Enhancing Access to Emergency Services through the Concepts of Geo-localization using Mobile Technologies

Gerald Kpangkpari
Department of Computer Science
Kwame Nkrumah University of Science and Technology
Kumasi, Ghana

Hayfron-Acquah J.B.
Department of Computer Science
Kwame Nkrumah University of Science and Technology
Kumasi, Ghana

Ernest D. Ganaa
School of Applied Science and Technology
Department of ICT
Wa Polytechnic
Wa, Ghana

ABSTRACT
This research sought to find out how the use of mobile phones could be harnessed to enhance access to emergency services particularly in developing Countries. The lack of knowledge of the street names/house numbering/addressing system poses a challenge to the whole emergency response process in that; mobile phone users are unable to direct the emergency service respondents to the site of incident requiring intervention and also the emergency service respondents are unable to easily identify the point where their services are needed thus delaying the response process.

In the light of these, the research presents a solution that would lessen the burden on mobile phone users in terms of keeping track of all the contact/phone numbers of emergency service agencies as well as being familiar with the location where the help of these emergency service agencies is needed. Also, the research solution would enable the emergency service respondents to quickly geo-locate the point a distress call emanates from. This will ensure a quick response to emergency situations.

General Terms
Cellphone Geo-localization.

Keywords
Emergency response; Geo-location; Distress call; Caller location, CellTower ID Positioning; Tri-lateration; Tri-angulation

1. INTRODUCTION
Day in day out as we live our lives, we encounter situations natural or man-made that require urgent assistance. Events like motor accidents and other emergency situations (such as burglary) that require Police, Fire and Ambulance Services are common each day. These events require the timely intervention of emergency service agencies in order to salvage the situation.

With the evolution of Information Technology, human lives are being changed. The contribution of mobile technology to these changes can never be over emphasized. It is estimated that mobile phones are going to replace Personal Computers when people are surfing the internet by the year 2016 (Shein, 2006). This suggests that more and more people are and will be using mobile phones.

Mobile technology brings people much closer through providing solutions that ensure social networking, video or voice phone calling among many others. It provides users with various ways to satisfy their needs. People can now choose the most comfortable and suitable ways for themselves to contact families and friends.

In effect, people's whole lives have become centered on mobile phones thus making it important to provide services that can run on it. With advancement in mobile technology, services now integrate the use of Geographical Position Systems (GPS). These services can be used to geo-locate a mobile phone or its user on a map. These services are of tremendous help to particularly tourists who hitherto would be seen on the street holding maps trying to find their way through.

In the same vein, the concept of geo-locating a mobile phone can be harnessed in an emergency situation to help emergency service agencies quickly identify the location of a distress caller and to respond swiftly in order to salvage the emergency situation. Thus, enhancing mobile phone users' access to emergency services.

2. AIM AND OBJECTIVES
This research seeks to harness existing mobile technologies into developing a one-stop solution that provides a location based alarm through which mobile phone users can broadcast their current location to an emergency service agency (Police, Fire and Ambulance Services) in order to be easily located.

The specific objective of this research is to:

- Develop a solution on a mobile phone that would send location coordinates of a user to an emergency service agency when the user requests for help. These coordinates will help the emergency service agency to quickly locate the distress caller. Thus ensuring a swifter response.

3. SCOPE AND LIMITATIONS
This research intends to employ the concepts of mobile technology in order to develop a solution. This solution will be in a form of client/server software application design. However, the solution will be limited to mobile phones that run an Android operating system (OS). Android has been chosen as the operating system for the research solution because of its ability to optimize the use of limited resources available on a mobile phone.

The client would be a mobile phone application developed in Java programming language and will run on an Android platform. When a distress call is initiated on the mobile phone, location co-ordinates (latitude and longitude) of the phone will be transmitted to the emergency service agency (where the server side of the system design would be

implemented) over existing telecommunication network infrastructure.

The server side design would comprise of an application that would integrate Google Map APIs. This would indicate the location co-ordinates of the mobile phone on a Map contained with the server application.

4. EVALUATION OF RELATED WORKS

(Thompson, 1992) invented a system for locating a phone call in an emergency situation. The system was computer based. This system was developed to receive emergency telephone calls which upon receipt of the phone call ensured a connection to the operator at an emergency response center. The system displayed a map indicating the location of the calling party (emergency phone caller). The Emergency phone call system was connected to an existing public telephone network.

The challenge with the system developed by Thompson was that the location of each phone number (its owner's name and address) must be pre-included in the system's database in order to be able to determine where an emergency call emanates from. Thus calls from phone numbers which details are not in the system's database or come from a location which is not within the jurisdiction of the system's digitized map of the local geographic area, it becomes difficult to trace or identify. Another challenge with the system was that when the owner and address of particular phone number changes, the information in the database had to be updated accordingly lest it became difficult to trace the location of the caller using that phone number in events of an emergency.

(Alpert, 1998) developed an emergency cellular mobile phone which automatically dialed one prescribed telephone numbers in an emergency. The device either allows users to initiate the calling of an emergency number by pressing a dedicated mobile phone button or it initiates an emergency call triggered by the occurrences of an accident which the phone detects. The cellular telephone was designed with a predetermined emergency number installed on it. A pre-recorded message was played indicating that the user of the phone was in distress and needed assistance immediately. Also, the user had the option to participate in the emergency call after he/she was notified of the completion of the automatic dialing and a connection had been established.

The system was designed in such a way that if the pre-defined emergency number is the telephone number of the Police or sheriff's department, information on the location of the user is sent directly to them, and help can be provided immediately. Also, the emergency telephone number can be a dedicated telephone number within the system. An operator at the central control station receives these distress calls, records the relevant location information, and dispatches a team to the rescue of those in need of help.

This invention came with its own challenges. The cellular phone could only be pre-programmed to handle only one emergency number. For example if a button was pre-programmed to call the Fire Service Department when pressed, the other emergency service agencies are left out (unless their phone numbers are manually typed into the cellular phone and dialed).

(Dunn et al, 1999) also in an attempt to enhance response to an emergency situation, propounded a system to help locate a wireless mobile phone/unit from which a request for emergency assistance was initiated. This system relied on existing telecommunication infrastructure that is the Public Switched Telephone Network (PSTN). The system consisted of a shared computer unit and databases among various mobile Switching Units. These Units served numerous Base Stations and each Base Station in turn served an even larger number of antenna and transceiving sites within a specified cellular region.

A shared computer system measures signal strength at each Base Station as the signals pass through the Switching Units. Using these signal measurement, the computer system calculates a small area within which the location of a mobile phone/unit requesting assistance can be determined. The area calculated by the computer system as well as information contained in a database system is passed on to the emergency service agency. This information helps the emergency service agency to get a precise mapping of the calculated area accentuating major landmarks that could be used to elicit specific responses from the caller in order to pin-point the location from where the distress call emanates.

The emergency service agency receives information that describes the calculated area and in addition to this information, it receives also the data extracted from the database through PSTN. Using this information, emergency service agency can elicit from the calling party, description of landmarks such as buildings, hotels, mountain, and rivers. Likelihood of locating the calling parties is enhanced with response to questions posed by the emergency center operators taking into account the description of the various landmarks. Quick rescue can then be dispatched to the calling party with the rescue team having the greatest likelihood of locating the calling party.

4.1 New technologies employed to enhance emergency service access.

Technological advancement over the years led to the invention of Global Positioning Systems (GPS). The United State Department of Defense (DOD) has operated this system since 1970 (Brandon, 2003). According to Brandon, the GPS used by the United States consists of Satellites. These Satellites help to determine the positions of people and objects. GPS was intended initially for military uses only, but the U.S. government in 1980 decided to make the system's positioning data available to other industries worldwide. Many industries since then have taken up the privilege to access position data and use it to enhance their products and services.

Liberalization of the use of the GPS led to the emergence of a concept known as Location Based Services. Location Based Services is defined by (Voisard, 2003) as services that integrate a mobile phone's location or position with other information so as to provide added value to a user.

A lot of services that depend on user's location have been developed but the technological market is yet to embrace such services wholly (Bouwman et al, 2001). The market is in its infancy (D'Roza, 2003). It can be particularly powerful when combined with other user profile information to offer personalized and location sensitive responses to customers (Searby, 2003).

Based on the concept of LBS, (Sprague et a1, 1995) developed a portable navigational system that uses location coordinates to enhance response of emergency service agencies. Sprague asserted that it would be beneficial if Police and Fire dispatchers were equipped with GPS receiver Base

Stations that could receive the current positions periodically of squad cars and fire engines to facilitate faster response times.

(Revell et al, 1998) developed a personal alarm device. This device is capable of broadcasting its location (in emergency situations) to a remote location such as an emergency service agency. The device is made up of an antenna, a cellular transmitter, a cellular receiver and a controller. The controller is attached to the transmitter and receiver, which are also soldered to the antenna. The controller regulates the transmitter and the receiver. It also receives a position location signal that is Global Positioning System (GPS) coordinates. The controller also enables cellular connection with a remote site (that is the emergency service agencies), and transmit the GPS coordinates to the remote site in order to easily locate the mobile phone. The connection between the device and its remote site is established through a telecommunication network made up of numerous cell Base Stations. However, this device was so bulky to carry on oneself as compared to a mobile phone.

(Parente, 2000) developed a system that was for notifying a central emergency station of an emergency situation. The system was made up of a central unit for monitoring a predefined geographic area. The system also included a remote control unit for activating and signaling the central unit. The central unit has a detector inbuilt which identifies an emergency situation and generates a signal in response to that situation. This signal is sent to a processor responsible for receiving the detected signal and thus generates an alarm signal in response. There is a receiver for receiving an emergency signal and providing the emergency signal to the processor and an alarm for alerting the central station upon receipt of one of the alarm/emergency signals. Challenge with this system is that, Emergency Signals sent from outside the predefined geographic area cannot be geo-localized.

4.2 Cell Tower ID positioning

Cell Tower ID positioning can be exploited to determine the position of a mobile phone (Talberg, 2006). It is an advantage in that the infrastructure needed for Cell Tower ID positioning already is installed almost everywhere in the world. However, the density of Global System for Mobile communications (GSM) Cell Tower is very high in urban areas.

Mobile phones are always in constant communication with these Cell Towers/Base Stations. As every mobile phone has an individual phone number that distinguishes it from others, every Cell Tower/Base Station has a special set of identifiers used to identify each individual Cell Tower (Talberg, 2006). These set of identifiers according to Talberg (2006) are Cell Base Station Identifier (CID), Location Area Code (LAC), Mobile Country Code (MCC) and Mobile Network Code (MNC).

GSM networks are basically divided into cells which ideally have a circular coverage area. Each of these cells is associated with a Cell Tower/Base Station. As a mobile phone moves through the coverage areas of each cell, it connects to the Base Station with the best signal strength available, which should be in most cases the nearest one relative to the mobile phone's position. The basic form of Cell ID Positioning therefore is to use the location of this Cell Tower/Base Station, whose position is already known to determine the position of the mobile phone. This method is referred as cell identification (Cell ID) Positioning.

To determine the position of a mobile phone using Cell ID Positioning, mathematical methods for measurements are introduced. To achieve more precise location information, geometric mathematics models are used to calculate for the position (Willaredt¸ 2011). These models require information on surrounding points of the mobile phone. The points can be Wi-Fi Access Points, GSM antennas or global navigation satellites. Depending on the underlying mathematical model, the information required is; how strong the signal is, what angle the signal comes from, what unique address the sender of the signal has. Based on this information, the following geometric mathematical models can be used to calculate the position of a mobile phone.

Tri-angulation: According to Willaredt (2011), the position of a mobile phone can be determined using the known positions of two Cell Towers. In the Triangulation example shown in figure 1, the angles α and β of two Cell Towers, P1 and P2 relative to the location in question (that is the position of the mobile phone/Distress caller) are measured. With these angles, the position of the desired location can be calculated when the distance of the two points is known. The distance of these Cell Towers can be determined by the signal strength of both towers relative to the mobile phone.

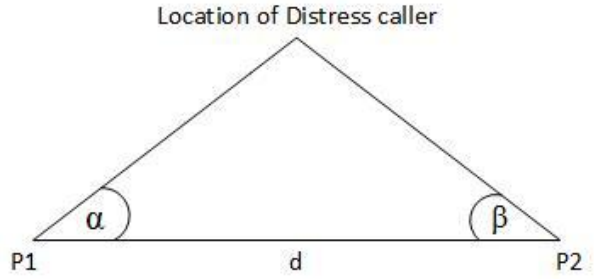

Figure 1: Triangulation of two Cell Towers.
Source: (Willaredt, 2011)

Tri-Lateration: Again, (Willaredt, 2011) asserted that a mobile phone's position could be determined by employing the positions of three Cell Towers that it receives signals from. Based on the distance of the mobile phone to its surrounding Cell Towers, it is possible to calculate the exact position of the mobile phone in question. Received signal strengths (RSS) are used to determine the distance between the Cell Towers and the mobile phone. Signals from a minimum of three Cell Towers at different positions relative to the mobile phone are used in this calculation. When measurements from a total of three Cell Towers are used to determine the position of a mobile phone, then the process is known as Tri-Lateration. However, if the number of Cell Towers exceeds three (3) then the process is referred to as Multi-lateration. The longitude and latitude of the Cell Towers in Tri-Lateration are considered as the coordinates of the center of the circle. The service coverage area of a Cell Tower is considered as a circle.

Figure 2. Depicts how the position of a mobile phone in communication with three Cell Towers can be determined. $O(x_0,y_0)$ is the location of the mobile phone/user.

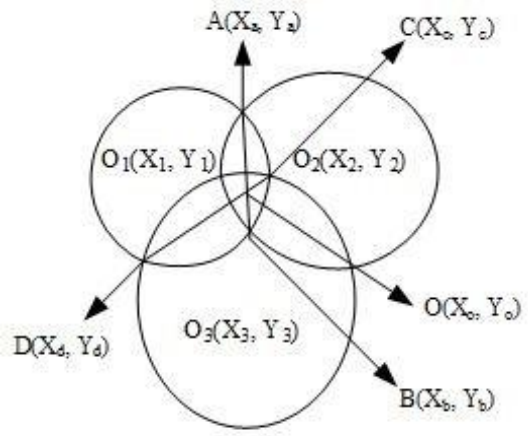

Figure 2: Tri-Lateration of three Cell Towers.

Source :(Willaredt, 2011).

5. SYSTEM ARCHITECTURE

The client-server architecture of system design was adopted for this project. The client application was developed in Java programming language. The client application will be installed on an Android OS enabled mobile phone whilst the server application was developed in VB.Net programming language. This server-side application will be installed on a computer system/server located at the emergency service agency's premises.

Figure 3 depicts a conceptual representation of the system. A mobile phone with a GPS receiver installed on it communicates with a GPS satellite in order to get its current geographical location coordinates. These location coordinates of the mobile phone could also be gotten through the approximation of Cell Towers' positions relative to the particular mobile phone's position that these Cell Towers are in communication with. When there is a need to call an emergency service agency, the mobile phone (with the client application installed on it) would transmit its current coordinates to a computer system/server situated at the emergency service agency. This computer system would have the server side application installed on it. These coordinates of the mobile phone will then be used to indicate the current location of the mobile phone on Google Map running on the server side application.

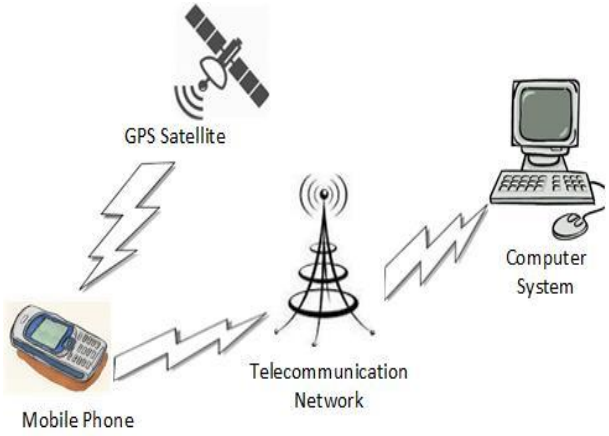

Figure 3: System architecture

Unified Modelling Language (UML) Activity diagram was used to depict the various behaviours of the system as shown in figure 4. This model abstracted the essential details of the system from its usually complicated real world.

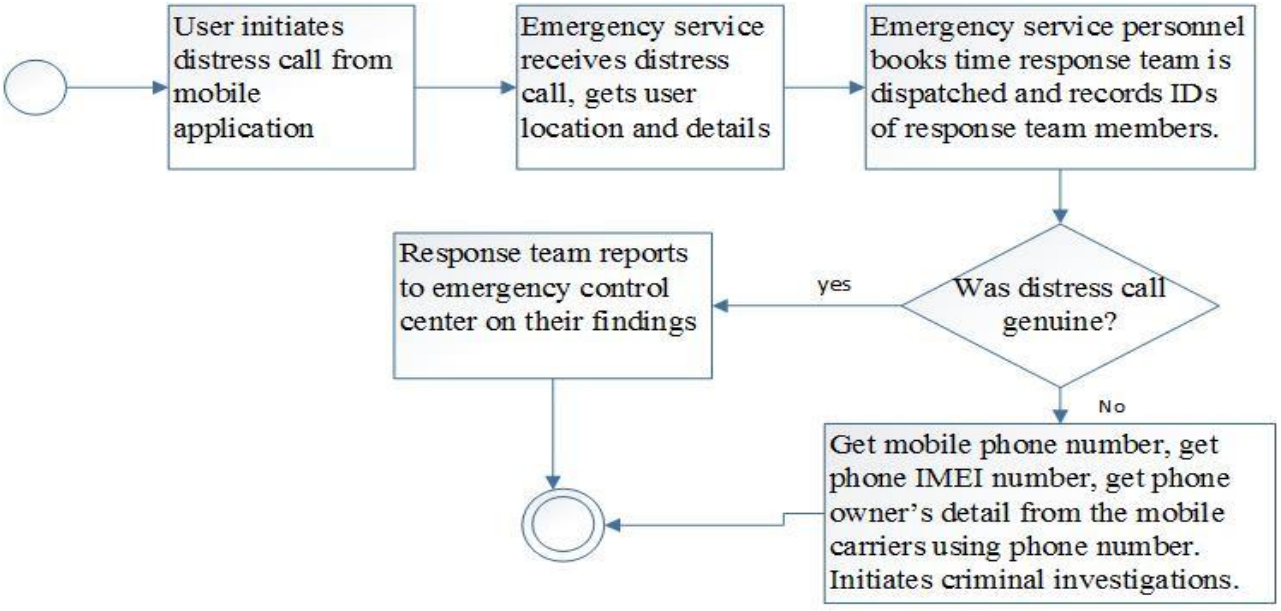

Figure 4: UML Activity diagram for the system.

6. LOGICAL DESIGN

Logical design of the system pertains to an abstract representation of the data flows, inputs and outputs of the system. It uses graphical representation for system's processes and the flow of data into and out of the various components of the system.

As indicated in the system architecture, the mobile application would serve as the client system. In designing this client application, the model-view controller (MVC) design pattern

was used. This model was employed in developing the client application particularly the user interface because it ensured a more extensible and readable coding better than coding without MVC.

The MVC pattern consists of three (3) layers namely;

- Model layer: This layer makes up of objects constituting the data in the application. For example, data like username, phone numbers and email address are represented in the model layer.
- View layer: The layout and appearance of the client application are represented in this layer. Objects like Windows, ListViews and Buttons are shown here.
- Controller layer: is a bridge between the model and view layers. It receives the notification from view layer and processes the action according to the data from model layer.

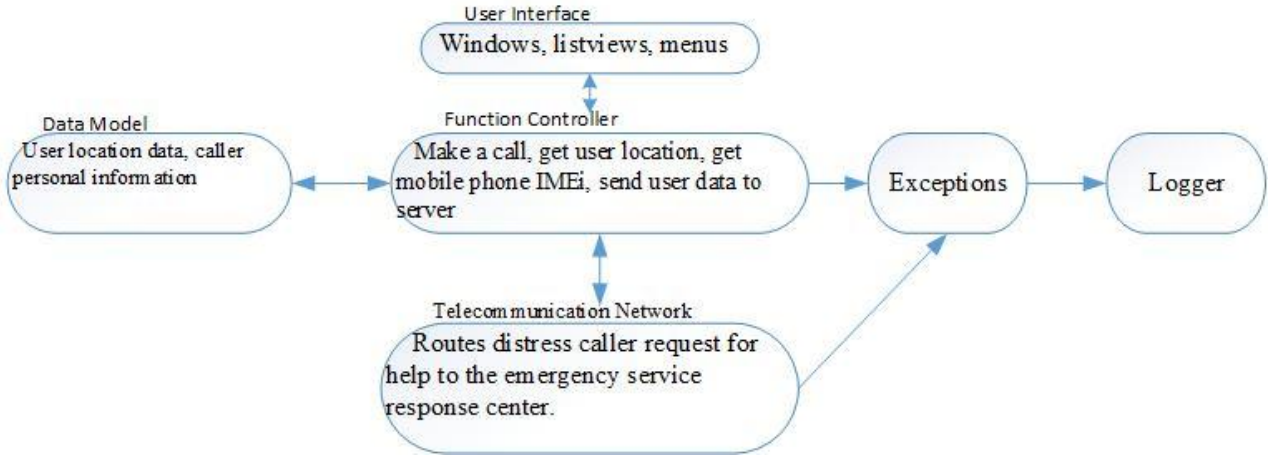

Figure 5: Logical design of the client application.

In Figure 5 above, User Interface (UI) represents the view layer of the MVC pattern and the function controller represents the controller layer of MVC pattern. The user interface is made up of ListViews that display buttons representing each emergency service agency to a user to choose from. The controller layer receives User Interface event from the view layer such as button clicking event. It is also responsible for sending notification to the view layer.

The telecommunication network layer is mainly responsible for transmission of phone calls and user location coordinates over a mobile network to the server situated at the emergency service agency's premises.

The server side application of the system would be situated at the various emergency service agencies. The complexities associated with designing the server side application have been abstracted in figure 6.

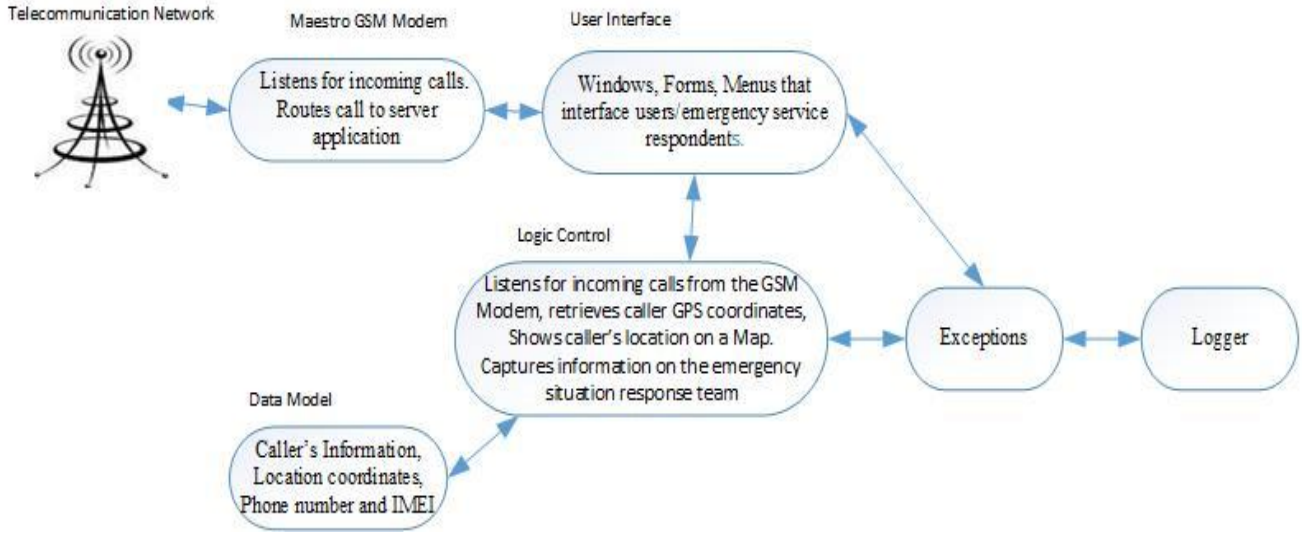

Figure 6: Server application logic flow.

Figure 6 shows the flow of logic; when a call is initiated from the client application to the server-side application. A distress call initiated from the client application is carried over a telecommunication network to the server application situated at the emergency service agency's premises.

A maestro GSM modem attached to a computer system will ensure that the user's location coordinates are received by the serve- side application and used to show the location of the user for a swift response. The system keeps track of the caller's phone number, the phone IME number and the phone's SIM serial number.

7. EVALUATION OF SOLUTION

A call initiated from the client application installed on a mobile phone carries along the location coordinates of the mobile phone as well as the mobile phone's IMEI and SIM serial numbers to the server application module. The interface of the client application is as shown in figure 7 below. The location coordinates of the mobile phone could be obtained through enabling a GPS receiver installed on the mobile phone, or through either the concept of Triangulation and or Tri-Lateration of Cell Towers or through Wi-Fi technology. The IMEI and SIM serial numbers are used to help trace prank callers.

The server side application responsibility is to display to the emergency service respondents on Google Map, the location of the mobile phone (used by distress callers) as shown in figure 8 below. The server application uses the location coordinates sent to it from the client application to show on a map where a call originates from.

This helps ensure swift response to the distress call by the emergency service agencies

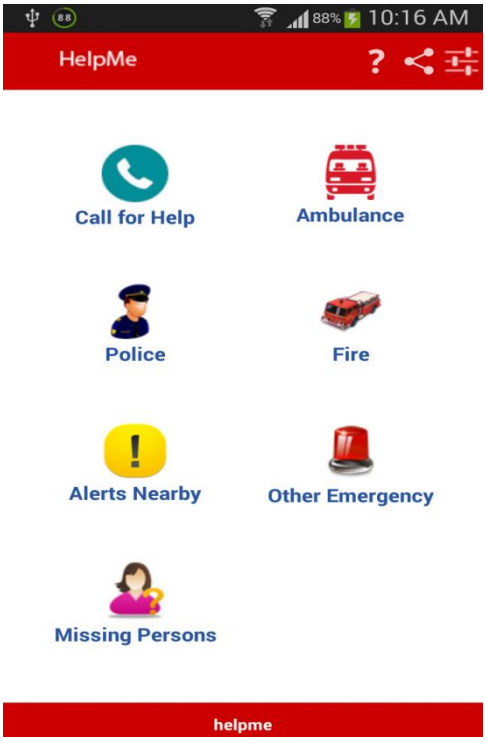

Figure 7: Client user interface.

7.1 Experimental Setup and Results

In determining the efficiency of the developed solution, random mobile phone users were sampled. These users were asked to install the client application on their mobile phones and requested to initiate a call to any of the emergency service agencies and the results were record as shown below.

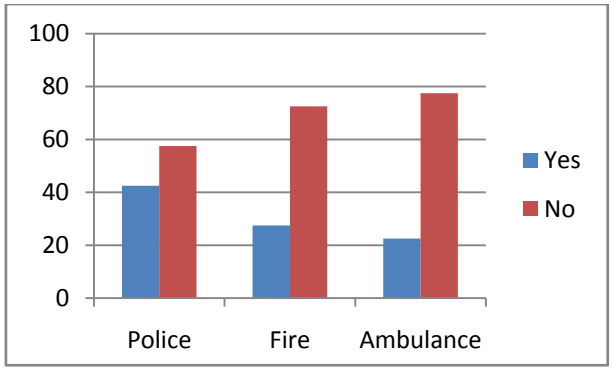

Figure 9 .Knowledge of emergency services contact numbers.

Figure 9 shows the percentage of mobile phone users who either had fore-knowledge of any of the emergency services numbers or not but was able to initiate a call for help through the user of the developed application. Out of 40 phone users, a total of 23 did not know any of the emergency contact numbers for the Police Service whilst a total of 17 knew. This represents 57.5% and 42.5% respectively of the population of participants. Also a total of 11 making up of 27.5% of participants knew the emergency contact numbers for the Fire Service Department whilst a total of 29 also constituting 72.5% of the participants did not know any of the Fire Service Department's emergency contact numbers. Again, a total of 31 representing 77.5% of the population of participants indicated that they did not know any of the emergency contact numbers for the Ambulance Service whilst a total of 9 participants representing 22.5% of the population knew.

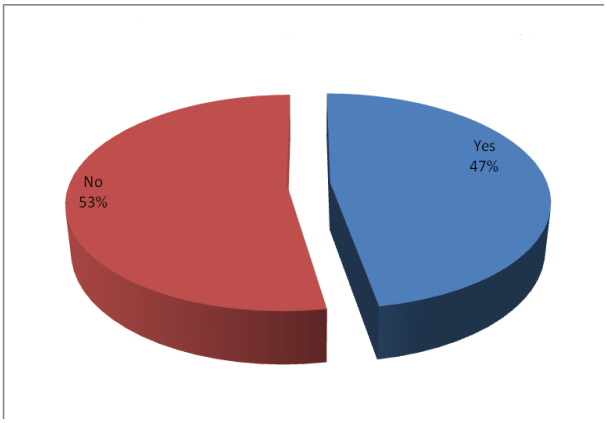

Figure 10. Mobile phone users knowledge of the street names.

Mobile phone users' knowledge of street names / house addressing systems particularly where the survey was conducted was investigated. The aim was to find out whether mobile phone users could easily direct emergency service respondents to that particular location in case of an emergency. The findings are as shown in figure 10. Out of 40 respondents, 21 representing 53% of the respondents did not know the street names of the area under investigation whereas a total of 19 participants representing 47% of the population of respondents knew.

In figure 11, emergency service respondents were interviewed to determine whether the solution was helpful to them. They were asked whether, from the system, they could approximate the location of distressed callers without the caller giving them their locations. A total of 15 respondents survey

affirmed that the system helped them approximate callers' location without help.

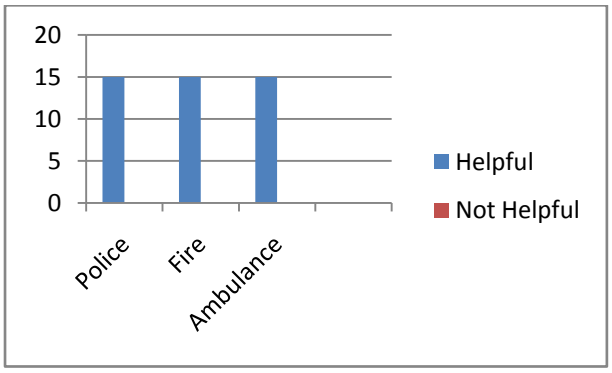

Figure 11. System helpful to emergency service respondents

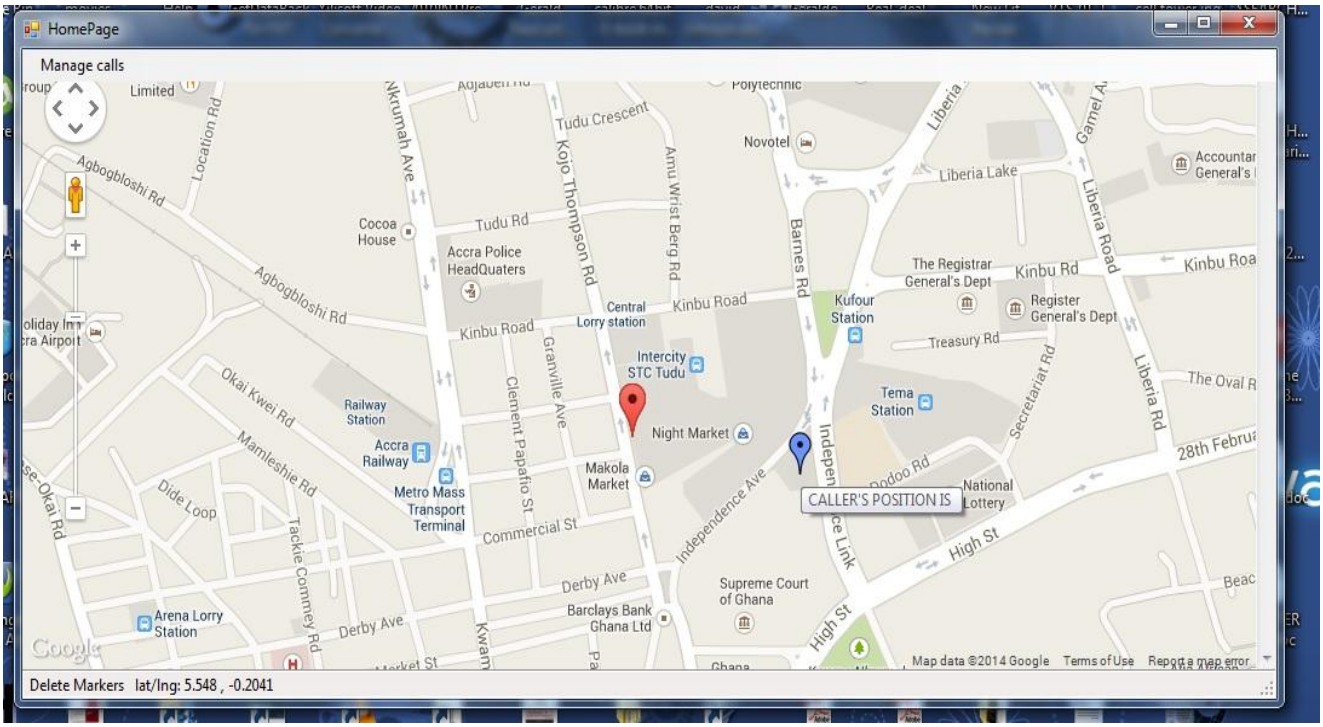

Figure 8: Server side Google map showing caller's location.

8. CONCLUSION AND RECOMMENDATION

This research solution would lessen the burden on mobile phone users who request for help from emergency service agencies. Mobile phone users will not be required to know the contact/ phone numbers of these agencies or be familiar with the location he/ she needs help in order to request for such help. Just with a touch of a button on the client application installed on a mobile phone, the appropriate emergency service agency is notified of the distress caller's location. This solution to the research problem will be invaluable to both a mobile phone user and an emergency service agency because it will ensure a swift response in emergency situations.

Research should be conducted into how the server application could show on a Map to the emergency service respondents of the shortest route to the point of incidence where their help is needed. This will ensure that the response team arrive at the location where help is needed within the shortest possible time.

It is recommended that, development of the client application be done for mobile phones that run other operating systems like iOS, Blackberry, Windows mobile OS and Symbian.

9. ACKNOWLEDGMENTS

An expression of gratitude goes out to Dr. Hayfron- Acquah J.B.(Academic Supervisor) and Dr. M. Asante, Head of Computer Science Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana for their invaluable contributions towards the completion of this work.

10. REFERENCES

[1] Alpert, M. (1998), "Emergency Mobile Telephone", U.S.Patent 5,742,666, filed 5 October, 1994, issued 21 April, 1998.

[2] Bouwman, H. & Van Der Kar, E. (2001),"The development of location based mobile services", Edispuut Conference, Amsterdam, October 17, 2001.

[3] Brandon, J. M. (2003),"The global Positioning System: Global developments and opportunities".

[4] D'Roza, T. & Bilchev, G. (2003)," an overview of location-based services". BT Technology Journal 21(1): 20-27.

[5] Dunn, M.J. & Stern, E.H. (1999),"Wireless 911 emergency location", U.S. patent 5873040A, filed 13 August, 1996, issued 16 February, 1999.

[6] Parente, G.T. (2000),"Portable alarm system", U.S. Patent 6094140 A, filed 22 December, 1998, issued 25 July, 2000.

[7] Revell, G.C. & Mark, A. (1998),"Personal Alarm device", U.S. Patent 583827 A, filed 22 May, 1996, issued 17 November, 1998.

[8] Searby, S. (2003)."Personalization – an overview of its use and potential". BT Technology Journal 21(1): 13-19.

[9] Shein, E. (2010),"Mobile Networks Penetrate 90% of World's Population", October 2010, http://www.informationweek.com/news/smb/mobile/227900281.

[10] Sprague, S.D., Tiwari, A. & Woo, A. (1995),"Global Position System Receiver", filed 25 October, 1993, issued 06 June, 1995.

[11] Talberg, E. (2006),"Positioning with Cell ID, Master's Thesis, unpublished Script.

[12] Thompson, W.R. (1992),"Emergency call locating system", U.S.patent5, 109,399, filed August 18, 1989, issued April 28, 1992.

[13] Voisard, A. & Schiller, J. (2003)," Location-Based Services", 1st Edition, Pg. 101-145.

[14] Willaredt, J. (2011) Wi-Fi and Cell-ID based positioning - Protocols, Standards and Solutions, SNET Project WT (2011).