ISSN : 0974 - 7451 Volume 7 Issue 8

Environmental Science
An Indian Journal

Trade Science Inc.

Environmental Policy Analysis

ESAIJ, 7(8), 2012 [279-287]

Framework of a real-time mobile GIS as early warning mechanism for epidemics

L.O.Omotosho*, C.O.Akanbi, D.O.Oladeji, M.A.Ibrahim
Department of Information and Communication Technology, Osun State University, Osogbo, (NIGERIA)
E-mail: inedune@yahoo.com

Received: 5th April, 2012 ; Accepted: 8th August, 2012

ABSTRACT

Health is wealth. Good health is one of the most essential necessities after the basics: food shelter and clothing. Diseases are a threat to individuals' enjoyment of good health. Epidemics or communicable disease however threaten communities, disrupting day-to-day activities, plummeting or totally incapacitating man-power and directly or indirectly affecting the economy of such a society. The Federal Ministry of Health has targets some twenty-one priority diseases in the Integrated Disease Surveillance and Response (IDSR) system for eradication one of which is Cholera. However, Cholera outbreaks in Nigeria were at their peak last year (2010). The influx of various technologies and technological know-how within the country the application of information technology in Nigeria is obviously not yet near world standard, particularly in the IDSR implementation. This paper presents a framework with a GIS core that incorporates other technologies such as mobile computing to fast track the collation of epidemic related data for prediction and management purposes. As a result of the ubiquitousness of Java-enabled phone (Java based applications) and the widespread integration of Global Positioning Systems (GPSs) into such phones, Location-based services can be used to enhance the ease of use and usefulness of data gathered by public health officials carrying out active surveillance. The components of the framework include a desktop server application, alongside an automated SMS gateway for notification to the populace, a mobile client application with capabilities to serve in different capacities both public health workers and individual public users.

KEYWORDS

Geographic information systems (GIS);
Surveillance;
Real-time data processing;
Mobile computing;
Epidemics.

BACKGROUND

Good health is wealth. Good health is one of the most essential necessities after the basics: food, shelter and clothing. Diseases are a threat to individuals' enjoyment of good health. Epidemics or communicable disease however threaten communities, disrupting day-to-day activities, plummeting or totally incapacitating man-power and directly or indirectly affecting the economy of such a society. An epidemic of an infectious disease is a public health problem characterized by the occurrence of an unusual high number of cases of such disease expected for a given place and time. Infectious diseases fall into two broad epidemic categories based on various factors such as spread rate or affected areas or individuals: potential and emergency state epidemics.Various thresholds have been placed by the Federal Ministry of Health to monitor outbreaks of the twenty priority diseases. For example Threshold considered in outbreaks are:

a. Action threshold – 5/100,000
b. Epidemic threshold CSM 15/100,000, r/f, cholera and yellow fever– 1/100,000

Active surveillance is a good approach to this problem, that is whether or not there is an epidemic continuous data gathering systems should be in place. This data can be useful over time in the management of epidemics. The Center for Disease Control and the Council of State and Territorial Epidemiologists in the United States defines Surveillance as:

"... ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control".

This definition encompasses the totality of a true surveillance system, in a surveillance system early warning or "timely dissemination" of data is very critical as it goes a long way to determine the number of casualties salvageable in the event of an occurrence. The Multi Disciplinary Committee on Epidemic Early Warning Mechanism for Nigeria defines early warning (a national priority for any country) as the provision of timely and effective information through intensified institutions that allows individuals exposed to a hazard to take action to avoid or reduce the risk and prepare for effective response.

An early warning mechanism should help in the forecast of impending events, be able to process and disseminate of warnings to stakeholders and aid in the carrying out of appropriate actions. The presented framework aims at delivering these services. The framework design also sought to provide a functional society based early detection and reporting system.

The surveillance performed on epidemics in any country should not be restricted to any part of the definition. Several tools have been employed successfully in various countries for the prediction and management of epidemics. One of such tools is Geographic information System (GIS) that is a computer-based system that allows us to study natural and man-made phenomena with an explicit bearing in space[14]. GIS allows us to enter data, manipulate or analyse data and produce interpretable output that may teach us about the phenomena.

GIS has been applied previously to various areas in solving human problems, such as Traffic management[13], Agriculture[1], Population census, Banking, Transportation, Environmental Management, HIV/AIDS Intervention and even epidemics[15].

In many public health and epidemiology projects GIS has recently emerged as an innovative and important component, sometimes even an essential tool. It is easy to determine spatial relationships between disease occurrence and other information that is geo-referenced differently from the disease data[9]. This goes to assert that Information Technology has a lot to offer the public health sector of Nigeria, the application of technologies like mobile computing, and GIS can greatly enhance the poor state of the surveillance system in Nigeria.

The use of geographical methods in relation to epidemiology is not new. Dr. Snow notably made use of maps during the London Cholera outbreak of 1855. Since then several epidemiologists have made use of various geographical methods in their investigations of epidemics. Epidemiology has seen a lot of contribution in its development over time from GIS, as Clarke et al[4] assert with cogent examples in their paper titled: *On Epidemiology and Geographic Information Systems: A Review and Discussion of Future Directions*. Throwing light on the functional capabilities of GIS, existing applications of GIS in Epidemiology, spatial analysis possible with GIS in relation to epidemiology, the hardware and software requirements etc. This paper focuses on the design of a surveillance system revolving around a GIS core. By making use of state-of-the-art tools methods and techniques, the design resolves many deficiencies in status quo systems and provides information for action. We present a design that substantially provides ways in which improvement could be in made in Nigeria's approach in the war against epidemics particularly the priority diseases; Cholera, Swine Fever, and Avian Influenza.

STATEMENT OF THE PROBLEM

However, according to the Nigerian IDSR policy document (2005) by the Federal Ministry of Health, the current disease surveillance system is still insensitive as it is incapable of detecting early warning signs of outbreaks. The efforts of the Federal Ministry of Health especially during the last cholera outbreak were very laudable, however, it is said that "prevention is better than cure". Some deficiencies in the IDSR implementation, abetting the systems insensitivity and ineffectiveness are summarised in the following stages:

i. Gaps at the stage of generation of early warning mechanisms for epidemics.
ii. Gaps at the stage of the Analysis of the early warning mechanism for epidemics.
iii. Gaps at the stage of dissemination of early warning information on epidemics.
iv. Gaps at the stage of application of early warning mechanisms for epidemics.

These lapses and gaps if not attended to could bring the Nigerian economy to its knees as the trend is towards larger occurrences of varying degrees depending on the disease in context. A multi-disciplinary committee on epidemic early warning mechanisms asserted that epidemics and diseases are the leading causes of death in Nigeria, stating that the top ten "natural" disasters in Nigeria were exclusively epidemic. For the prevention and management of epidemics In 1998 WHO/AFRO, following the resolution of the 48th assembly, held in Harare Zimbabwe, started promoting Integrated Disease Surveillance and Response (IDSR) for all member state to adopt as the main strategy to strengthen national disease surveillance system. The IDSR serves in spear-heading the war against epidemics in Nigeria and is an integral part of the National Health Management Information System (NHMIS) which is a GIS framework controlled by the Federal Ministry of Health. However, the implementation of the system is in a apologetic state.

The resultant effect of the poor surveillance system is high mortality, morbidity and disability, as recorded in the 2010 Cholera outbreaks. The 2010 Cholera epidemic is reported according to UNICEF to be Nigeria's highest caseload so far (at 38,173 cases, including 1,555 deaths as of October 2010). This may be unrelated to the fact that our home, planet earth is evolving and our climate is changing. Ford et al briefly highlighted this in their work, *Using Satellite Imagery of Environmental Changes to Predict Infectious Disease Outbreaks.* It is important to note that the Cholera epidemic earlier referred to, usually in terms of origin has a lot to do with environmental changes (seasonal and related to presence or bloom of *Vibrio cholerae* in water bodies) which is one of the reasons the use of remote sensing is very applicable. This is an indication that the trend may be downwards in the surveillance capabilities of the systems on ground, this is inferred since an effectively functional surveillance system with an early mechanism would have aided the management of the outbreak and reduced mortality relative to previous outbreaks.

REVIEW OF RELATED WORK AND EXISTING SYSTEMS

Some related literature from which our framework builds are reviewed in this section.Systems with similar structure and frame work are presented in the following works.

Implementing internet GIS with java based client/ server environment

The work Babu (2002) describes the use of Java Virtual Machine and Servlets in Web servers in a Client-Server architecture for an Internet GIS. The Interaction between servlets and applets in the design is shown in Figure 1.

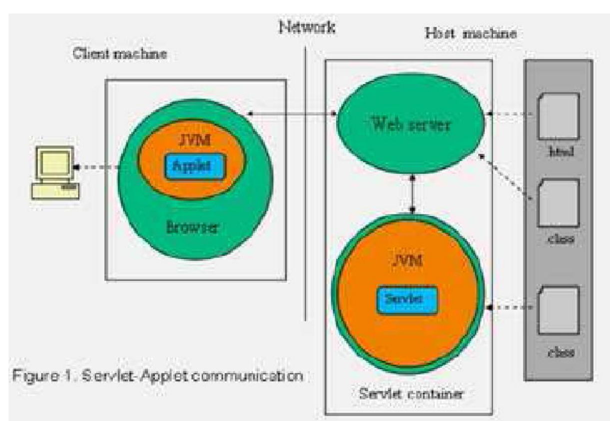

Figure 1 : Server-applet communication in an internet GIS

Real-time mobile GIS prototype: Design, architecture, and usability study

In the paper by Aslabhan[2], the design proposed is a server-client network application in which mobile phones are used to a server via the internet. This paper proposes a real-time mobile GIS architecture that integrates a GIS with a hydrological model. The architecture is shown in Figure 2 below

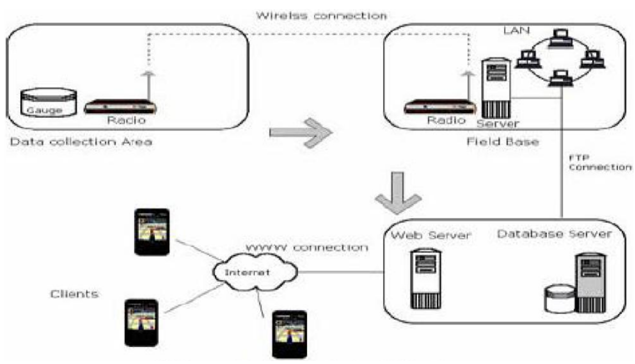

Figure 2 : Project architecture (Source: Real-time mobile GIS prototype: Design, architecture, and usability study)

The author speculates that the use of Location-Based Services can be introduced to the GIS prototype on J2ME mobile phones. Location-based services are a key feature of our framework. In our design, GPSs are used dually; for reporting/gathering of data and information presentation that is for example of nearest health facilities or in allocation of resources as need to manage the outbreak.

PROPOSED FRAMEWORK

To create a satisfying design and to put forward a wholesome framework that encompasses the basics of a functional disease surveillance system and goes on to make use of available state-of-the-art technology. The design eliminates one of the major problems which prompted the World Health Organisation's recommendation of an integrated approach which is that: National Surveillance data on infectious diseases is usually collected by programmes under different authorities, including the ministry of health, and the ministry of agriculture. In addition, academic or research institutes may conduct specific surveillance activities while the private sector and nongovernmental organizations (NGOs) may also run surveillance systems in their area of interest. Within the health sector, multiple surveillance systems may operate in parallel, sometimes in complete independence. This problem can be exacerbated by the influence of strong outside donors who may support specific surveillance and control programmes. Our design however, is based on a single mega-network which acts for the whole nation rather than for individual endeavours.

Features of the framework

Data gathering: The design is to include a databank of information on the various priority diseases amongst other categories of data demographic and users' contact information. This would include data relevant to aiding the system in making predictions, for example, from past records of occurrences and rate of spread in a particular area models have been developed that can be used for analysis of such data. The system takes into cognizance the need for expert knowledge on various diseases. In other not to fore-stall the usability of the system for various diseases as said of some surveillance systems in the country[12] the design is for a system that is not disease-specific but allows for expansibility; diseases can be added to the database and updates can be made.

Fuzzy Logic alongside Mathematical Models as which have been tested and implemented in other countries like South Africa Graeme et al[8] and in the work of Cláudia[5]. The models proposed are adopted to aid in the prediction.

Remote-sensing: As rigorously discussed in the articles *Remote Sensing for disease prevention in Nigeria* by Mariel J.[11] and *Using Satellite Images of Environmental Changes to Predict Infectious Disease Outbreaks*[7], remotely sensed data have been used in prediction models for cholera and can also be used for other epidemics depending on the nature of the disease. This design integrates the use of remote sensing in epidemiological surveillance.

Notification: Just like the routine (weekly or monthly) reports on probable occurrences, real-time occurrences are delivered through Application notifications or through Short Message Service (SMS) this is targeted at decision-makers, health workers, and individuals that is the general populace.

Analysis for decision-making: This is the function performed by the GIS core.

Visual presentation: The display of results of analysis is in such a way that priorities area or critical zones are easily recognised and decisions can be made faster.

FRAMEWORK ARCHITECTURE

The framework architecture is presented in Figure 3 below:

The design is a client-server architecture the clients in this case include both PCs and mobile devices; and to achieving real-time data delivery a lot of attention was paid to the source of spatial data and the optimizing of such existing database. The objectives are to minimize the process time and to improve the data accuracy. For this reason MySQL is the recommended Relational Database management System (RDBMS), apart from this MySQL is also a free RDBMS.

HARDWARE AND SOFTWARE REQUIREMENTS

Tools for development of the system

Open-source geographic information systems

There are various Open source GIS in the market now with fast-growing support communities which have been used in the deployment of similar systems. Some examples of Open Source GIS are uDIG, GRASS, gvSIG OpenJUMP, and Quantum GIS For example in Spain, gvSIG has been used severally and variously by the government to solve various problems in different sectors some of which are similar to the framework being proposed and developed. For the purpose of the framework and the need to have a scalable and light-weight system, either of OpenJUMP or Quantum GIS are recommended. The GIS core being developed is shown in Figure 4.

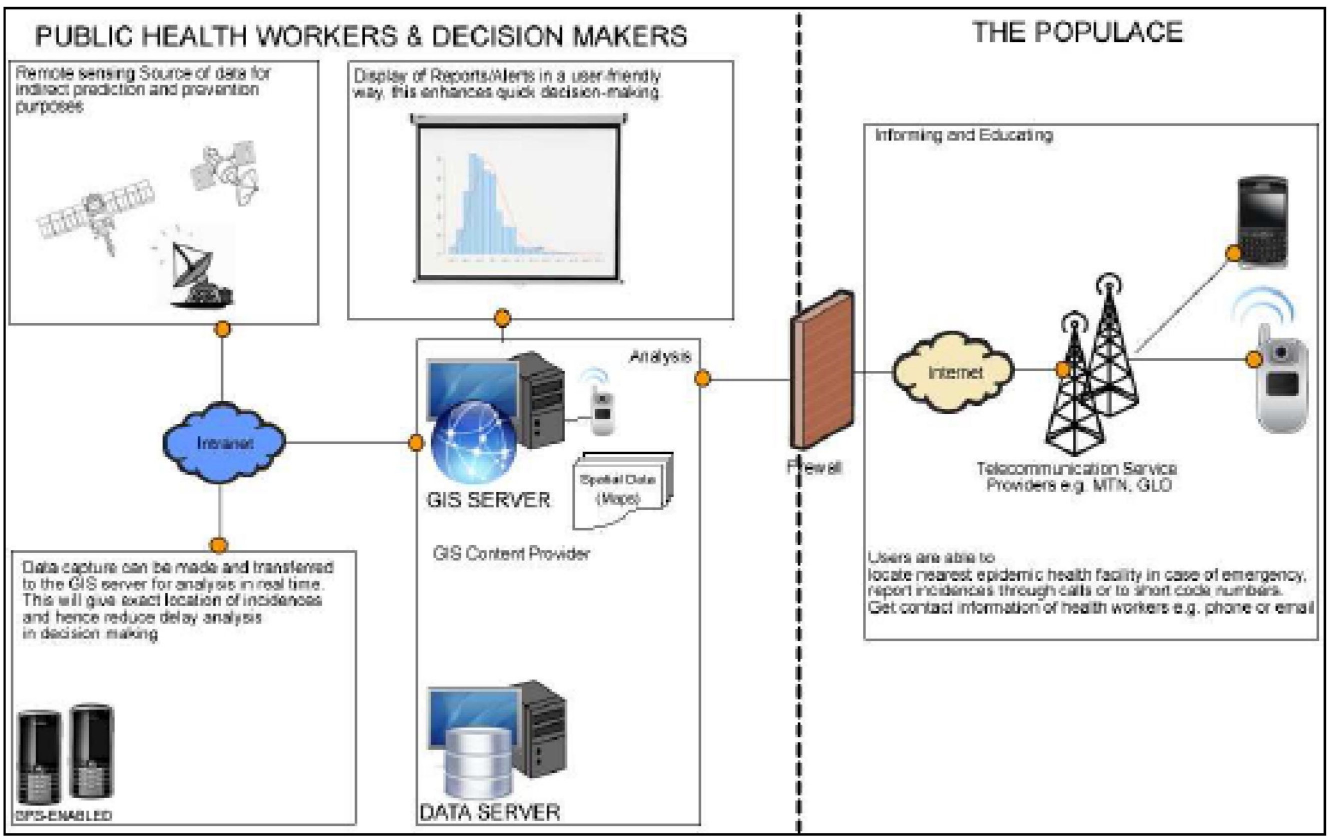

Figure 3 : Diagrammatic illustration of system design

NetBeans: Java development environment

This Integrated development Environment (IDE) is the pop of development environments in Java, extensible for development on various platforms: Java™ ME Platform SDK 3.0,Through this versatile IDE the application can be deployed to various phones through various platforms such as

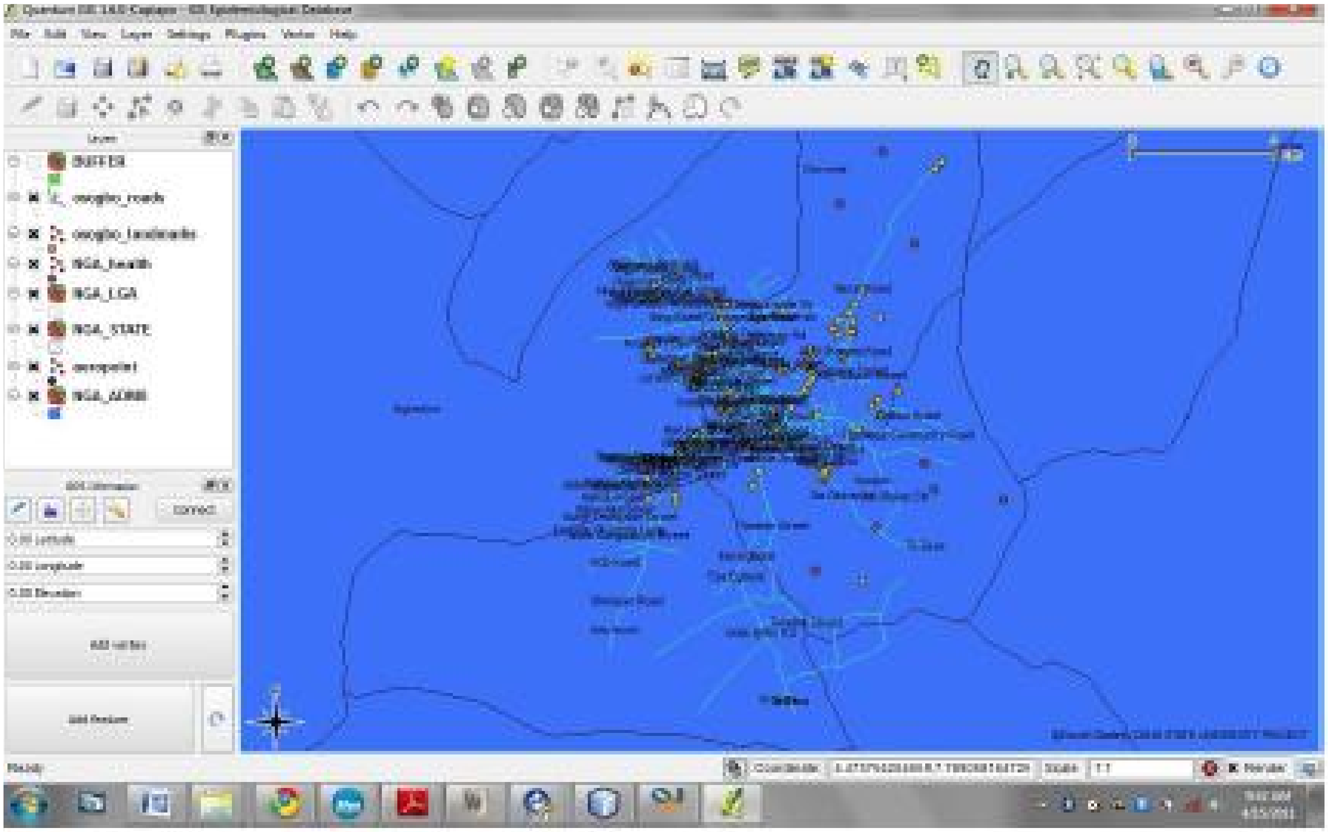

Figure 4 : Interface of GIS development environment: Quantum GIS.

Components of the design

Mobile client application: MIDlets packaged together to give various functions to the users of the service that connects to a servlet to obtain various forms of data through the internet or through an intranet depending on the user i.e. mobile users can access the data server either as health workers reporting cases of an outbreak, or search for information on diseases and health facilities as an ordinary user.

GIS server: The GIS server carries out analysis on the data gathered from various sources, mobile phones and remote sensing. Coupled with results from previous data gathered the GIS server cues the Surveillance Desktop Application (at action or epidemic thresholds) that send alerts from an attached mobile device without any physical or direct human intervention. Open-source GIS applications are preferable for easier customisation, and interoperability with custom software and database.

Database server: Works in tandem with the GIS Server and acts as a reservoir for past data and a share-point for data being continuously gathered. The data gathered is used in simulation alongside remotely sensed data to predict possible outbreaks. The Location based data gathered through GPSs helps improve on the prediction model employed based on the work of Graeme et al[8].

Custom-designed surveillance desktop application: A Java-based application integrated with the GIS Server providing an interface for onward transmission to large screen visual display units in the stations (health facilities), to mobile client applications and to mobile phones (by SMS) when necessary. In the server-client architecture presented, this is run on the main server and client PCs run similar applications. This is where the number of diseases under surveillance may be reviewed.

Web-Interface/web server: A servlet is uploaded accessible over the internet or intranet as the case may be from which requests and submissions are made from mobile clients. Also, results of analysis and predictions are made available to the general public, and an international audience. Queries can also be made on this interface.

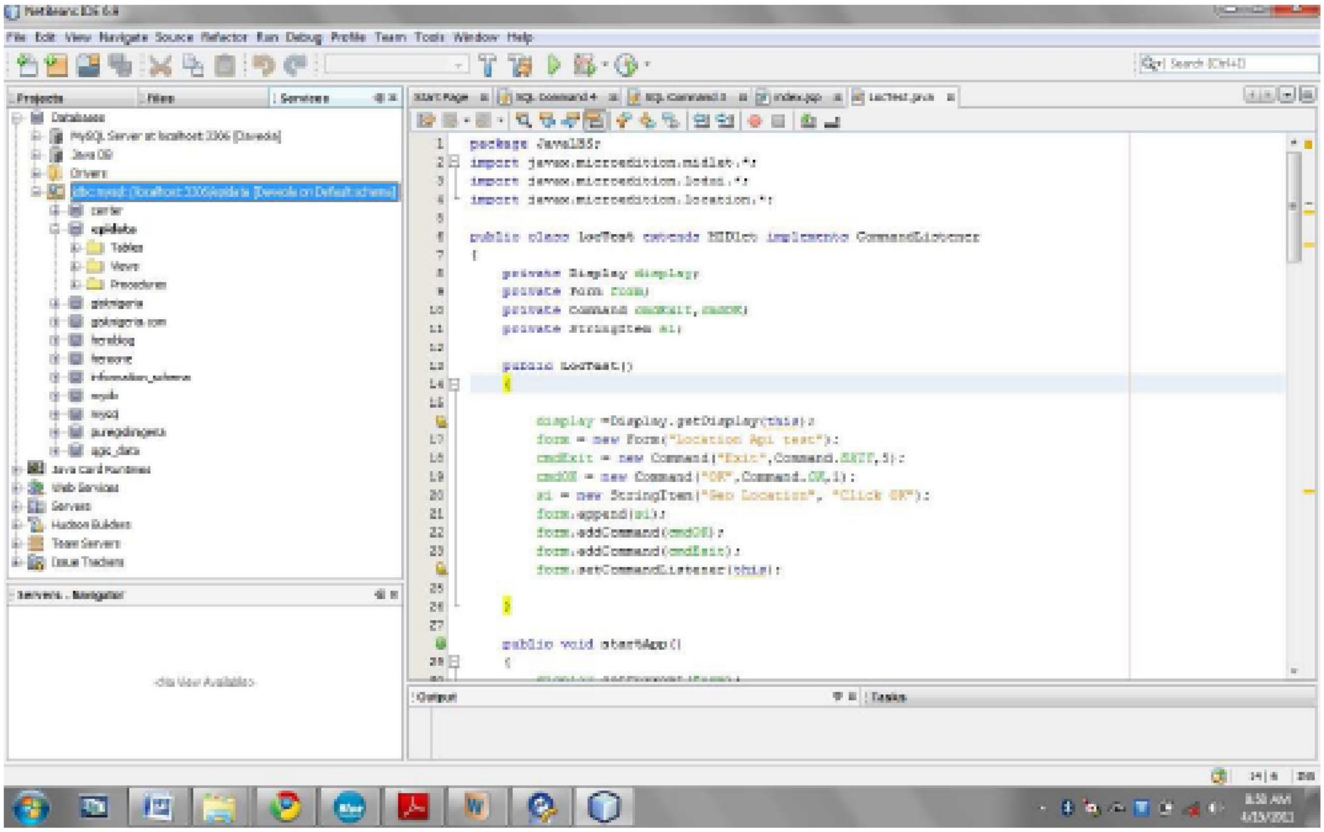

Figure 5: The NetBeans integrated development environment

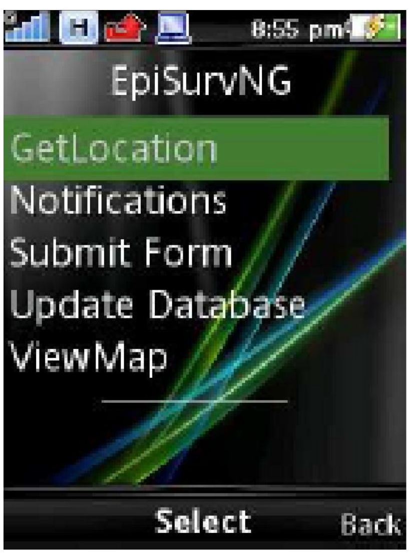

Figure 6 : Screenshot of mobile application in development

DISCUSSION

Currently the IDSR makes use of paper forms to report outbreaks (DSN 001 and DSN 002). Karras et al.[10] stated that a Java-enabled wireless phone was inherently deployable, portable and that minimal orientation to new hardware was needed since everyone was comfortable with entering numbers (as well as alphabets) on a phone keypad and pushing the send button.

Chen et al[3] in their paper titled *Design of a real-time GIS*; divide Mobile GISs into two groups: system construction and system utilization. The former concentrates on creating the GIS, such as data collection, data checking, data updating among other aspects. The system utilization aspect concentrates on the use of an existing system, for example, location searching, path finding, and information seeking, this is on the side of the target population. This design implements both types depending on the user of the application. The rapid increase in mobile phone usage as a result of the ease and mobility allowed by mobile phones accentuates the advantage of integrating a mobile GIS as part of the design. According to the an estimate by the Central Intelligence Agency (CIA) World fact book, the Nigerian population was 155,215,573 people in 2010 and according to the Nigerian Communication Commission (NCC) active mobile phones users as at 25th March, 2010, had grown to 78.5 million meaning at least 50% of the nation's populace can be reached directly through mobile phones. A simplistic approach to design cannot be over-emphasised here since the variety of target audience expertise is very wide. Mobile GIS provides health workers the ability to take along GIS with them into the field, also mobile phones allows making accessible necessary information to the populace when necessary and useful, in real-time.

Marrying GIS and GPS for location based services enhances the quality of spatial and non-spatial data for analysis and decision making by providing an integrated approach to disease control and surveillance at the local, regional, and/or national level[4]. The wide-spread integration of Global Positioning Systems in Mobile phones also makes it easier to allow us take advantage of GIS's capability to provide location-based services (LBS). In the framework presented design through the LBS, mobile devices with GPS capabilities can view their location relative to fixed assets (health facilities), mobile assets (other users of the application or health personnel) or to relay their position and case report locations back to a central server. Mobile phones with GPS integrated or GPS capable are getting increasingly more powerful and cheaper. Alternatively, Cell-IDs attached to base station masts in Telecommunication networks being used by a mobile user can be used to estimate a mobile device's longitude and latitude.

Conclusion and future work

Epidemics if not well managed before growing out of control pose a large-scale threat, to not individuals only but the economy at large. Overtturning this problem just like GIS, requires knowledge from various fields and various tools even within Information and Communication Technology (ICT). Advancement in computing techniques and technology particularly manifested recently in GIS and mobile phones can be harnessed to further expand the capabilities of the current GIS-Epidemiology surveillance systems allowing for real-time data capture and automated dissemination of information to appropriate stakeholders and hence delivering information for action.

A prototype of the proposed framework is underway in order to demonstrate the feasibility and potential strength this design could give the Federal Ministry of Health. This would help the proper integration of disease surveillance in the country as preached by the World Health Organisation.

In the very near future, Cloud Computing Services can be integrated to add location-aware functionalities to the system. In other words, the notifications or alerts for example are only displayed or sent when a user is in certain vicinity, for example around a particular area susceptible to the a particular epidemic or close to a health facility with advantageous information for the user. An example of such a service is available from http://www.locomatix.com.

REFERENCES

[1] F.O.Adekayode, M.O.Ogunkoya; The use of geographic information systems (GIS) in estimating a potential fadama land area for inland farming: The buffering technique, Journal of Food, Agriculture & Environment, **7(3&4)**, 705-709 **(2009)**.

[2] W.Aslabhan; Real-Time mobile GIS prototype: Design, architecture, and usability study. DCSNS International Journal of Computer Science and Network Security, **10(2)**, **(2010)**.

[3] S.Chen, L.Shi, L.Wang; Designing a real-time mobile GIS. GIS development; the geospatial resource portal, Available online from: http://www.gisdevelopment.net/technology/mobilemapping/ma04088.htm; [accessed: 17th October, 2010], **(2000)**.

[4] K.C.Clarke, S.L.McLafferty, B.J.Tempalski; On epidemiology and geographic information systems: A review and discussion of future directions, Emerging Infectious Diseases, **2(2)**, **(2006)**.

[5] T.C.Cláudia; A mathematical model for epidemic and endemic cholera: The role of the aquatic reservoir, Programa de Computacao Cientifica Fundacao Oswaldo Cruz, Rio de Janeiro, Brazil, BioMed Central Infectious Diseases, **(2001)**.

[6] Federal Ministry of Health Nigeria, National Policy on Integrated Disease Surveillance and Response (IDSR), **(2005)**.

[7] T.E.Ford, R.R.Colwell, J.B.Rose, S.S.Morse, D.J.Rogers, T.L.Yates; Using satellite images of environmental changes to predict infectious disease outbreaks. Emergent Infectious Disease. [Epub ahead of print], **(2009)**.

[8] M.Graeme, M.Van Der Merwe, G.Fleming, K.Murphy; Fuzzy expert systems and GIS for cholera health risk prediction in Southern Africa, The Southern African Council for Scientific and Industrial Research; ESRI User Conference 2004, **(2004)**.

[9] U.Hjalmars; 'Environmental epidemiology and GIS, commentary on' GIS in public and environmental health: Visualisation, exploration and modeling.' by Anthony Gatrell; Department of Pediatrics, Östersunds Hospital; *International Geographical Union (IGU) Commission on Health, Environment and Development* Workshop 4, **(1999)**.

[10] B.T.Karras, S.H.Huq, D.Bliss, W.B.Lober; National pharmaceutical stockpile drill analysis using XML data collection on wireless java phones. Proceedings of AMIA symposium. [PMC free article, PubMed, 365-391 **(2002)**.

[11] J.Mariel; Remote sensing for disease prevention in Nigeria, Space Foundation USA, **(1999)**.

[12] N.Nwankpa, C.Ojembe; Improving the national capability for disease surveillance, detection and diagnosis in public health systems in Nigeria, a paper presented to the Meeting of Experts of States Parties to the Biological Weapons, Convention, in Geneva, Switzerland, **(2010)**.

[13] E.F.Ogunbodede; Assessment of traffic congestions in Akure (Nigeria) using GIS approach: Lessons and challenges for urban sustenance, **(2006)**.

[14] A.D.Rolf, R.A.Knippers, Y.Sun, M.C.Ellis, M.Kraak, M.J.C.Weir, G.Yola, M.M.Radwan, C.J.van Western, K.Wolfgang, E.J.Sides; Principles of geographic Information System: An introductory textbook, **(2001)**.

[15] O.B.Shittu, I.Akpan, T.O.S.Popoola, J.A.Oyedepo, E.O.Ogunshola; Epidemiological features of a GIS-supported investigation of cholera outbreak in Abeokuta, Nigeria, Journal of Public Health and Epidemiology, **2(7)**, 152-162 **(2010)**.

[16] World Health Organisation; An integrated approach to communicable disease surveillance, Weekly epidemiological record. Available from: http://www.who.int/csr/labepidemiology/projects/surveillance/en/index.html; [accessed 3 March, 2011], **(2000)**.