A Framework for A Blood Seeker - Donor Matching System

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Abstract

The work designed, implemented and evaluated the blood seeker-donor (BSD) matching system. The system comprises of a backend server and a mobile application that serves as the main interaction interface between the users and the system. This is with the view to providing a computerized system that enables blood seekers and blood donation centers in the Nigerian geographic space to find and communicate with prospective blood donors, in a fast and efficient manner. The system connects the users using the blood type compatibility, relative location between the users, and other blood donation related attributes specified by the users. The backend service of the system was implemented using the Firebase platform. The mobile application was implemented using Java programming language on the Android platform. The results of the evaluation showed that; on a scale of 1 – 10, the system has a mean score of 7.02 for its effectiveness. The mean score for ease-of-use is 7.17 and the score for learnability is 7.39. The work concluded that geo-location technologies, through the use of mobile applications, can provide an easier, faster and efficient means of finding and communicating with prospective blood donors.

Keywords: Android, Blood Donation, Blood Group Compatibility, Geo-Location Technologies, Global Positioning Systems, Mobile Applications.

1. Introduction

Blood donation is a process where a person voluntarily has blood drawn from his/her body for the purpose of a blood transfusion [1]. The World Health Organization (WHO) in [2] states that blood donation saves live and improves health, but many patients requiring transfusion do not have timely access to safe blood. Donated blood can be used for women with complications of pregnancy before, during or after childbirth, children with severe anaemia often resulting from malaria or malnutrition, cancer patients, people with severe trauma and many other complex medical and surgical procedures [3].

As stated by the reports in [4] and [5], There is a major imbalance in access to safe blood between developing countries and industrialized countries with high income. Only about 40% of the blood collected globally each year is donated in developing countries, which are home to over 80% of the world's population. The WHO estimated in [4] that more than 5 million people die each year from trauma related to violence and injury. Uncontrolled bleeding accounts for more than 40% of trauma related deaths. The reports about global maternal mortality rates in [4] shows that 99% of the 530 000 women who die each year during pregnancy and childbirth live in developing countries with haemorrhage, which invariably requires a blood transfusion, the most common cause of maternal deaths.

According to the studies in [6], Nigeria as a developing country is not able to meet half of its 1.5 million pints a year requirement estimated by the National Blood Transfusion Service (NBTS). Lack of sufficient blood supply is one the main causes of death in Nigeria, especially in emergency situations. Reports in [7] shows that there are about 800 deaths per 100,000 live births in Nigeria which may be caused by shortage of blood. As shown in [6] and [8], A major reason for insufficient blood supply in the country is shortage of blood donors.

The recruitment strategy for blood donors in Nigeria as seen in [6], [8] and [9] is dominated by sourcing for donors from patient's family members and people who are recruited commercially to donate blood for monetary benefits. These sources, as shown by the stats, are not sufficient to bridge the nation's blood supply deficits. In addition to the present recruitment methods, a cheaper and more convenient way could be developed by providing a means of finding and engaging blood donors electronically, through the use of smartphones. Smartphones have become popular asset that is common among people. Various smartphones feature like mobile telecommunication and geo-location capability can be leveraged upon to effectively find and connect blood donors with blood seekers and blood donation centers, within a close proximity. This paper presents a test implementation of a system that connects blood donors, blood seekers, and blood donation centers. The system uses geo-location technologies and blood type compatibility to connect blood seekers with blood donors, under the supervision of blood donation centers in the Nigerian geographic space. The mobile application component of the system can be used by three categories of users. These include blood donors, blood seekers, and blood donation centers. The application was evaluated with respect to its ease-of-use, learnability, effectiveness, and frequency of error occurrence.

1.1 Related Works

For a successful implementation of a blood donation application, it is necessary to understand blood group systems and the corresponding blood types. As stated in [10], There are about 33 blood group systems representing over 300 antigens. Among the 33 systems, ABO system and Rh-system are the most important in blood transfusion. The ABO system has A and B antigens and the RhD system has the D antigen. The major blood groups under the ABO system are A, B, AB, and O. When combined with the Rh system, the four major groups in the ABO system are each further divided into Rh positive or Rh negative types [11]. For high level of safety and effectiveness, it is necessary for blood donation applications to check the blood type compatibility between users when searching for blood donors. Fig. 1. shows the blood type compatibility between blood donors and recipients.

Recipient's blood type	Donor's blood type							
	O-	O+	B-	B+	A-	A+	AB-	AB+
AB+	✓	✓	✓	✓	✓	✓	✓	✓
AB-	✓		✓		✓		✓	
A+	✓	✓			✓	✓		
A-	✓				✓			
B+	✓	✓	✓	✓				
B-	✓		✓					
O+	✓	✓						
O-	✓							

Fig. 1. Red blood cell compatibility chart [12]

Attempts have been made in various part of the world to find and engage blood donors electronically, using computerized systems. A system was proposed in [13] that allows Turkish blood donation centers to contact and request for blood from their registered regular donors. A similar system was implemented in [14] for Indian blood banks but with a different approach for notifying regular donors. The process of notifying blood donors in [14] is through campaign activities where blood requests are broadcasted periodically to registered donors. The process for finding blood donors in [13] and [14] can only be initiated by blood banks at specified periods. Additional layer of flexibility was shown in [15] and [16] in systems developed to connect blood donors with blood seekers and blood banks in India. In addition to blood requests initiated by blood banks, the system in [15] and [16] allows individuals to search for registered blood donors at any time. The systems discussed in [13],

[14], [15] and [16] employ the client-server architecture where a backend server that stores user information is interfaced by either a web or a mobile application.

Attempts have also been made in Nigeria to provide an information system to save blood donors data electronically. A system was proposed in [17] that serves as an electronic database for blood banks to record information about their regular donors. While the system provide access to regular donors' information, it does not provide ability to to find and engage new donors. In addition to maintaining an electronic database of blood donors, results of systems implemented in some other parts of the world as seen in [14], [15] and [16] shows that ability to search, locate and engage new donors based on geographic location can generally improve the blood supply deficit.

This work aim to develop a system that allows blood seekers and blood donation centers to find and connect with nearby blood donors in Nigeria, in a timely and efficient manner. This is with the view to replicating the positive results shown in [14], [15], [16] and blood donor finder systems in most developed countries in the Nigerian geographic space. In addition to incorporating the features present in the systems described above, the BSD system was designed by taking some of the factors that might affect the use such systems in Nigeria in to consideration. The factors include among others, insufficient donors enlightment, insufficient approach to prospective donors for donation [8], and users security. The BSD system attempts to address the security concern by allowing blood donors to schedule meetings with blood seekers at nearby blood donation centers after the acceptance blood requests, as opposed to meeting at any random location or sharing contacts. In an attempt to address insufficient enlightment and approach to donors, the BSD mobile application gives donors the ability to view general information about blood donation and it also notifies them for blood donation at required times.

2. Materials and Methods

2.1 Design Architecture

The mobile application is accompanied with a backend server to form a complete system. The system uses a client server architecture where the mobile client communicates with the backend server. Data stored in the cloud database is exposed to the mobile client by the backend web service via Application Programming Interface (API) endpoints. The system architecture diagram is shown in Fig. 2.

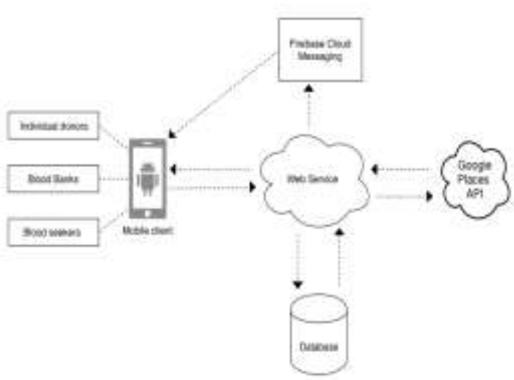

Fig. 2. System Architecture

The components shown in the architecture diagram are discussed as follows:

A. Mobile Client

The mobile client is implemented as an Android application. It is the main interaction interface between the users and the system. It consumes data from and push data to the web service. This component enables users to search for blood donors, request for blood, schedule donation appointments with blood donation centers, check donation history, receive push notifications from the Firebase Cloud Messaging (FCM) component and perform other system functionalities.

B. Web Service

This subsystem handles data exchange through RESTful APIs consumed by the mobile client. The RESTful APIs adhere to the Representational State Transfer (REST) architecture to provide various data exchange operations as required by the mobile client. The data exchange includes storage and retrieval of data stored in the database component. The web service and the rest of the system's backend service is powered by-products from Firebase Platform. Firebase is Backend-as-a-Service (BaaS) platform that allows fast and efficient development of mobile and web applications. Firebase was used because it provides a simplified but efficient backend solution for rapid development. The Firebase products as described in [18] include Firebase Realtime Database, Firebase Authentication, Firebase Cloud Messaging (FCM). The Firebase products and services used in the development of the BSD system is described as follows:

1. Firebase Realtime Database: The Firebase Realtime Database is a cloud-hosted database. Data is stored as JavaScript Object Notation (JSON) and synchronized in realtime to every connected client [19].
2. Firebase Authentication Service: Firebase Authentication provides backend services and software development kits (SDKs) to authenticate users to web and mobile applications. It supports authentication using passwords, phone numbers and other popular federated identity providers [20].
3. Firebase Cloud Messaging: FCM is a cross-platform messaging solution that reliably deliver messages at no cost. It is used to send push notifications to the Android and iOS apps [21].
4. Firebase Database Security Rules: The security rules add additional layer of security and authentication to read and write activities that is performed on the database [21].

C. Database

This is the persistence data layer of the system. It stores data that is required for the system operation. The data stored in the database include authentication data, user accounts data, blood donation requests data, blood donation history of users, users' location data and blood donation schedule data.

D. Google Places Application Programming Interface

This service is used to get location and distances information when the system is trying to filter and sort blood donors based on their proximity with blood seekers and blood donation centers. It is also used to get the map navigation information between blood donors, blood seekers, and blood donation centers.

2.2 Model Design

The design of this system was done using object oriented modeling. The guidelines that were used for the development of the system are discussed as follows:

A. Use case diagrams

The use-case diagram in Fig. 3. and Fig. 4. show various user activities that can be performed in the system. The use cases are described as follows:

1. Register: This is the first interaction point of the user with the system. It allows the user to provide registration information to the system. Information collected at this stage include name, blood type, phone number, relevant health history information etc. This use case is common to all user categories.
2. Login: This interaction point is called when the returning user wants to access the system. The use case is common to all user categories.
3. Find blood donors and blood donation centers: This use case allows the user to find blood donors and blood donation centers that have the same blood type with the requested blood type. The use case can be performed by blood seekers.
4. Send blood request message: This use case allows the user to send blood request messages to blood donors and blood banks. The use case can be performed by blood seekers.
5. View route on map: The use case allows the user to view navigation information to reach blood donation centers on a map. The use case can be performed by blood seekers and blood donors.
6. Declare intent to donate blood: This use case allows the user to declare his or her intent to be connected with blood seekers. This use case can be performed by blood donors and blood donation centers.
7. Receive blood request notifications: This use case allows the user to receive push notifications when there is a new blood request from blood seekers. This use case can be performed by blood donors and blood donation centers.
8. Post multiple entries of blood type availability: This use case allows the user to declare blood availability for multiple blood types. This can only be performed by blood donation centers.
9. Schedule blood donation: This interaction point is called when the user (blood donor) wants to schedule meeting with a blood seeker at a blood donation center.
10. View information about blood donation. This use case is common to all user categories.

B. Activity diagrams

The activity diagram shows the list of system actions available to users via the mobile application. It is used to present the flow of action from the authentication step to the schedule step. Fig. 5. shows activity diagram for blood seekers while Fig. 6. shows the activity diagram for blood donors and blood banks.

2.3 Implementation

A. Mobile application implementation

The BSD mobile application was implemented using Java programming language for logic and eXtensible Markup Language (XML) for user interface. Android studio integrated development environment was used in the development stages. Android applications request permissions from users at installation time. Permissions allow users to keep track of sensitive activities that applications can perform on Android devices. Various user permissions were requested by the BSD mobile application in order to function properly. The permissions include "ACCESS NETWORK STATE", INTERNET and "ACCESS FINE_LOCATION". The permissions were requested by adding the following code snippet in the AndroidManifest.xml file:

```
<uses-permission android:name="android.permission .ACCESS_FINE_LOCATION"/>
<uses-permissionandroid:name="android.permission .ACCESS_COARSE_LOCATION"/>
<uses-permission android:name="android.permission .ACCESS_COARSE_LOCATION"/>
```

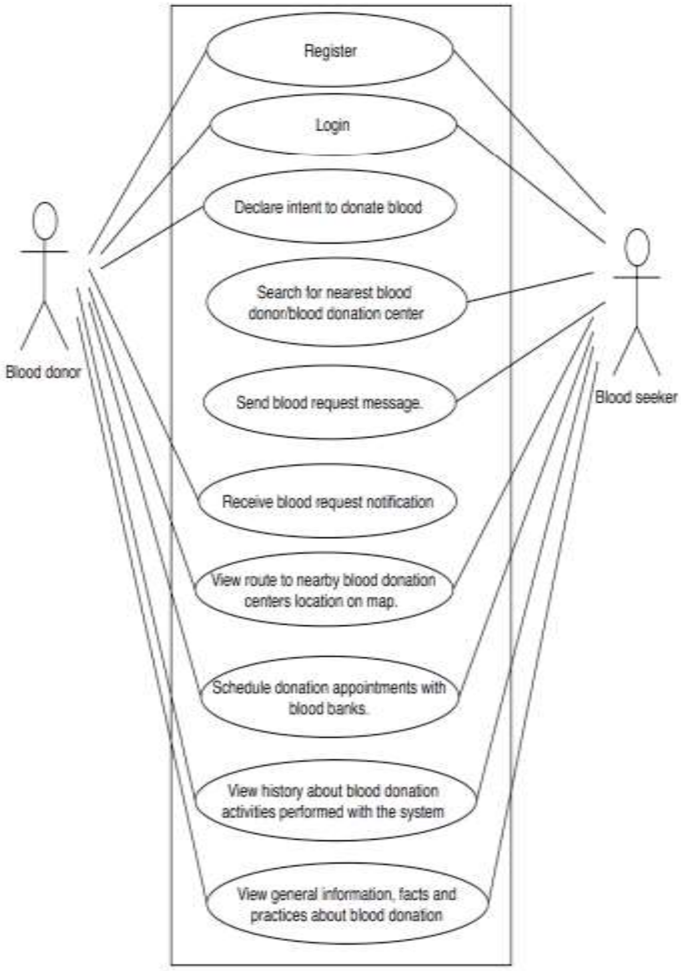

Fig. 4. Use case diagram for blood seekers and blood donors

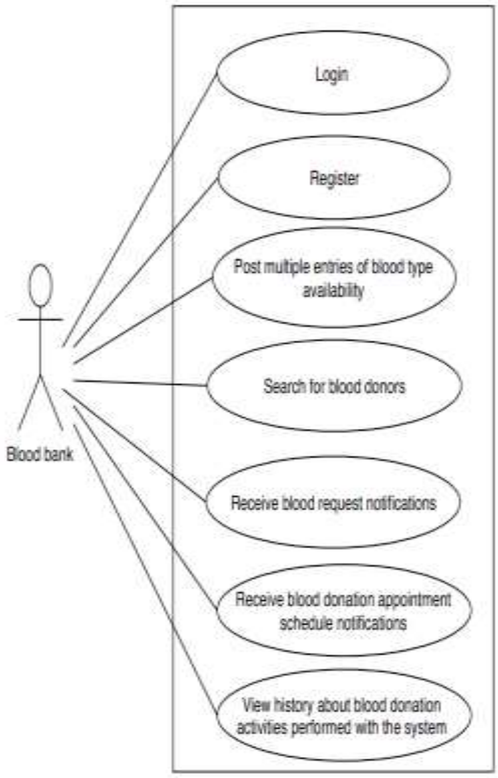

Fig. 3. Use case diagram for blood banks

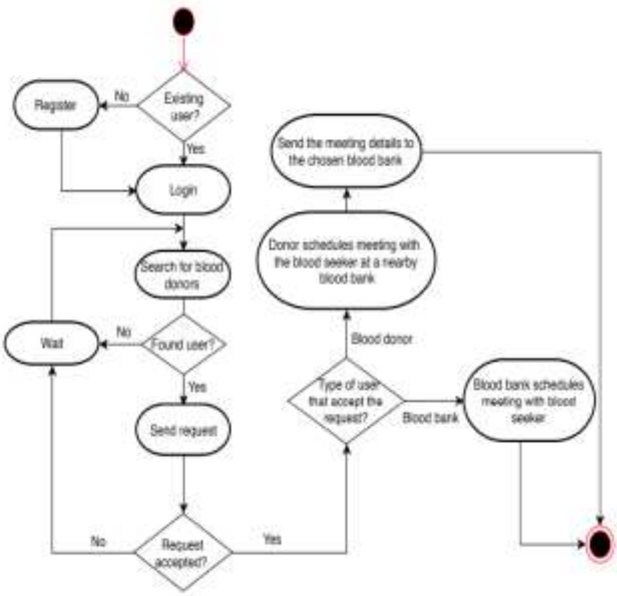

Fig.5. Activity diagram for blood seekers

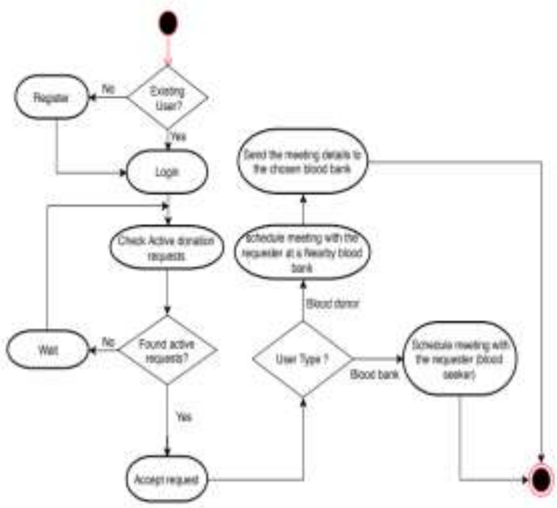

Fig. 6. Activity diagram for blood donors and blood banks.

The BSD mobile application comprises of five components that are integrated together to achieve its aim. The components include Authentication module, Blood search module, Blood availability upload module, Notifications module and Records/History module.

1. Authentication Module: For the application to be used, users are required to register on the application by providing their mobile number, password and other relevant details for authentication on the system. Users can login to access the application contents in subsequent times. The authentication module of the app uses Firebase auth REST API. The base url for the API endpoints used in this module is:

   POST: "https://www.googleapis.com /identitytoolkit/v3/relyingparty/xxx"

2. Blood Search Module: The blood search module is the part of the mobile application that allow users (blood seekers) to search for blood donors and blood donation centers. The steps involved in the search process is shown Fig. 7. Registered blood donors are filtered based on their blood type compatibility with the blood seekers. The resulting list is sorted using distances between the blood seeker, each donor, and nearby blood donation centers. Fig. 8. shows a screenshot of the application after a search for blood donors.

3. Blood Availability Upload Module: The blood availability upload module is the part of the application that allow users (blood donors and blood banks) to declare an intent to donate blood. This module allows users to add new blood donation entry to the system by uploading their blood type, blood donation motivation (paid or free), contact details and other relevant information. After a blood donation entry is collected via the application, the data will be sent to the backend server for future use. This module communicates with the backend server using Firebase Database REST API. During user interaction sessions with the application, data is exchanged with the backend server using the JavaScript Object Notation (JSON) objects. A sample JSON object for blood donation availability is shown below:


```
{
  "creation_time": "1550084897164",
  "donation_type": "free",
  "donor_blood_type": "B-",
  "donor_email": "johndoe@gmx.com",
  "donor_firebase_id": "enAZVYkMhcTncl0HA7pdskNYwQP2",
  "donor_location": { "address": "Test road A, Ife, Nigeria", "latitude": 7.5028544, "longitude": 4.5116913 },
  "donor_name": "John Doe",
  "donor_phone_number": "08123456789",
  "acceptance_status": "pending"
}
```


4. Notification Module: The notification module is an important part of the application that informs users of various activities in the system. The module allows blood seekers to send blood request messages to blood donors and blood donation centers. It also allows blood donors and blood donation centers to send acceptance messages to blood seekers. The acceptance message contains information about a meeting schedule that shows when and where the actual blood donation will take place. The notification module uses FCM to send push notifications at the required times. The API endpoint called to send notification messages is:

   POST: "https://fcm.googleapis.com/fcm/send".

   The endpoint is called with a payload in form of JSON objects that contain the actual messages being sent. Fig. 9. shows a screenshot of the application showing sample of a blood request message notification which was sent to a blood donor.

5. Records and Information Module: The records and information module is the part of the mobile application that shows user's blood request and donation history. The module shows the records by fetching the relevant logs from the backend server. It also allows blood donation centers to keep track of their regular donors. This module also allow users to view general information, facts and practices about blood donation.

B. Backend Server Implementation

The backend server comprises authentication module and database module. The authentication module is powered by the Firebase Authentication Service and it is responsible for actual user registration on the platform. It manages user sessions and other user authentication activities. The module saves user login details to a private and secured database which can be checked against when returning users want to access the system. The database module is responsible for storing user data. It is powered by the Firebase Realtime Database. The database structure is implemented as a collection of JSON trees and nodes. The database saves authentication data, user accounts, blood donation requests, blood donation history, donor's location information, and other relevant information. Fig. 10. shows the database structure with a sample data. The backend server is secured by Firebase database security rules with prevents unauthorized access to user data. The mobile application can only exchange data with the server by providing necessary security tokens.

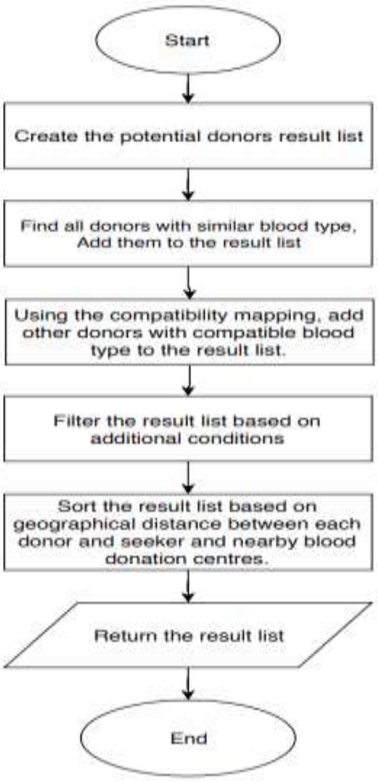

Fig. 7. Donors search Algorithm

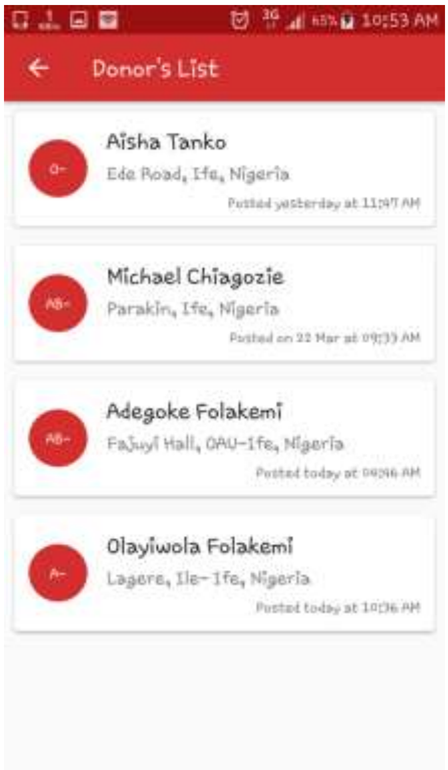

Fig. 8. Potential donors list

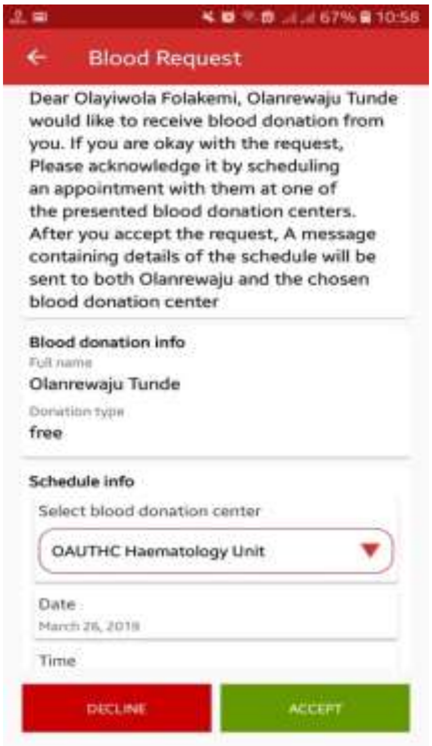

Fig. 9. Blood request message notification

Fig. 10. Firebase database structure

3. Results and Discussion

Several evaluators were given the BSD matching mobile application to install on their devices. The evaluators were registered with the different categories of users available on the system. In addition to the evaluators registered as blood banks, some evaluators were registered as blood donors and the remaining evaluators were registered as blood donors. The evaluators were asked to use the application to perform the system functionalities available to the user category they registered with. The evaluators were interviewed and asked to evaluate the system based on the evaluation criteria after a few days. The following are the evaluation criteria employed:

1. Ease of Use: This refers to how easy it was to use the application.

2. Learnability: This refers to how fast it was for the user to master the application functionalities.

3. Effectiveness: This refers to the level to which the application enhances the connection and communication between blood donors and blood seekers. It was also used to assess the ability of the application to connect the three different categories of users present the in the system (blood donors, blood seeker, and blood banks).

4. Error: This was used to assess how often users encountered error while trying to perform available tasks with the application. Errors include crashes, incorrect distance calculations, blood type mismatch etc.

The result of the evaluation is presented in Table 1. All metrics are on a scale of 1 (lowest score) – 10 (highest score)

Table 1 Evaluation Results

User category	Ease of use (Avg.)	Learnability (Avg.)	Effectiveness (Avg.)	Error (Avg.)
Blood donors	6.25	7.25	6.75	1.3
Blood seekers	7.27	7.42	7.33	0.67
Blood donation centers	8	7.5	7	2.1
Grand Average	7.17	7.39	7.02	1.35

The mean scores were computed for each criteria and the results show that the mean scores for ease of use, learnability, and effectiveness are all above average (7.17, 7.39, and 7.02 respectively). This implies that the application and the system as a whole was able to achieve its stated aim and objectives. The low mean score for error (1.35) also implies that the evaluators experienced minimal difficulties while using the application. It was observed that the evaluators who experienced zero "error" gave high scores for other evaluation criteria. Averagely, the scores are lower for testers who experienced errors while using the application. This implies that learnability, ease of use and most importantly, effectiveness can be further improved if errors are further minimized.

4. Conclusions

The paper presented a blood seeker-donor matching system. The system used blood groups compatibility and geo-location technologies to suggest potential blood donors to blood seekers. The system employed the use of the object oriented modeling techniques. The performance evaluation results of the mobile client showed that geo-location technologies, through the use of mobile applications, can provide an easier, faster and efficient means of finding and communicating with blood donors. Further work intends to make the system accessible to more users. This can be achieved by implementing the mobile client on the iOS platform. Further accessibility can also be achieved by implementing the functionalities present in the mobile client on the web platform. Finally, the backend service, along with the cloud database can be restructured and improved to provide better scalability. The improved scalability will allow the backend service to cope with the increased traffic that might result from the iOS and web patforms.

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