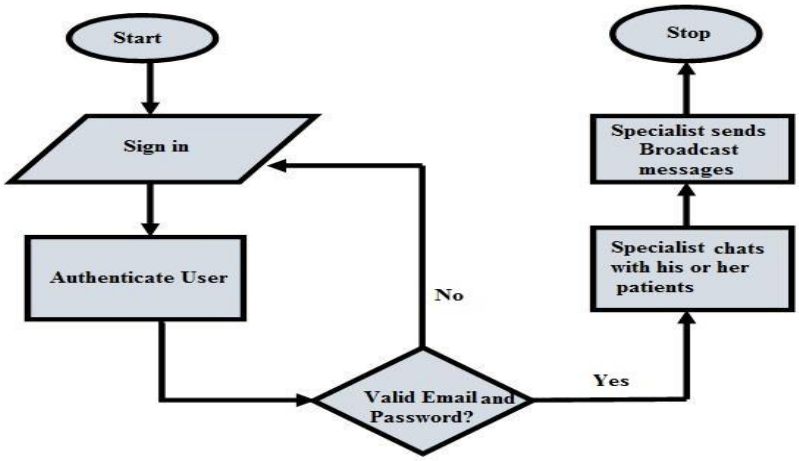

Figure 4: Flow Chat Diagram showing a Doctor's activity using the mobile application

Unified modeling language (UML) was used for designing some of the scenarios of the application. Figure 5 shows the UML use case diagram showing a description of how the system receives external request and responds to it, while Figure 6 shows the data flow diagram.

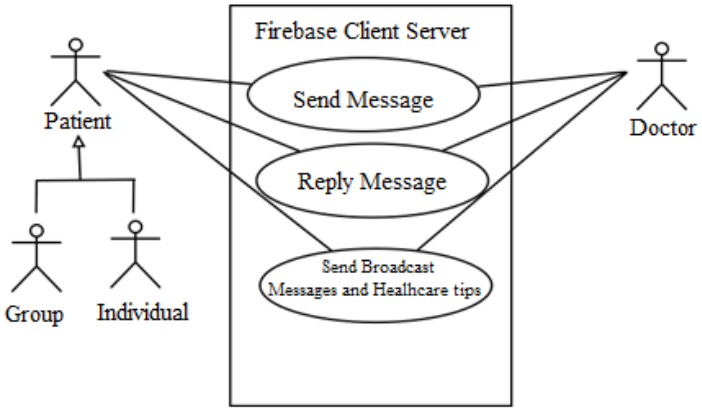

Figure 5: UML Use Case diagram of the system

Figure 6 is the Data Flow Chat Diagram of the system and figure 7 is the architectural view of the system.

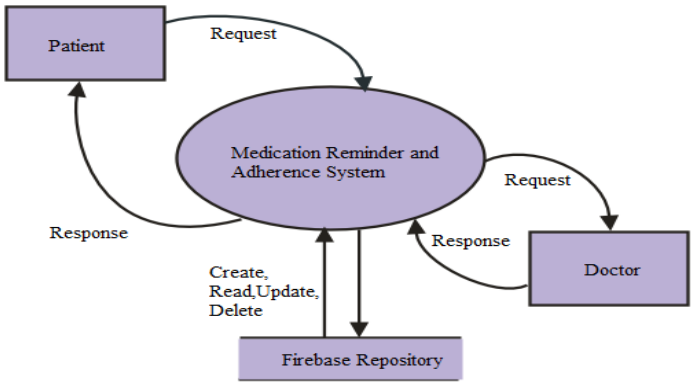

Figure 6: Data Flow Diagram of the system

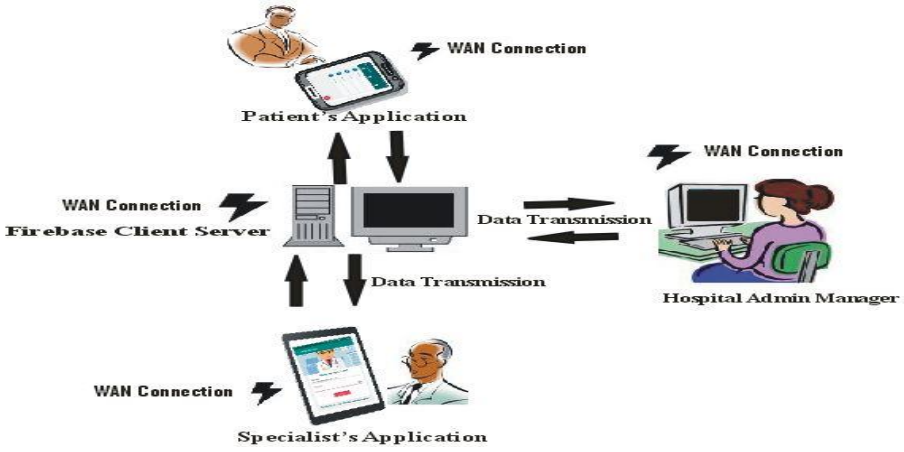

Figure 7: Architectural View of the Medication Reminder and Adherence System

6.0 Coding

The application was implemented in Java Programming Language while the user interface implemented using Extensible Markup Language (XML) using android studio.

7.0 Testing

The developed system was deployed on mobile phones and tested. Unit testing was conducted using the patient and doctor's applications as units. The patient's application was first tested and later the doctor's application too was tested for validity and efficiency. Thereafter, Integration Testing was carried out, after the firebase client server has been integrated into the system. And finally, System Testing was done. The mobile medication reminder and health care system is tested as a whole in this phase.

8.0 RESULTS AND DISCUSSION

The application is launched on an android phone running on android OS version 4.4 Kitkat, it displays the patient's application welcome page (LTH Consult) and the specialist's applications welcome page (LTH Specialist) Figure 8 and Figure 9 respectively and request that the user enter registration details and login. After a patient successful login, he or she can view the list of specialists available, it then shows Figure 10 and then he can navigate to the icon "GROUP" as shown in figure 11.

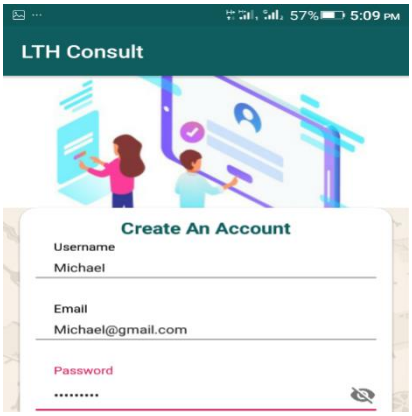

Figure 8: Patient's Registration Page

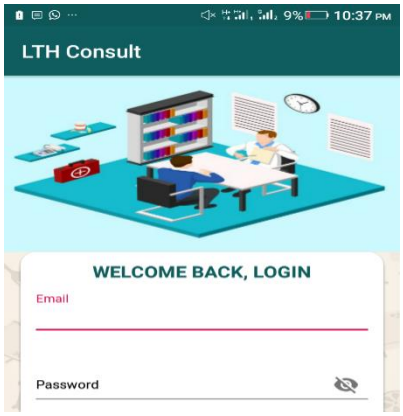

Figure 9: Patient's Login Page

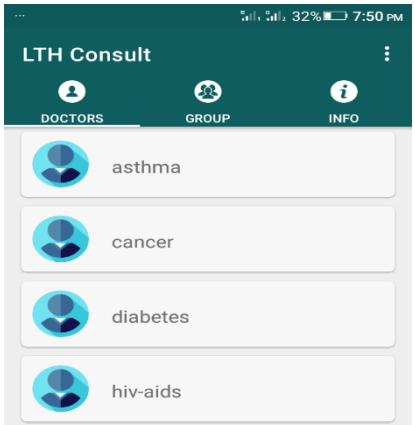

Figure 10: List of specialist Doctors Added

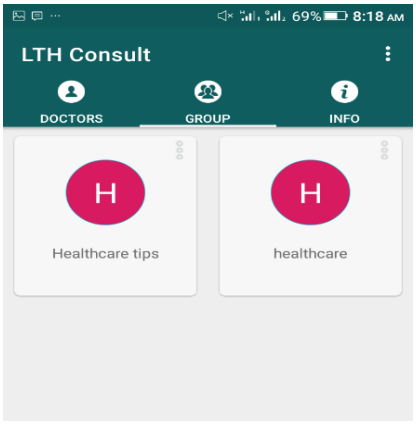

Figure 11: Health-care tips groups

The patient can proceed to chat with one of the doctors to fix an appointment. Figure 12 shows the health-care tips received and figure 13 shows the alarm clock settings.

Figure 12: Health-care tips sample

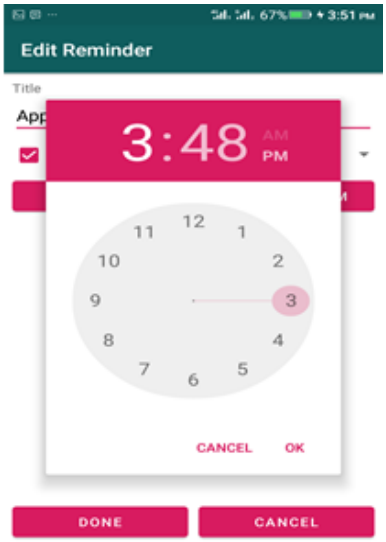

Figure 13: Setting alarm clock

The patient can also set as many as possible alarms as he wishes, and set his own customized alarm ringing tone. Figure 14 shows the various alarms he set while figure 15 shows the notifications received according to a particular alarm setting made. The INFO icon contains the patient's basic information like: name, email address and an option to sign out.

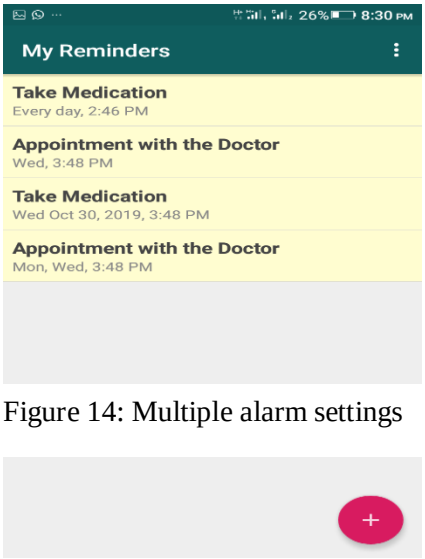

Figure 14: Multiple alarm settings

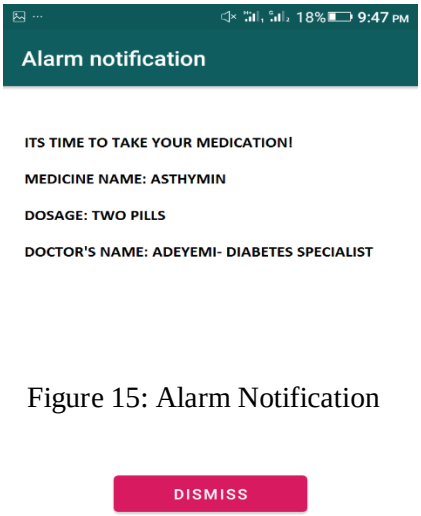

Figure 15: Alarm Notification

On the specialist's application a doctor who specializes in HIV-AIDS logged into his own application using the pre-registered email address and password. Figure 16 shows the specialist's login page and figure 17 shows the list of patients under the specialist and their respective conversations with the specialist.

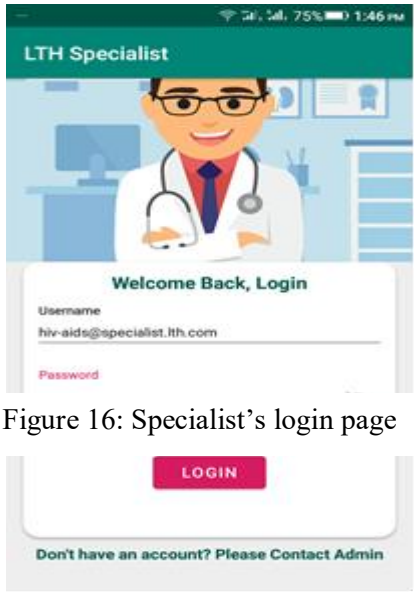

Figure 16: Specialist's login page

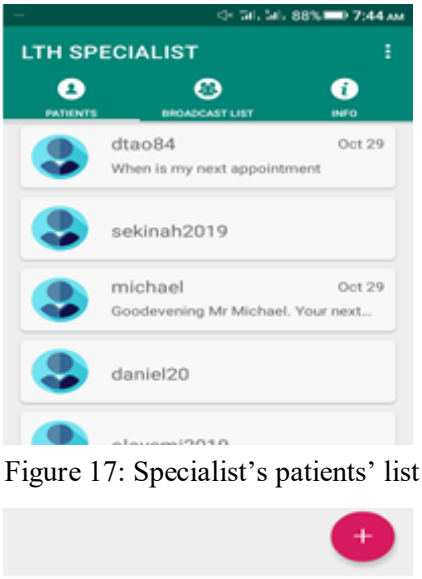

Figure 17: Specialist's patients' list

On the BROADCAST LIST icon, the Doctor is able to send broadcast messages to any of the groups he has previously created and added different categories of his patients to their required groups. The INFO icons contain the specialist's basic information like: name, email address and an option to sign out. In conclusion, a survey was carried out among 50 users comprising patients, healthcare givers and Computer programmers y installing the Android Based Medication Reminder and Adherence system's application on their smart phones and using the functionalities like reminder and notification modules, the chat message box, searching for specialists given the specialists' e-mail addresses, receiving broadcast messages and other health care tips revealed the results described in the chart in figure 18 below based on their likes for the inbuilt functionalities of the application.

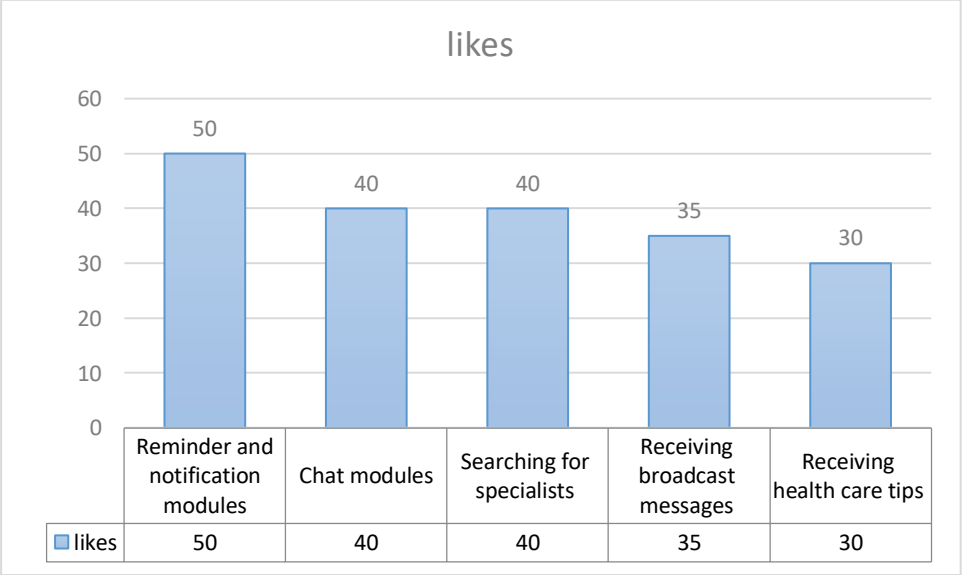

Figure 18: Chart showing the likes for the functionalities of the Applications.

Results of the 50 respondents of the survey conducted as shown in figure 18 revealed 100% likes for the reminder and notification functionality, 80% likes for the chart module of the application, another 80% likes for the searching for specialist module, 70% likes for the receiving broadcast messages and 60% for receiving health care tips

9.0 CONCLUSION

A lot of M-health phone based applications have been developed and in use within the e-health and telehealth domain. The adoption and use of reminder system is gradually gaining more and more acceptance in Africa among nursing mothers and the elderly with chronic diseases. This work was developed on android operating system, due to the prevalence and wide spread availability of android phones in Nigeria to remind patients to take their medication, and thereby improving adherence. The system also provides interfaces for patients –Doctor Interaction.
Other features of the system include but not limited to Patient been able to set single or multiple alarms and reminders for their medications, chat with medical personnel and receive broadcast messages about the availability of their medications. They can further receive health care tips from the various specialists.
Conclusively, the application is light weight, easy to use and adequately meet the minimum expectations for which they are intended.

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