Dynamic Location-based Healthcare System towards the Attainment of Healthcare Delivery for Africa

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Abstract

Quality and equitable healthcare delivery in Africa still remain a daunting challenge (Ditsa & Ojo, 2011). There is a great potential that contemporarily advanced e-health technologies hold to enhance the quality and equity of the health systems in Africa. This paper examines some of the healthcare challenges in Africa and presents a prototype Dynamic Location-based eHealthcare system to augment some of the healthcare challenges in Africa.

Keywords: e-Health Technologies, e-Healthcare Delivery, Mobile Computing, African Healthcare System, Dynamic Location-based Systems.

Introduction

Major developmental challenges face African countries. These include economic diversification, poverty and unemployment, quality and equity health for all, and the sustainable use of natural resources (Ditsa & Ojo, 2011). Quality and equity healthcare challenges are much more daunting and have grave repercussions for other developmental challenges in African (Adigun et al., 2006; Ditsa & Ojo, 2011). According to WHO's report, the severe burden of disease in the African continent subsequently affects the developmental growth of other sectors in the continent (WHO African Regional Report, 2005, 2011).

The UN Assembly (2000) initiated Eight Millennium Development Goals (MDGs) targeting: poverty, hunger and disease; greater survival prospects for mother and child; better educated children; equal opportunities for women; and a healthier environment. The Eight Millennium Development Goals (labelled MDG 1 to MDG 8) with 18 targets and 48 indicators were set around this vision. The first three of the eight goals, MDG 1 to MDG 3, respectively focus on eradication of extreme poverty and hunger, education for all, and gender equity and women empowerment. The MDG 4, 5 and 6 are concerned about health for all, while MDG 7 deals with environmental stability, while MDG 8 is a capstone goal advocating for global partnership for development (Ditsa & Ojo, 2011; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016).

The contemporary rapid e-health technologies development together with digital telecommunication technologies and wireless developments create the capabilities that can be harnessed to alleviate the health challenges of Africa. The costs of these e-health technologies and digital telecommunication devices are falling within affordable limits of businesses and individuals. These diverse but manageable technologies can be easily integrated with organizational resources to provide mobile services and computing to address the health issues of Africa. The prerequisite knowledge required in building complex mobile and computing services are available and are often found in different places across firms, industries and country boundaries (Yoo, Lyytinen, & Yang, 2005; Sallabi, et al. 2010a; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016).

Mobile computing is guided by the concept of connecting anytime and anywhere (Kalakota, Stallaert, & Whinston, 1996; York & Pendharkar, 2004; Sallabi, et al. 2010a; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016). Mobile computing has been predicted to be a significant area of information technology (IT) and human-computer interaction (HCI) research, development and applications (Chandra, et al., 2000; Hewett et al., 1996; York & Pendharkar, 2004; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016). As early 2000, conservative estimates based on the 2000 Census report suggested that by 2006 10% of USA workers would be completely mobile with no permanent office locations. This wave was brought about due to the level of maturity of mobile computing technologies. Certainly, more opportunities and feasibilities for mobile computing applications are enhanced as wireless telecommunications get more advanced. Similarly, the use of handheld computing devices becomes more popular among individuals and organizations as capabilities of these devices advanced and their costs fall. The increased advances in technology subsequently leads to increase in coverage, data speeds, usability, and greater user acceptance which motivate the development of new mobile computing applications that are more feasible, flexible and advanced (Barbash, 2001; Turisco, 2000; York & Pendharkar, 2004; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016). However, the rapidly changing pace of mobile computing has made it difficult to keep up with to understand and to utilize. Competitive advantage can however be gained by industries and countries by deploying mobile computing if the deployment is appropriately done and managed in work settings and understood by users (Porn & Patrick, 2002; Sallabi, et al. 2010a; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016).

Mobile commerce (m-commerce) is one of mobile computing applications. M-commerce can be defined as any e-commerce or e-business done in a wireless environment. M-commerce services are classified by industry or by application (Turban, et el., 2004; Varshney & Vetter, 2001; Sallabi, et al. 2010b; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016).

One of m-commerce applications mentioned above is product locating and services, which is referred to as location-based commerce/services (l-commerce or LBS). *LBS is m-commerce transactions targeted to individuals in specific locations at specific times*. LBS offers the following to consumers and businesses (Turban et al., 2004; Sallabi, et al. 2010b; Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016):

- ***Safety*** - A person can connect to an emergency service with a mobile device and have the service pinpoint their exact location;
- ***Convenience*** - People can locate what or who is nearby without having to consult a directory, payphone, or map; and
- ***Productivity*** - People can optimize their travel and time by determining points of interest that are within close proximity.

The basic LBS services revolve around 5 key areas:

1. ***Location*** - Determining the basic position of a person or a thing;
2. ***Navigation*** - Plotting a route from one location to another;
3. ***Tracking*** - Monitoring the movement of a person or a thing;
4. ***Mapping*** - Creating maps of specific geographical locations and
5. ***Timing*** - Determining the precise time at a specific location.

The above applications of mobile computing have recently been employed in the healthcare sector; resulting in the terminology *electronic-Health or electronic-Healthcare*, in short, *e-Health* or *e-Healthcare*. Some of the areas in the healthcare sector that mobile computing is being employed include:

- *Telemedicine;*
- *Mobile Healthcare Surveillance/Telemonitoring/Telecare*, which includes: preventative healthcare programs; physiological monitoring; functional monitoring; and assessment of quality of life.

The last point above primarily employs Location-based services (LBS) to locate points of interest (POIs) for healthcare surveillance, monitoring and healthcare delivery.

In this project, we developed a Dynamic Location-based Healthcare System (DLBHS) which is aimed initially at healthcare surveillance, monitoring and healthcare delivery for HIV/AIDS patients, prenatal care for mothers, and postnatal care for mother and child. The DBLHS allows community healthcare workers to locate patients at their addresses to deliver healthcare and transmit healthcare data to a central repository. Patients can as well use the DBLHS to communicate with community healthcare workers about their conditions. The DBLHS consists of a frontend, a backend and healthcare providers. Community healthcare workers use the frontend to send Location Based Service (LBS) request to the backend that replies to the POIs as requested by the users. Healthcare providers need to access the backend server to add or update their services.

Currently, healthcare fieldworkers manually capture patients' data, which are reentered into electronic systems; use trial and error in locating patients' locations; and etc. The developed DBLHS will provide potential benefits such as saving time and money, more accurate and instant patients' data, and more convenience and satisfaction to healthcare workers and patients.

In wireline-based applications, users normally input their addresses in order to filter service options based on the users' locations. In the conception of LBS, the user's location is determined automatically without requiring the user to explicitly provide it. There are many different techniques that have been developed for automatic location outdoor and indoor identifications. Locating users in outdoor environments can be divided into three broad categories: handset based GPS approach, cellular network-based approach, and hybrid approach that combines two or more techniques. The discussion on these approaches, including strengths and weaknesses are summarized in (D'Roza & Bilchev, 2003). A number of different techniques for the provision of location specific services to users in indoor environments are available in (Steinfield, 2004).

The DLBHS prototype implementation in this research is based on a mobile device as the frontend device getting its GPS signal through a GPS bluetooth mouse and communicating with a local gateway through the GSM network and Web services.

The first phase of this research project developed a fully functional DLBHS prototype. In the second stage of this research, a controlled experiment will be used to test the acceptance of the DLBHS prototype by potential users. The acceptance test of the DLBHS prototype is planned for South African healthcare service providers and the targeted patients. It is also planned to test the prototype in a surrounding country to South Africa and in Ghana, where a collaboration with a university in the project is taking place.

The remainder of this paper is organized as follows. A brief literature review on LBS is next presented followed by the DBLS framework, preliminary testing and analysis. Finally a conclusion and future work is presented.

LBS Literature Review

There were more than one billion cellular phones in the world in 2002 (Steinfield, 2004) These include other wireless handheld computing devices such as personal digital assistants (PDAs) and pocket PCs, which offer considerable opportunities for ubiquitous computing growth. Ubiquitous computing is an emerging paradigm of personal computing, characterized by the shift from dedicated computing machinery to pervasive computing capabilities embedded in our everyday environments. Characteristics of ubiquitous computing are small, handheld, wireless computing devices. The pervasiveness and the wireless nature of devices require network architectures to support automatic ad hoc configuration. An additional reason for the development of automatic configuration is that, this technology is aimed at ordinary consumers (Ditsa, Amanquah & Muwanguzi, 2015.

A key technology of true *ad hoc* networks is service discovery; functionality by which "services" (i.e., functions offered by various devices such as cell phones, printers, sensors, etc.) can be described, advertised, and discovered by others. All of the current service discovery and capability description mechanisms (e.g., Sun's JINI, Microsoft's UPnP) are based on *ad hoc* representation schemes and rely heavily on standardization, that is, on a priori identification of all those things one would want to communicate or discuss.

Current LBS systems present the POIs to mobile users as static icons displayed on a location map. In this case, the mobile users cannot differentiate between open and closed service points. Meanwhile, the size of the transferred file is too big as it includes the location map which is usually represented in a picture format. The proposed Dynamic LBS in this project will eliminate those two problems by differentiating between the open and closed POIs, and the backend server needs just to send the position of the POIs (Ditsa, Amanquah & Muwanguzi, 2015; Ditsa & Muwanguzi, 2016). Key points of the Dynamic LBS are as follows:

- ***Simplicity*** - the system is simple to use by end users and service providers. Users need just to indicate the POI and send a request to the backend server. Service providers have access to the database and can manage their POIs;
- ***Flexibility*** - the system is very flexible in showing the POIs. Service providers may update the database at any time to add or remove services. This is in contrast to existing systems, where all POIs are hard coded into the digital map and are updated once at a given time;
- ***Affordability*** - The system does not rely on third party's digital map. This will reduce the service cost. In addition, the amount of information sent by the backend server is reduced, which reduces the communication costs; and
- ***Powerful*** - At the frontend system, there is an application that receives the GPS positions together with patients' (clients) information and then draws the POIs in a window relative to the user position. The application updates the user's position as he/she moves and guides him/her to the point of interest.

Although the markets for LBS are not yet matured, a wide range of services that rely on users' location information have been conceived. The user location can be particularly powerful when combined with other user profile information to offer location responses to customers (Searby, 2003). Van de Kar & Bouwman (2001) distinguished between emergency services, mobile network operator services, and value-added services (VAS): focusing on the latter category as the primary e-commerce opportunity. In the VAS category, they described a number of different service areas, including information, entertainment, communication, transaction, mobile office and business process support services. D'Roza & Bilchev (2003) classified services into two broad categories: those that are requested by users once their location is determined, and those that are triggered automatically once a certain condition is met. In addition, D'Roza and Bilchev (2003) identified five groups of application areas: communication; fleet management; routing; safety and security; and entertainment.

A forecast from the International Telecommunication Union (ITU) (2011) predicts worldwide revenues from LBS would exceed $2.6 billion in 2005, and reach $9.9 billion by 2010 (Liete & Pereira, 2011). A recent report on the CyberAtlas Web site refers to an ARC Group study indicating that LBS will account for over 40 percent of mobile data revenues worldwide by 2007 (Greenspan, 2011). This optimistic forecast further goes on to predict that there would be 748 million worldwide users of LBS as early 2004, up from an estimated 72 million in 2001. The ARC Group believes that by the end of 2004, nearly all wireless-enabled computing devices would use some form of location service.

eMarket (2015) puts the figure of mobile phones users worldwide currently at 4.55 billion, which is about 63.5% of the world population. From their analysis, global smartphone audience total 1.75 billion in 2014, which surpassed the 1 billion mark forecast in 2012. They estimate a steady growth of mobile phone users worldwide from 4.77 billion in 2015 through 4.95 billion in 2016 to 5.13 billion users in 2017; covering about 69.4% of the world population in 2017. According to the paper, mobile phone users are rapidly switching over to smartphones as the devices become more affordable and 3G and 4G networks advance. They estimate smartphone users currently account for a majority of users in 10 of 22 countries included in their forecast and they expected this would increase to 16 countries during 2014. The paper adds that mobile phone usage is nearly ubiquitous in Western, Central and Eastern Europe and North America. However in Latin America, Asia-Pacific and the Middle East and Africa, particularly people living in low-income countries with sparely populated rural with vast terrains, are less likely to own and use a mobile phone or smartphone.

Given the general global trend of growth in usage of mobile phone, particularly smartphones, it is expedient to develop mobile applications to enhance efficiency, effectiveness and productive in all sectors. And research project is about achieving this in the health sector.

Healthcare Utility-Service Broker (HSB)

Olugbara, et al., 2007a proposed an integrated Utility Grid Computing-Body Area Network (UGC-BAN) technology that gives rise to new healthcare services and applications that can provide remote diagnosis and treatment capabilities. Using this integrated technology, healthcare practitioners and patients will have access to resources that cannot be provided by BAN only. For example, a patient health record could be moved around and a healthcare practitioner would be able to collaborate with colleagues from other locations and make informed diagnosis and decisions anytime by sharing resources. The vital signals that are measured and transmitted to a software broker could be adequately analyzed using the discovered grid resources. The result of the analysis could be effectively delivered to the user in real-time. Thus, enabling remote management of patient conditions and quick detection of health emergencies whilst maximizing patient mobility and minimizing healthcare costs. The consideration of BAN for several e-Healthcare applications raises some entirely new requirements for utility grid-based infrastructure. These requirements can be met by a new type of Grid Resource Broker (GRB), a Healthcare utility-Service Broker (HSB) (Olugbara, Ojo and Adigun 2007). The HSB acts as a mediator between the user and the network resources to perform various tasks such as patient health status monitoring, diagnosis and treatment, using sensors and the discovered grid services. Fig. 1 depicts the on-demand assemblage of healthcare services using the HSB technology.

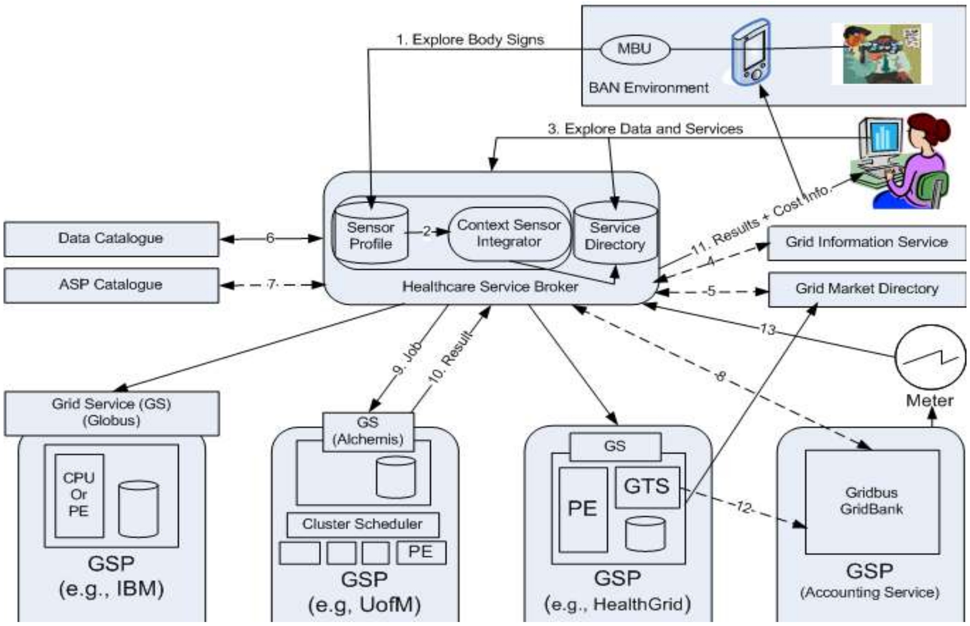

Figure 1: On-demand Healthcare Service Provisioning in Utility Grid (Source: Olugbara, et al., 2007b)

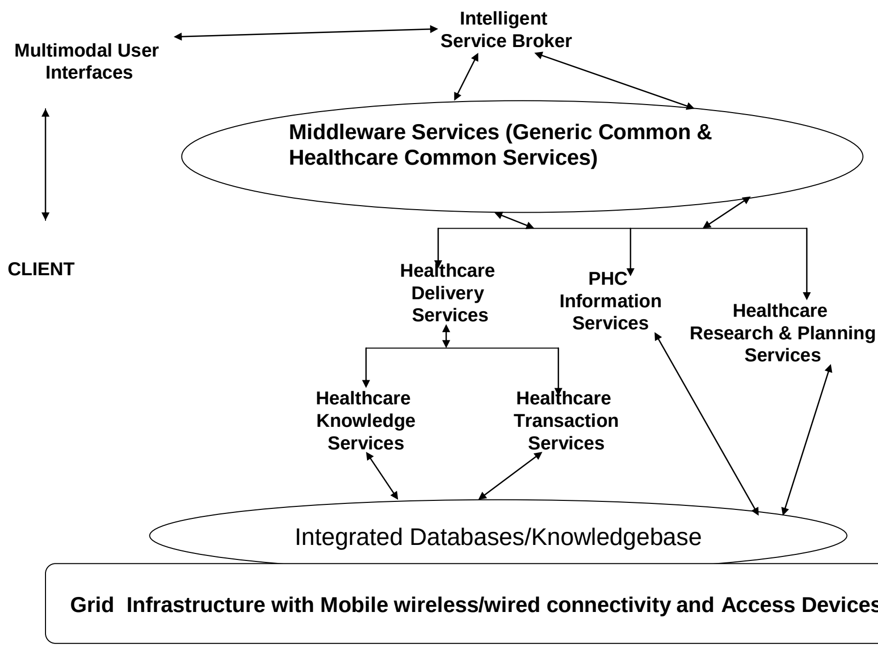

Figure 2: A Reference Model for e-Health Services Infrastructure (Source: Olugbara, et al., 2007b)

Research, Innovation and Partnership Agenda for E-Health in Africa Healthcare Systems

Relevant research, innovation and partnership (RIP) is key to maximal exploitation of e-health in Africa Healthcare Systems towards attaining the MDGs. Figures 3 shows our grid-enabled framework and reference model for e-health research and innovation, while Figure 4 shows a partnership framework being proposed.

The thrust of the RIP strategy should be to exploit the complementary strengths of the partners from the industry, academia and relevant government agencies. Elements of the RIP strategy should include the need for expanding e-health access and participation, leveraging the potential for e-health uptake (e.g., through mainstreaming in relevant education and training programs) engagement and entrepreneurship, extending research and innovation, scholarship and graduate studies, enhancing capabilities, and exploiting the Utility Grid enabled approach to complimentary resources provisioning and sharing (Ditsa & Ojo, 2011).

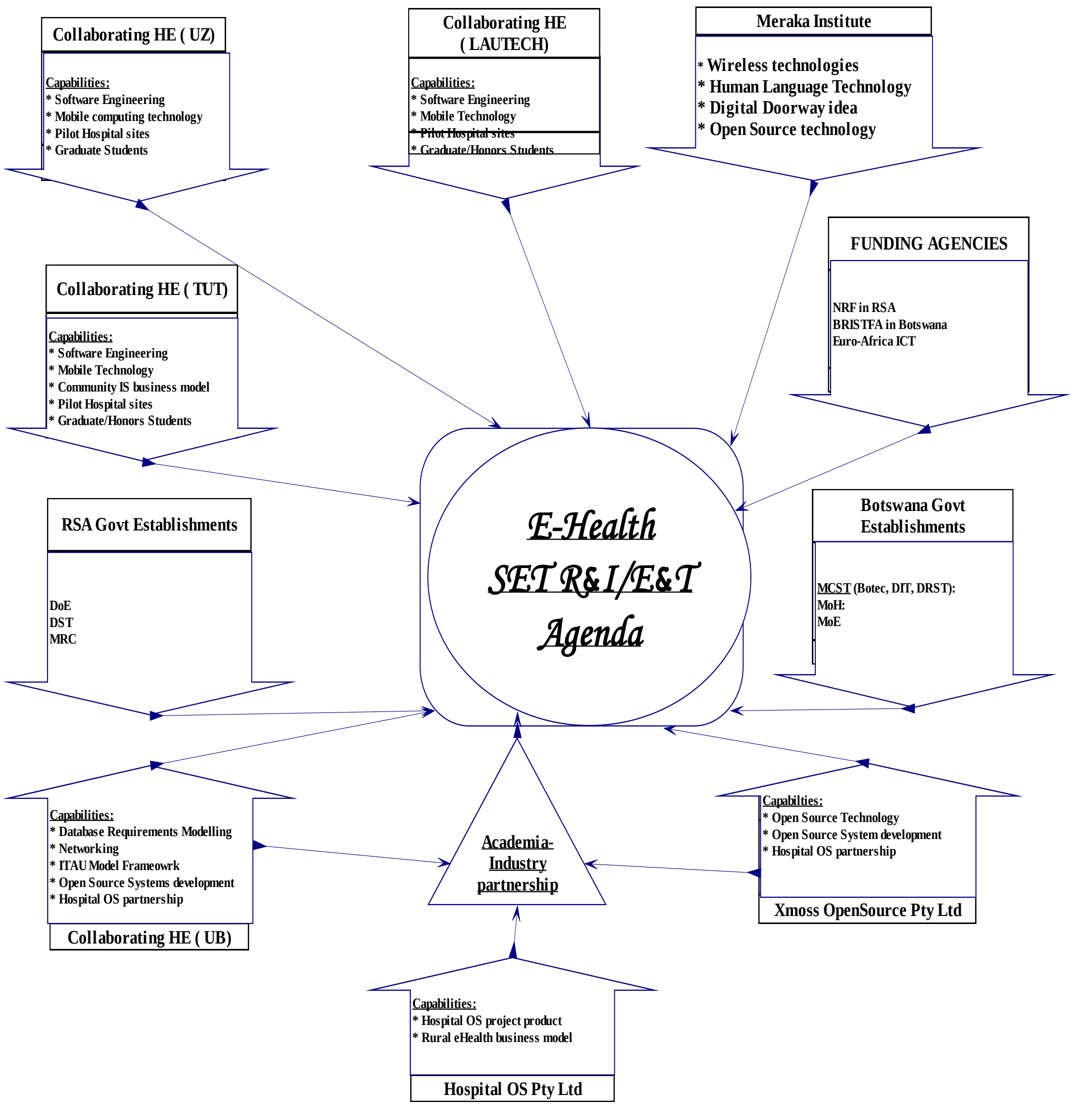

Figure 3: e-Health Research & Innovation Partnership Framework (Source: Olugbara, et al., 2007b)

The Dynamic Location-Based Healthcare System (DLBHS) Framework

DLBHS framework was designed with the following objectives in mind:

- **Interoperability** - Since it is to be used across different computing platforms, information exchange between all platforms should be uniform in order for the different applications to communicate with each other;
- **Scalability** - Technology advances all the time, the architecture should therefore cater for any new advances in technology;
- **Modularity** - The architecture should be flexible enough to cater for any new functions as required. DLBHS is component based, the architecture allows for new component plugins as required by the end user; and
- **Ubiquitous** - DLBHS information and data should be accessible anywhere and anytime on any device as required, depending on the user's level of authorization.

Figure 4 below depicts the Dynamic Location-based Healthcare Systems (DBLHS) framework. The healthcare framework is made up of 3 distinct modules working together, each with its own functionality, namely:

1. **Backend Server:** This is the centralized server used to store, analyze and report on all patient records captured both in the field and in the clinics. It is made up of 2 components:
    a. *Electronic Health Records Database* (*eHealthRDB*) used for safe and secure storage of patients data;
    b. *Decision Support Processing System* used to process the data stored in the eHealthRDB into information which can be understood by the relevant users.
2. **Frontend Client:** The frontend client is the interface used by healthcare fieldworkers to capture patients' information in the field at their point of care. Currently the DLBHS uses an Android mobile application for this because of the flexibility and portability it offers.

The Android application was built with the following objectives in mind:

a. *Ease of use:* The forms to be filled by the fieldworkers were built with predetermined values in order to minimize errors, spelling mistakes and completion time;

b. *Flexibility:* Due to the dynamic nature of fieldwork, new forms can be created by field workers or administrators and send to the phone application while the application is running;

c. *Location Based Tracking:* GPS functionality to track patient movement and to verify and authenticate the data being captured by the healthcare fieldworker.

3 **Information/Communication Channel:** This module is used for communication between the backend server and the frontend clients. A distinct model was created solely for this to cater for interoperability between the different devices communicating with each other.

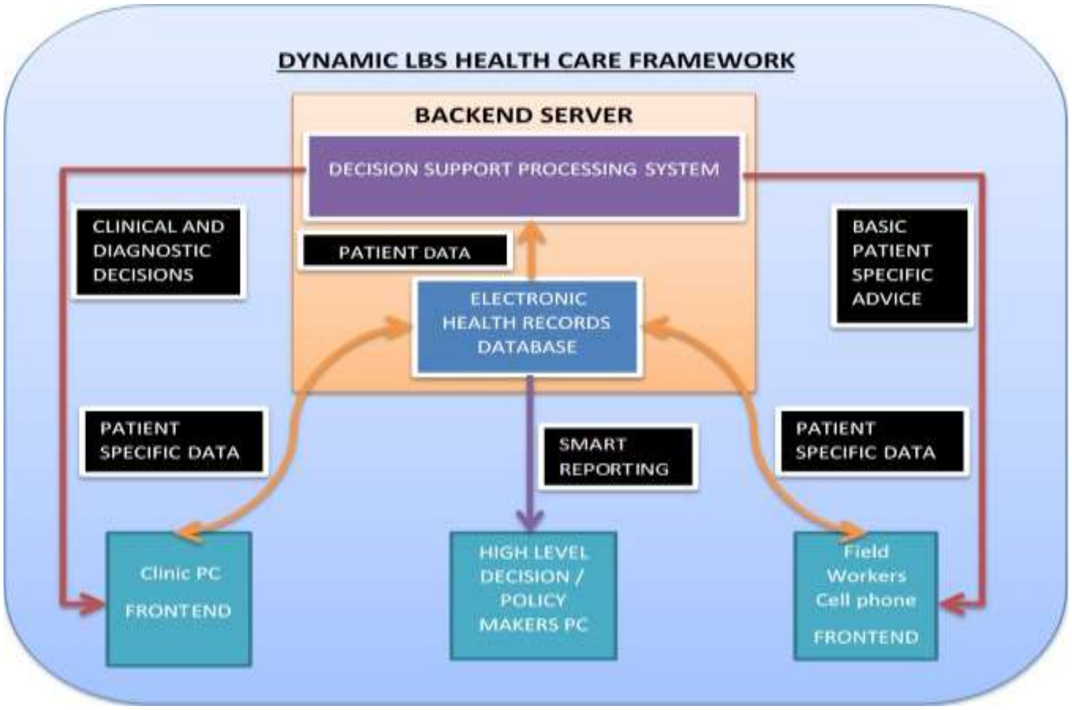

Figure 4: Dynamic LBS Healthcare Framework

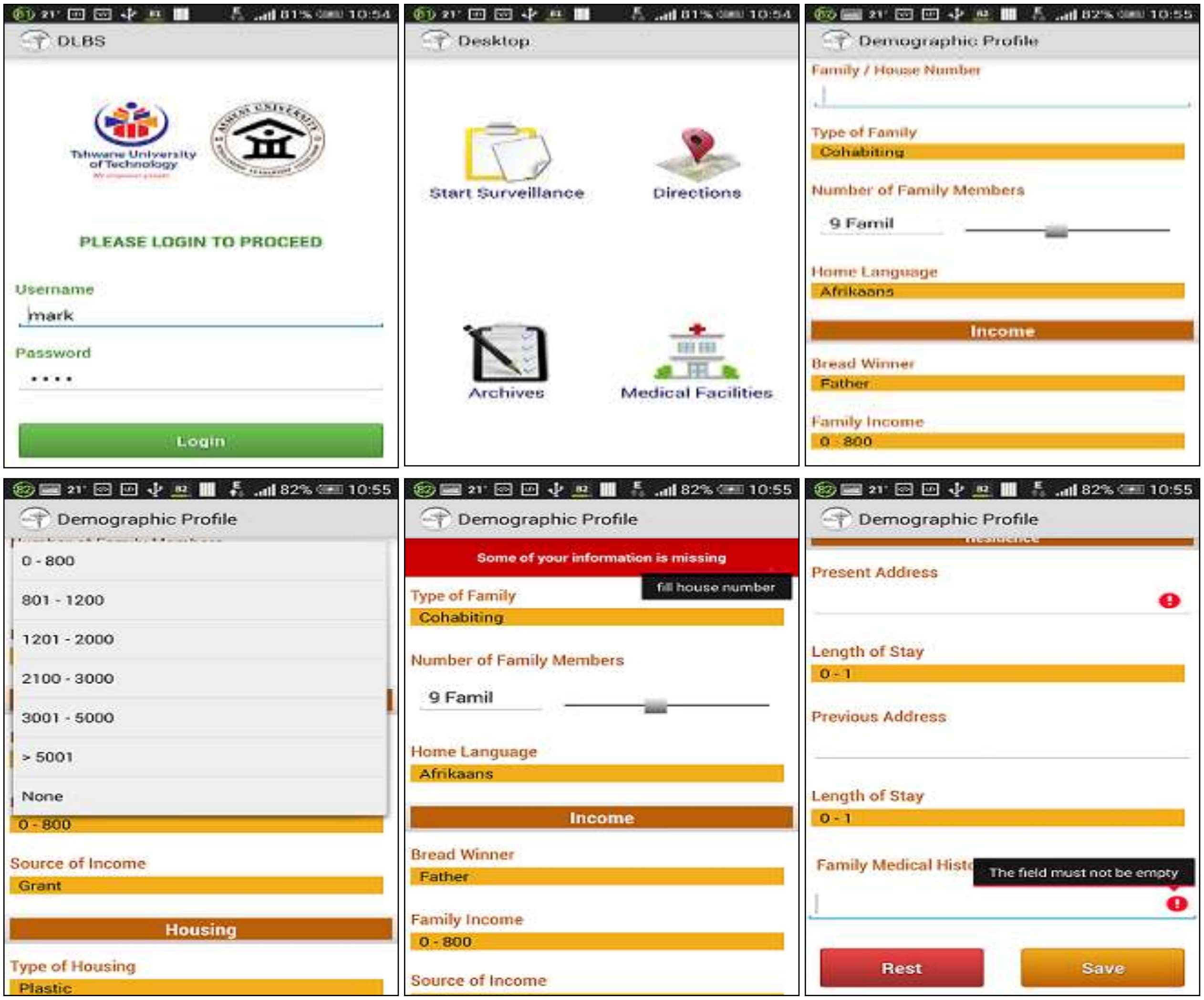

Figure 5: Screenshots of Android Application

Preliminary Testing and Analysis

Preliminary testing was done on several Android devices - ranging from smartphones to tablets all of different makes, screens sizes and prices - with different cell providers. It was noted that the quality of the data capture was dependent on the following factors:

- GPS signal in crowded areas with buildings and trees was obstructed;
- Most of this field work is done in rural areas that have little or no cellphone coverage;
- Battery life of the device;
- Safety of the fieldworkers carrying some of these expensive devices; and
- Extensive training of fieldworkers was required on both the application and the device.

The server for the preliminary testing and analysis is located in the cloud to enable connections from anywhere in the world through a data provider. The database tables and fields were tested by populating it with some test data from the healthcare sector in South Africa.

The mobile phone is connected to the backend system using GPRS connection provided from local wireless service providers. Once the application is launched on the mobile phone the GPS component searches for the GPS signal to get the current position of the field worker. If the GPS signal is found, it will make it available to the directions module. If not found, it searches for a cached GPS position if it does not exist it returns an error message.

We have pilot tested the application at different times of the day at different locations and different cities with users in South Africa. The round trip delay incurred by the GSM/GPRS wireless network was very reasonable and within acceptable limits. The pilot testing was not meant for the usability and acceptance testing prototype, which is the second phase of this research project.

Conclusion and Future Work

This paper describes the development and preliminary testing of a dynamic location-based Healthcare system (DLBHS) for healthcare in Africa. The DLBHS framework was presented and a preliminary testing and analysis of the prototype of DLBHS presented. The next phase of the research project is to test usability and acceptance of the DLBHS.

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