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**Mobile Health Architecture for Health-Care Information Delivery:
Case study: A Breast Cancer awareness mobile application
(PINK RIBBON)**

By

Carolyne Wariara Gakinya (068783)

**A Dissertation submitted in partial fulfilment of the requirements for the
degree of Master of
Science in Mobile Telecommunications and Innovation
(MSc.MTI)**

Faculty of Information Technology

Strathmore University

May 2013

DECLARATION

I certify that this dissertation is my original work and that all material which is not my own work has been duly referenced. I further certify that no material has previously been submitted and approved for the award of a degree by this or any other University.

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This research project report has been submitted for examination with my approval as the University Supervisor.

SIGNED _____ DATE _____

Dr. Joseph Sevilla
Director @iLab Africa
Strathmore University

ABSTRACT

Mounting interest in the field of m-Health—the provision of health-related services via mobile communications—can be traced to the evolution of several interrelated trends. In many parts of the world, including the developed and the developing countries, access to health care is a basic need yet this is not a reality to a large section of the population in these countries. These challenges normally arise as a result of high costs of healthcare, few medical personnel compared to the patients to be served and few medical facilities. In the developing countries, other challenges such as poor infrastructure, poor policy implementation, literacy levels and language barrier are stumbling blocks to access health care services. Yet in these same places, the explosive growth of mobile communications over the past decade offers a new hope for the promotion of quality healthcare. This reliable technology helping to bridge the ‘digital divide’ gap.

There is a growing body of evidence that demonstrates the potential of mobile communications to radically improve healthcare services—even in some of the most remote and resource-poor environments. The research explores the usage of m-Health applications in developing countries especially Kenya as well as the health needs to which m-Health can be applied. It determines the design requirements of an m-Health architecture that can be used both as an informative and educative tool to the masses. This architecture is implemented by analysing, designing and testing a primary m-Health application that can be used to raise awareness about Breast Cancer as well as assist Community Health Workers to educate the general public about other general health related information. In conclusion some key design, business and technical requirements that need to be considered are suggested.

Key words: M-Health, Healthcare Information delivery.

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CHAPTER 1: INTRODUCTION

1.1 Background

In 2000, the global community made a historic commitment to eradicate poverty and improve health and welfare of the world's poorest people within 15 years. The commitment was set forth as the Millennium Declaration (WHO, 2005). Health is at the heart of the millennium Development Goals –recognition that health is central to the global agenda of reducing poverty as well as an important measure of human well-being.

1.1.1 Health Situation in Africa

In the world today, most countries in Africa –which are mainly middle income and especially low-income countries, face a plethora of constraints in their healthcare systems. These countries face a severe lack of human and physical resources, as well as some of the largest burdens of disease, extreme poverty and large population growth rates. Additionally, healthcare access to all reaches of society is generally low in these countries.

It is evident that Healthcare is a huge problem in the developing world and improving health of individuals and communities and strengthening health systems, disease detection and prevention are crucial for poverty reduction and development of any country in these regions, including Kenya.

Kenya's vision for health is to provide "equitable and affordable healthcare at the highest affordable standard" to her citizens (Vision 2030). However the majority of Kenyans still do not have access to affordable health care. Preventable diseases, such as HIV/AIDS, malaria and tuberculosis, as well as road carnage, continue to exact a heavy toll on the population. The next few sections will highlight the health system in Kenya; present a preview of mobile technologies adoption in the country and the potential it presents to strengthen the delivery of healthcare.

1.1.2 Structure of the Kenyan Health Care System

Kenya's health system is pluralistic in nature with widespread public health services, non-governmental (NGOs) services, military health services and the expanding private sector. The Ministry of Health (MoH) operates a nationwide system of facilities and is the largest provider and financier of health care services, accounting for about 52% of the total facilities in the country. In addition to the MoH, Charitable/Mission or NGOs mostly located in rural and under-served areas provide both curative and preventive care. They rely on voluntary donations and user fees while private for profit (private sector) provide specialized curative care and preventive care to those who can afford. The private for profit that also include Pharmaceutical outlets are concentrated in the major towns and cities.

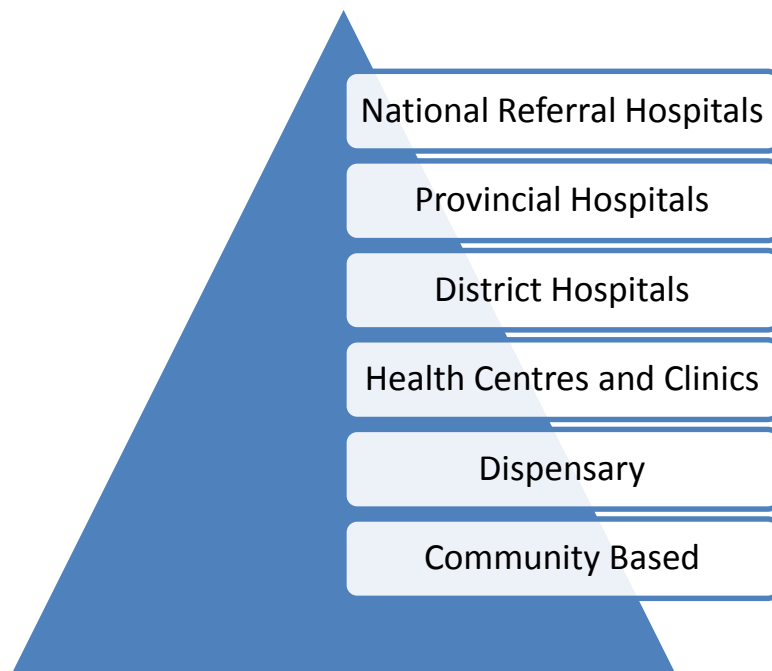


Figure 1.1The Kenyan Health System

The health sector comprises of the public system, with major players including the MOH and parastatal organizations, and the private sector, which includes private for-profit, NGO, and FBO facilities. Health services are provided through a network of over 4,700 health facilities countrywide, with the public sector system accounting for about 51 percent of these facilities. The public health system consists of the following levels of health facilities: national referral hospitals, provincial general hospitals, district hospitals, health centers, and dispensaries.

National referral hospitals are at the apex of the health care system, providing sophisticated diagnostic, therapeutic, and rehabilitative services. The two national referral hospitals are Kenyatta National Hospital in Nairobi and Moi Referral and Teaching Hospital in Eldoret. The equivalent private referral hospitals are Nairobi Hospital and Aga Khan Hospital in Nairobi.

Provincial hospitals act as referral hospitals to their district hospitals. They also provide very specialized care. The provincial level acts as an intermediary between the national central level and the districts. They oversee the implementation of health policy at the district level, maintain quality standards, and coordinate and control all district health activities. Similar private hospitals at the provincial level include Aga Khan Hospitals in Kisumu and Mombasa.

District hospitals concentrate on the delivery of health care services and generate their own expenditure plans and budget requirements based on guidelines from headquarters through the provinces.

The network of health centers provides many of the ambulatory health services. Health centers generally offer preventive and curative services, mostly adapted to local needs. Dispensaries are meant to be the system's first line of contact with patients, but in some areas, health centers or even hospitals are effectively the first points of contact.

Dispensaries provide wider coverage for preventive health measures, which is a primary goal of the health policy. The government health service is supplemented by privately owned and operated hospitals and clinics and faith-based organizations' hospitals and clinics, which together provide between 30 and 40 percent of the hospital beds in Kenya.

Table 1.1: Number of Registered Health Personnel per 100,000 Populations in 2003 and 2004 (MoH, 2005)

Personnel	Number	2003 Number 100,000 population	per Number	2004 Number 100,000 Population	per
Doctors	4813	15	5016	16	
Dentists	772	3	841	3	
Pharmacists	1881	6	2570	8	
Pharmacists and pharmacy technologists	1405	4	1620	5	
Bsc. Nursing	-	-	280	1	
Registered Nurses	9869	33	10210	32	
Enrolled Nurses	30212	100	30562	96	
Clinical Officers	4804	4953	16		
Public Health Officers	1216	4	1314	4	
Public Health Technicians	5627	19	5861	18	
Total	60509	192	63227	198	

1.1.3 Mobile Penetration in Kenya

For a long time Kenya has suffered from the digital divide especially as regards technologies like computers and the Internet. With recent advancements in the technology sector, Kenya ranks third in mobile growth after Nigeria and South Africa among African countries this is according to ITU (2009b). There has been an increasing trend in the growth of the mobile phone market in Kenya. Safaricom, the biggest mobile service provider in Kenya in the second quarter of 2010/2011 recorded an active subscriber population of 17.4 million as at March 2011 (CCK, 2011). According to the Communications Commission of Kenya (CCK) 4th Quarter Sector Statistical Report –April to June 2010/2011, the total number of mobile subscriptions increased from 25.22 million in March 2011 to 25.27 million at the end of June 2011 registering 59,066 new subscriptions, representing a marginal growth of 0.23 percent this translates to 64.2% of the total population.

This reflects year-on-year growth of 25.6 percent during the same quarter, previous year. As illustrated in Table 1.4, new subscriptions grew by 1.04 percent compared to 2.0 percent reported in the previous period, a decline of 0.96 percentage points. Total net addition grew by 0.23 percent

compared to 1.0 percent reported in the previous period. The growth in number of mobile subscriptions is shown in Table 1.2.

Table 1.2 Mobile Subscriptions (CCK-Operators' Returns, 2011)

Subscriber Base	June-11	Mar-11	Dec-10	Sep-10	% change over Mar-11 (3mths)	% change over Dec-10 (6mths)	% change over Sep-10 (9mths)	Annual % change (12mths)
Prepaid Subscriptions	25,048,774	24,993,814	24,756,190	21,819,822	0.02	1.17	14.80	25.63
Post-paid Subscriptions	230,994	226,888	212,701	213,846	1.81	8.60	8.02	27.89
Total Mobile Subscriptions	25,279,768	25,220,702	24,968,891	22,033,668	0.23	1.23	14.7	25.65

It is worth noting that in Kenya, most areas have mobile network coverage. This means that most citizens have access to mobile telephone network regardless of their location.

Nowadays, especially in the developing countries, mobile technology is being embraced to improve the way of life. This trend is slowly gaining momentum as people realize the benefits that accrue from using mobile technology for everyday use. Top on the list are money transfer applications e.g. **M-Pesa*, entertainment, applications, mobile commerce, social networking, gaming and also business process applications.

Despite the fact that technologies like Internet exist, they would really help doctors working in isolated rural villages to access up-to-date medical information and communicate with colleagues in urban areas, and even to diagnose illnesses and treat patients. Yet, these health workers who care for 80 to 90% of the populations still live in rural areas that are at times impassable and have no meaningful access to the Internet. The rapid growth and widespread use of mobile technologies provides the best opportunity to reach these isolated health workers. **M-Pesa –is a mobile money transfer service by Safaricom Limited.*

There is therefore high possibility that m-Health could just as well be the answer to Kenyan health problems and expedite the accomplishment of the MDGs set by WHO. It is however worth noting that most health systems developed are still either technology-driven or adopted without due consideration to local settings. For m-Health to be successful in developing countries such as Kenya, development of m-Health related applications must be done in view of local infrastructure and needs.

Furthermore, since the implementation of m-Health is at its initial stages in Kenya, the high mobile phone penetration in the country presents a very huge opportunity to enable easier and effective access to healthcare services by a large part of the population. This will go a long way in raising awareness about many health care concerns as well as reduce the burden of cost that is mostly limiting when it comes to accessing health care services.

1.2 Problem Statement

Access to healthcare, nutritional information and facilities is a basic need for every human being. However, this is not a reality for many people in developing countries such as Kenya.

The rising health care costs, shortage of medical practitioners, inaccessibility to hospitals, lack of information and a poor ratio of citizens to physicians and nurses is a serious concern in most communities globally. With these facts in mind, it is evident that large portions of the population especially those in the rural and remote areas do not have access to healthcare attention, information and resources.

This research investigates how mobile technology can be used to bridge the gap that exists in health care delivery in Kenya and propose a generic architecture that can be used when developing an m-Health application that will serve both education and awareness purposes.

1.3 Research Objectives

- i) To investigate the use of mobile technology in healthcare delivery in Kenya.
- ii) To propose an m-Health architecture that can be used to develop an m-Health application.

- iii) To develop an m-Health application that can be used to educate and raise awareness on a specific medical condition. The application will address Breast Cancer.
- iv) To test the m-Health architecture.

1.4 Research Questions

- i) What is the usage of mobile technology in healthcare delivery in Kenya?
- ii) What are the design requirements for an m-Health architecture?
- iii) How can the m-Health application be used to educate the masses on a specific medical condition?(the application will address Breast Cancer)
- iv) How can the m-Health architecture be tested?

1.5 Significance of the Research

In a world with severe healthcare resource constraints, mobile digital technology can be a major "force multiplier" (Tsega, 2009). This research sought to empower both patients and medical practitioners to have access to information they needed to make informed decisions about health issues from healthy living habits, to health care provision and monitoring of diseases.

The research further sought to assist the medical practitioners understand m-Health and how it can be used to augment the delivery of healthcare. Though the architecture is developed in the Kenyan context, it is expected that health problems and the infrastructural status cut across other developing countries and as such, they too would be able to borrow from this study.

For university students and researchers, the study provided a basis to which further research and work can be carried out. Therefore when the architecture was implemented, it had the capacity to improve accessibility to healthcare information primarily to the patients and then assist healthcare providers to get feedback from patients. The architecture was tested by implementing a mobile application that was used as an information tool to raise awareness on Breast Cancer.

1.6 Scope and Limitations

The medical field is wide and as such it is also expected that the applications of technology in such a field will also be broad and varying. This study was limited to developing an m-Health architecture that was used to provide health care information. In this case, a case study was done based on Pink Ribbon which is a Breast Cancer awareness mobile application.

The application was done in English yet the target of such m-Health applications in developing countries like Kenya may be illiterate and the use of a local language would be preferred. At the same time, this study did not include the determination of literacy levels of the individuals who use mobile applications and what impact it would have on the adoption and acceptance of m-Health applications. Another aspect that the research did not include is the Technological awareness of the individuals who use mobile devices.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

As the first decade of the 21st century draws to a close, leaders in many developing countries can point with pride to tremendous strides made in their efforts to improve the lives of their citizens. In many parts of the world, citizens in emerging economies have begun to taste the fruits of higher incomes and greater access to tools that promise to increase their quality of life and that of their children. Yet formidable obstacles remain. Health challenges present arguably the most significant barrier to sustainable global development. Disease and the lack of adequate preventative care take a significant toll on both developing populations, measurable in disability-adjusted life years (DALYs), and economies. Despite the broad economic advances of this decade, the 2008 UN report on progress toward meeting the Millennium Development Goals (MDGs) indicates continuing dire conditions in crucial public health areas.

For example

- i) A child born in a developing country is over 33 times more likely to die within the first five years of life than a child born in an industrialized country, even though the leading causes of deaths (pneumonia, diarrhea, malaria, and measles) are preventable through basic services and vaccinations.
- ii) An estimated 2.5 million people were newly infected with HIV in 2007.

Communicable, and entirely avoidable, diseases such as tuberculosis (TB) and malaria continue to claim lives due to preventable factors such as lack of access to proper drugs, bed nets, medical treatment and information (World Health Organization, 2011).

The ability of developing countries to overcome these serious health challenges is hindered by several core obstacles, among them a global shortage of healthcare workers. According to the WHO, among 57 countries, mostly in the developing world, there was a critical shortfall in healthcare workers, representing a total deficit of 2.4 million healthcare workers worldwide (World Health Organization, 2009).

This human resources constraint intensifies the already increasing pressure on developing-world health systems. Not only must they cope with the burden of containing the spread of communicable

diseases associated with extreme poverty, they must also contend with the growing incidence of chronic diseases, such as diabetes and heart disease, an effect of new-found (relative) affluence. Governments, businesses, NGOs, foundations, and multilateral organizations all recognize the importance of leveraging new tools and solutions to address these distinct but interrelated health challenges.

2.2 Understanding M-Health

M-Health is a sub segment of e-Health. E-Health is defined as the use of information and communication technology (ICT)—such as computers, mobile phones, and satellite communications—for health services and information while m-Health is defined as the use of mobile communications—such as PDAs (Personal Digital Assistant) and mobile phones—for health services and information. (Istepanian et al., 2009). M-Health and e-Health are inextricably linked this is because both are used to improve health outcomes and their technologies work in conjunction. For example, many e-Health initiatives involve digitizing patient records and creating an electronic ‘backbone’ that ideally will standardize access to patient data within a national system. M-Health programs can serve as the access point for entering patient data into national health information systems, and as remote information tools that provide information to healthcare clinics, home providers, and health workers in the field.

The concept of m-Health represents the evolution of ‘traditional’ health systems from desktop platforms and wired connections to the use of more compact devices and wireless connections in e-health systems. The emerging development of m-Health systems in the last decade has been made possible due to the recent advances in wireless and network technologies and ubiquitous computing systems (Kyriacou et al., 2006). Thus m-Health could be identified as a subset of e-health as shown in Figure 2.1.

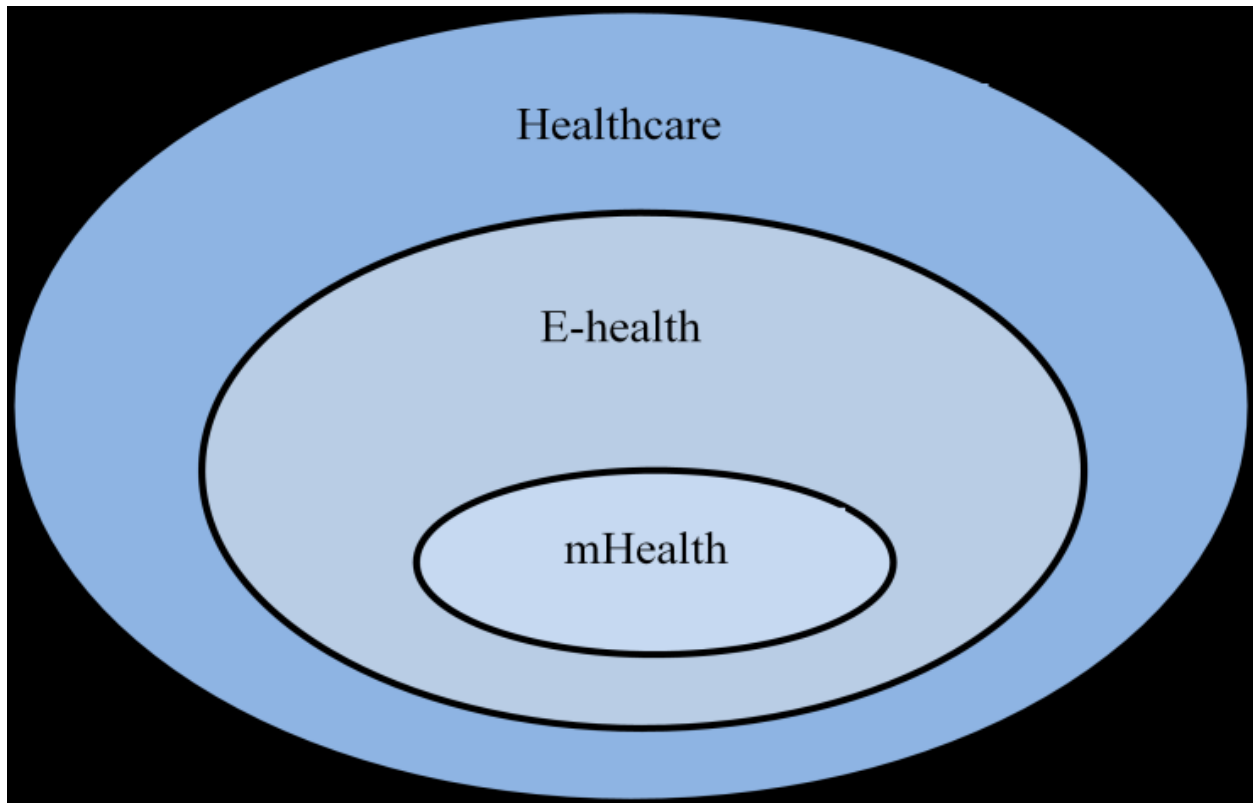


Figure 2. 1 Defining M-Health in E-Health Context (Odongo, 2010)

According to Istepanian et al., 2009, the advances in the mobile technologies will soon prove to have a powerful impact on the way different health care delivery organizations will reshape the future of these services globally by utilizing such emerging technologies for the enhancement of future healthcare services. This is currently true as m-Health is currently redefining the original concept of telemedicine as “medicine practiced at a distance” to include the new mobility and “invisible communication technologies” to reshape the future structure of global healthcare systems.

2.3 Mobile Technologies

2.3.1 Mobile Devices

A mobile device is a pint-sized computing device. Mobile phones have a number of features in common, although manufacturers also try to differentiate their own products by implementing additional functions to make them more attractive to consumers. This has led to great innovation in mobile phone development in the recent past.

The common components found on all phones are:

- A battery, providing the power source for the phone functions.
- An input mechanism to allow the user to interact with the phone. The most common input mechanism is a keypad, but touch screens are also found in some high-end Smartphones.
- Basic mobile phone services to allow users to make calls and send text messages.
- All GSM phones use a SIM card to allow an account to be swapped among devices. Some CDMA devices also have a similar card called a R-UIM.
- Individual GSM, WCDMA, iDEN and some satellite phone devices are uniquely identified by an International Mobile Equipment Identity (IMEI) number.

Low-end mobile phones are often referred to as feature phones, and offer basic telephony. Handsets with more advanced computing ability through the use of native software applications became known as Smartphones.

2.3.2 Advantages of Mobile Devices

Below are several advantages of mobile devices.

2.3.2.1 Low acquisition and recurring cost

Mobile devices range from very low cost equipment to high end equipment. For most applications of m-Health, low cost devices can be used. The cost of acquiring is also relatively low.

Moreover, the cost of voice communication over the mobile phone in Kenya has become more and more affordable to the consumer because of the stiff competition among competitors.

2.3.2.2 Ease of use

Mobile phones are easy to operate. This makes a mobile device to be the most appropriate medium to introduce technology to users who are not computer savvy. Applications such as m-Health systems can be made to make use of the basic mobile phone features, thus making the experience easy and more helpful to the user.

2.3.2.3 High mobile penetration in developing world

The adoption of mobile technology in the developing world is much greater than that of PC's (Personal Computers). This is mostly due to its efficiencies. For example, Kenya recorded a mobile phone penetration of 51% in the first quarter of 2011 (CCK, 2011). With the high availability of mobile devices in households, the technology can be used to render other services to the user such as information about health care.

2.3.2.4 Real- time interaction

Mobile devices provide an environment for real-time interaction either between a number of systems, people or mobile devices. This ensures a more effective way of delivery and acquisition of information, a key requirement in efficient m-Health applications.

2.3.4 Challenges of Using Mobile Devices

2.3.4.1 Affordability to a large number of the population

Even though the mobile phone penetration all over the world has grown tremendously in the recent past, there is still a large population which cannot afford to own a mobile phone, or any other mobile device that can be used for accessing health care information.

In some cases, the cost of recharging as well as topping up a mobile phone is very high, thus discouraging people from purchasing them. Evrard and Moaligou (2011) observed that situations where the cost of owning a mobile phone is very high are typical in developing markets that have limited competition between operators, e.g. in Africa and South America. This results in high prices and lack of innovation.

2.3.4.2 Social barriers to penetration

Besides the cost barrier of the penetration of mobile technology in the developing world, other barriers e.g. social factors are still imminent in some markets. A research done by Evrard and Moaligou (2009) revealed that in parts of India, Pakistan and Nigeria, social rather than economic barriers were slowing down the adoption of mobile handsets, especially by women.

2.3.4.3 Poor network coverage and failure

In most developing countries, poor network is imminent especially in the rural areas. Most mobile operators concentrate on the densely populated urban areas before deploying good quality network coverage in the rural areas. Consequently, most geographical areas may experience poor network coverage of the GSM network, which may inhibit the implementation of mobile applications.

2.4 Application of Mobile Technology in Health

In the world today, a number of initiatives have been started to address the different health needs that are evident in different societies. To this end, a growing number of developing countries are using mobile technology to address these health needs. The m-Health field is remarkably dynamic, and the range of applications being designed is constantly expanding. The key applications for m-Health in developing countries are education and awareness, remote data collection, remote monitoring, communication and training for healthcare workers, disease and epidemic outbreak tracking, diagnostic and treatment support (Vital Wave Consulting, 2011)

Figure 2.2 illustrates the typical use of mobile devices in the health sector in different parts of the world.

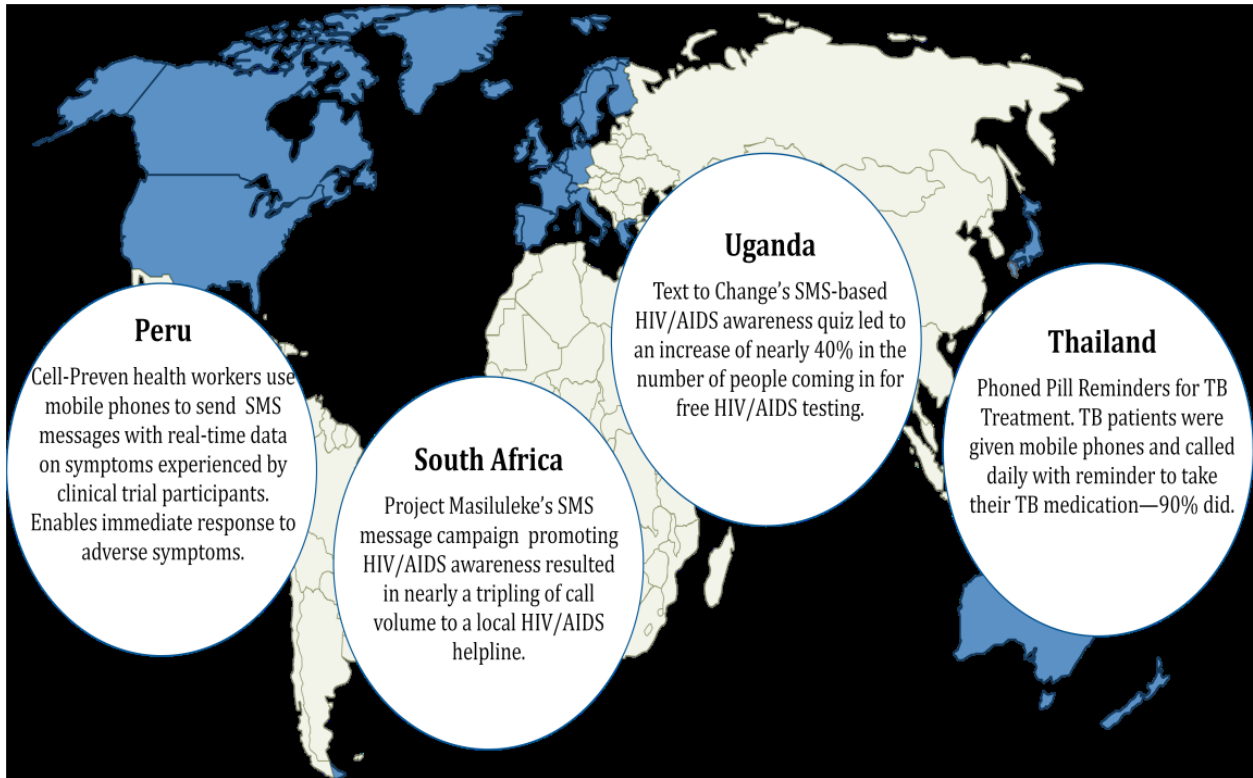


Figure 2.2 M-Health Applications in Developing Countries (Vital Wave Consulting, 2011)

The following section describes the major m-Health applications in developing countries and provides examples of projects where the application has been put into action.

2.4.1 Education and Awareness

In South Africa, Project Masiluleke was used to provide a ‘please call me’ free text messaging service. The objective was to build awareness of HIV status, encourage HIV/AIDS testing and treatment and halt the disease’s spread. Messages were written and sent in local languages, and used to direct recipients to the National AIDS Helpline. According to the project “By capitalizing on the ubiquity of mobile devices in even the most resource constrained areas, this project has the potential to revolutionize the public health response to HIV/AIDS in South Africa and other parts of the globe” (Vital Wave Consulting, 2011) .

Apart from Project Masiluleke researchers have developed “Cell-Life” - a novel application for mobile phone technology that helps health workers monitor HIV patients cheaply and efficiently (Khan Tamar, 2004).

The Cell-Life project uses software that lets clinic workers use their mobile phones to monitor patients’ treatment and spot health problems before they become life threatening. The phones are equipped with a special menu that allows the counsellors to record data on a patient’s symptoms and whether they are sticking to drug regime as well as other factors that might affect their health- such as a lack of money for transport or a shortage of food. The data is transferred to a central database which clinic staff can access over a secure Internet connection. HIV/AIDS is one of the pandemics that unfortunately continues to receive high stigma in developing countries and one of the causes of increased mortality rates in Kenya making it on top of the list of the health related MDGs. It is also an area where it is believed that leapfrog technologies such as mobile communications will have a great impact in developing countries in providing home based care and support (UNCTAD, 2007).

“Text to Change” was implemented in Uganda and it was geared at improving HIV/AIDS education and encouraging counselling and testing while maintaining anonymity. This was carried out as a pilot study where 15,000 users were each sent an SMS-based multiple choice interactive quiz in exchange for free airtime. Correct answers were provided for the quiz. A 40% increase was recorded in the number of patients who came for HIV/AIDS testing (Vital Wave Consulting, 2009). As seen in Scott and Batchelor (2004), mobile phones can be used as health education tools using push and pull technology where people can be educated about different health factors and diseases such as HIV/AIDS. According to Vital Wave Consulting (2009), the ubiquity and low cost of SMS messages hold the potential to shift the paradigm for health education by communicating with people in an accessible, engaging manner that both respects their privacy and gives them the tools to make informed choices.

2.4.2 Remote Data Collection

Data collection is another crucial component of public health programs. Policymakers and health providers at the national, district, and community level need accurate data in order to gauge the

effectiveness of existing policies and programs and to shape new ones. In the developing world, collecting field information is particularly important since many segments of the population are rarely able to visit a hospital, even in the case of severe illness. Gathering data where patients live is vital, and information should ideally be updated and accessible on a real-time basis. The data collection process is more efficient and reliable if conducted via smart phones, PDAs, or mobile phones rather than paper-based surveys that must be submitted in person and manually entered into the central health database. Data collection programs have been deployed in multiple developing world countries, mainly as pilot projects. The most successful programs are scaling up and beginning to be deployed in multiple countries or regions. These initiatives are closing the information gap that currently exists for patient data in the developing world, enabling public officials to gauge the effectiveness of healthcare programs, allocate resources more efficiently, and adjust programs and policies accordingly. (Vodafone foundation, 2011).

An example of an area where mobile phones have been used as a tool for data collection is in Thailand whereby TB patients were given mobile phones so that healthcare workers (who are former TB patients) could call these patients on a daily basis to remind them to take their medication. Medicine compliance rates reached 90% due to the introduction of this remote monitoring application.

2.4.3 Communication and Training for Healthcare Workers

An acute shortage of healthcare workers is a major challenge facing developing country health sectors. Training new cadres of health professionals and empowering current workers in order to increase job satisfaction and reduce attrition are essential to meeting human capital needs. Connecting health workers with sources of information via mobile technology is a strong basis for empowerment, as it provides the support they need to perform their functions effectively and self-sufficiently. There is also a pressing need to improve communication among different health units to facilitate more efficient patient care. Due to the reduction of landline phones and Internet-enabled computers, it is not uncommon, for example, for a patient to be sent to the regional hospital by the local clinic, only to find that there is no bed available. Mobile phones can help bridge these communications gaps that in the health context can often mean the difference between lives lost and lives saved (Vodafone Foundation, 2009).

2.4.3.1 Education and Training of Health Workers in Kenya.

In Kenya, the Africa Medical Research Foundation (AMREF) has developed an innovative eLearning Programme that has been used to train and upgrade health workers. AMREF has been involved in training of human resources for health as its core operation since 1962. To date, AMREF has trained over 500,000 health workers and reaches nearly 60 million people in Africa. With close to 50 years of health development in Africa, AMREF is now using modern technology to revolutionize the skilling and up scaling of health workers in Africa to help alleviate the critical need for health workers on the continent. A key challenge to introducing eLearning in Africa has been lack information to provide guidance on costs, logistics, policies and implementation (Mbindyo C, 2009).

AMREF has also set-up a Virtual Nursing School (AVNS), which is used as a laboratory for researching into and testing eLearning best practices as a method for training health workers in Kenya and Africa as a whole.

2.4.3.2 Amader Gram Breast Care -India

In India, doctors with the International Research Foundation in the University of Toronto have partnered with a Bangladeshi NGO to create Amader Gram Breast Care -whose mission is to reduce the suffering and death by Breast Cancer in Khulna Division (population 15,000,000). Their mission is the creation of sustainable social businesses with innovative and cost effective interventions. Amader Gram Breast Care is a web-based electronic record system. It is the first resource evidence based guideline for cancer treatment in the country. The reason for developing this system is because 80% of the patients in Khulna, India who are aware that they are have Breast related complications, delay seeking help or a Doctor's opinion. They describe complex barriers like poverty, gender bias; stigma and a generally believe that Breast Cancer is death sentence as reasons for not seeking medical attention.

Building on the wide spread availability of inexpensive mobile phones in the developing country, a mobile health application was developed mPower Health (a local start-up in India) to counter this problem. The m-Health application developed is an inexpensive system which would help

Community Health Workers to identify, refer and track Breast Cancer patients using the mobile phone application. Community Health workers can be able to use the mobile application to determine the seriousness of a breast problem and therefore advice the patient to visit the centre for further evaluation. The initiative is to encourage as many patients to come for assessment and adhere to treatment and follow up (International Breast Cancer Research Foundation, 2008)

2.4.3.2 Impact of Amader Gram Breast Care

This initiative has yielded many benefits which include; increased cases of early detection of breast cancer, awareness to the general public about Cancer and how the public can best prevent or manage it. The Community Health Workers provide advice and follow-up to the patients on the ground while the doctors receive updated information and they are able to keep track of the progress of different patients. Another benefit of Amader Gram Breast Care mobile Application that it is available in the local language. This makes it easier to use by the local Community Health Workers as well as widen the area of coverage to the remote rural areas.

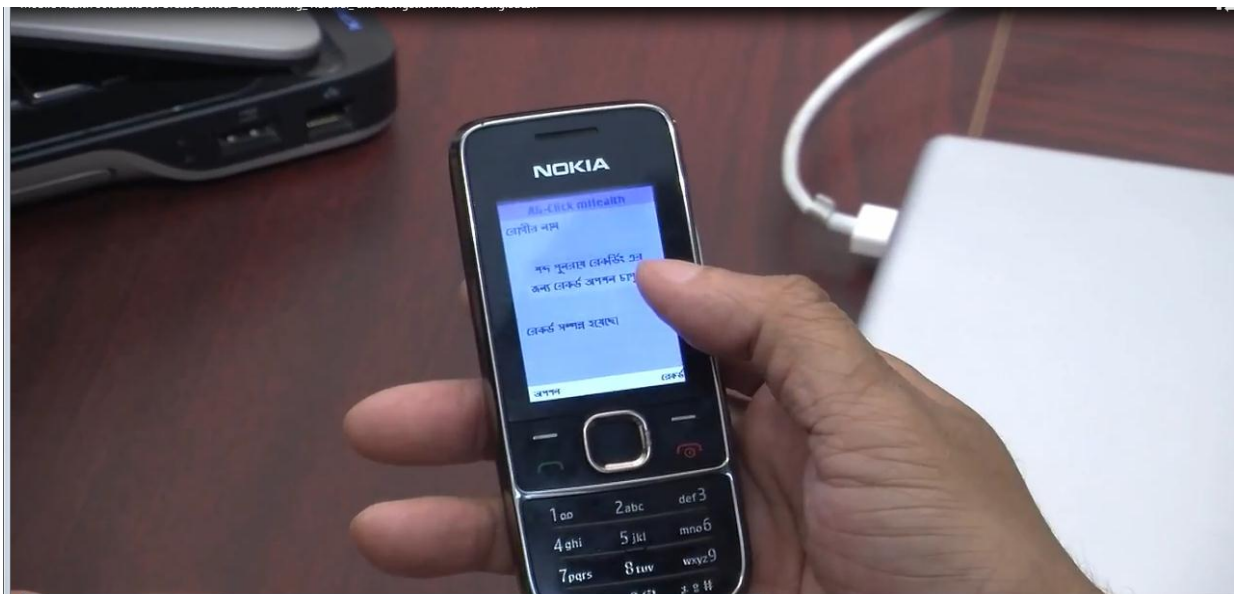


Figure 2.3 Amader Gram Breast Care Mobile Application (Mobile Health Solutions, 2011)

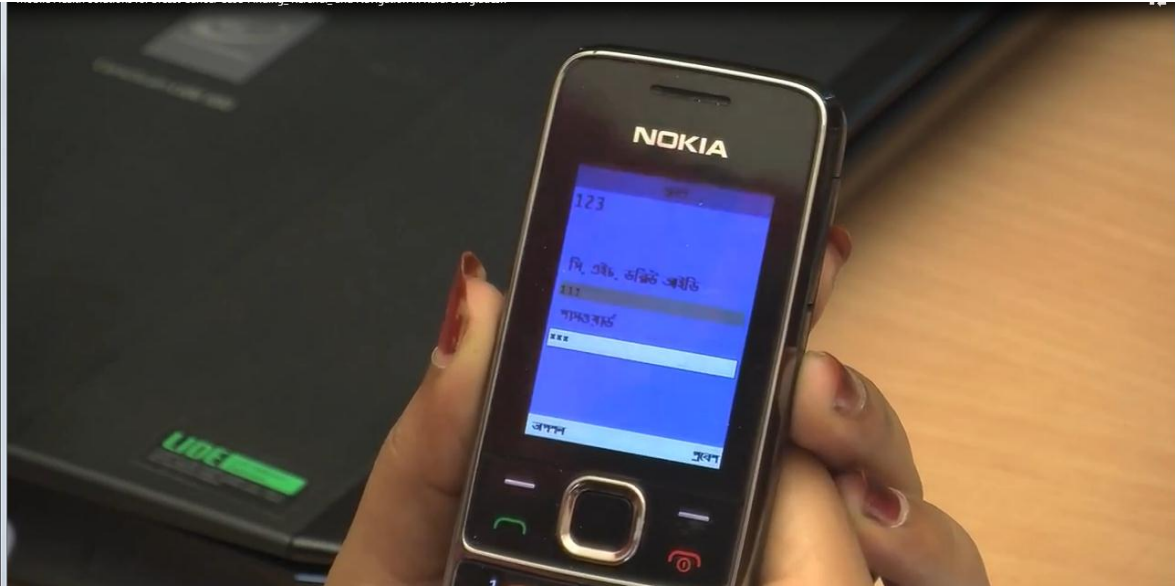


Figure 2.4 A Community Health Worker Inputting Information (Mobile Health Solutions, 2011)



Figure 2.5 Community Health Worker Taking Patient Information (Mobile Health Solutions, 2011)

2.4.4 Disease and Epidemic Outbreak Tracking

More often than not, most disease and epidemic outbreaks are as a result of delayed action from the time initial signs are noticed to the time action is actually taken. In developing countries like Kenya, this is mostly because of the time consuming data collection process which is mostly paper

based. Hence, most outbreaks of communicable diseases often begin small and when left undetected, can develop into epidemics. Disease and epidemic outbreak tracking m-Health applications are being used in Peru (Figure 2.2), Rwanda, and India as an early warning system, allowing public health officials to monitor the spread of infectious diseases. Deployment of mobile devices, with their ability to quickly capture and transmit data on disease incidence, can be decisive in the prevention and containment of outbreaks. (Vodafone Foundation, 2009).

Example of Disease and Epidemic Outbreak Systems

Acute Encephalitis Syndrome Surveillance Information System (AESSIMS)

In India, through a partnership between Voxiva – a Program for Appropriate Technology in Health (PATH) and the Government of Andhra Pradesh, a project named Acute Encephalitis Syndrome Surveillance Information System (AESSIMS) was developed to help contain the Japanese Encephalitis which is a devastating mosquito-borne illness that can be prevented by a vaccination. The vaccination is not always administered due to its high cost and a lack of data on the disease's true prevalence and impact.

To begin to tackle this problem, the Government of Andhra Pradesh, where the disease is endemic, pilot tested an Acute Encephalitis Syndrome Surveillance Information Management System (AESSIMS) in one of its districts. Local health workers used mobile phones (or web-based technologies) to report incidences of the disease to the AESSIMS system. Decision makers could access and analyze this data in real time via a variety of tools, including GIS-based maps.

It was envisioned that if the pilot test were a success, the AESSIMS system could be rolled out across India and into other Asian countries. However the Project was not scaled up nor extended. (Vital Wave Consulting, 2009).

2.4.5 Diagnostics Treatment and Support

M-Health applications in this area are designed to provide diagnosis and treatment advice to remote healthcare workers through wireless access to medical information databases or medical staff. With m-Health-enabled diagnostics and treatment support, patients are able to receive treatment in their villages and homes, averting the need for expensive hospital visits, which are beyond reach for many. Diagnostic and treatment applications use the phone as a point-of-care

device. Health workers' phones are typically equipped with specialized tools, such as built-in software that leads the worker through a step-by-step diagnostic process. Once data are entered into the system (typically symptoms and an image of a patient's injury captured on the mobile phone), remote medical professionals can diagnose the illness and prescribe treatment. By eliminating the need for patient travel, these applications have the potential to dramatically increase access to health care (Vital Wave Consulting, 2009).

Example of Diagnostics Treatment and Support Systems

a) Cell Phone Applications for Clinical Diagnostic Therapeutic and Public Health Use by Front Line Healthcare Workers

This project was implemented in Mozambique in March 2008 as a series of pilot programs. This is because Mozambique has extensive cellular network coverage and a high percentage of health workers who own mobile phones. This project, supported by Microsoft Research, was aimed at taking advantage of Mozambique's 'wired' reality. The project principals, researchers from the University of Melbourne, created a suite of applications that can run on standard mobile phones. The applications provide Mozambican health workers with diagnostic and analytical tools including reference material in the phone's memory, a calculator for determining drug dosage, and a program for analyzing inputs from medical sensors (e.g., low-cost pulse oximeter probes or a simple electrocardiogram).

-An Oximeter is an instrument for measuring the oxygen in arterial blood whereas an electrocardiogram is a graphical recording of the cardiac cycle produced by an electrocardiograph. It is used to diagnose cardiac dis-orders.

b) Digital Inclusion Kit in Health and Higher Education (DIKHAE)

This is another project developed in the Diagnostic Treatment and Support section in Argentina through partnership between the University of Buenos Aires, Fundapers (an Argentinean NGO) and the Microsoft Research Digital Inclusion Program. Patients in marginalized areas in both urban and rural Argentina lack access to specialized medical centres, which are often the only sites where vital diagnostic tools are available. Researchers at the University of Buenos Aires are creating a Digital Inclusion Kit in Health and Higher Education (DIKHAE), which will allow Smartphones to wirelessly connect to diagnostic tools like electrocardiograms, enabling sophisticated diagnoses

to be conducted remotely. The test results can be stored on the Smartphone until it is in range of a cellular signal, and then uploaded to a patient records system. A pilot conducted in 2006 received high marks from medical professionals for the system's usability. Project sponsors also envision that the DIKHAE will be able to connect to X-ray, MRI, and other tools in the future.

2.5 M-Health Usage in Kenya

In the recent past, Kenya has recorded some usage of mobile devices in the public health sector in the past few years. The uses of mobile technology in health are discussed in this section.

2.5.1. Epi-Surveyor

Epi-Surveyor, an open-source tool designed for data collection was used in 2006 on PDAs by Kenyan health workers to evaluate the emergency polio vaccination campaign that resulted from refugees fleeing violence in Somalia. The tool was used for generating real-time results that showed where follow-up efforts were still needed and where children had been left unvaccinated (BBC, 2009; CIO, 2009; Vital Wave Consulting, 2009b). EpiSurveyor was used to control supplies and monitor which areas needed to be vaccinated. According to one of the health workers, "... the quick flow of information helped us in achieving very good results".

2.5.2. Household Morbidity Surveillance Study-Disease Surveillance

In disease surveillance, Centre for Disease Control (CDC) established collaboration with Carolina for Kibera (CFK), a non-profit organization run by the University of North Carolina. In partnership with CFK, the CDC launched a Household Morbidity Surveillance Study (Njuguna HN et al, 2013) to identify the sources and burden of various diseases affecting a section of Kibera slum dwellers. The interviewers were equipped with PDA's (Porta Digital Assistant) which were loaded with an electronic survey. They used the devices to collect, store, and transfer and enter data, hence improving the previously demanding task when the same was done using paper forms. According to one of the project coordinators, the use of PDAs to perform epidemiology and surveillance in Kibera was "an amazing discovery" as this improved efficiency and data integrity leaves the future of scientific research in rural Africa bright. To tap on the growth of mobile phones, the CDC and the MoH also launched a second project exploring text messaging as a means of conducting disease

surveillance and health communication. The objective of this was to work to design an automated system that would use short message service (SMS) for surveillance of disease, outbreak updates and alerts, training, and delivering health messages to the public. This was to be implemented using the case of Avian Flu. This project is not recorded as complete.

2.5.3. The Mobile Map of Medicine for Kijabe Hospital

In 2006, the Kijabe Hospital in collaboration with UK National Health Service (NHS) and Cisco's Internet Business Solutions Group (IBSG) worked on a joint program to help address the problem faced by doctors in rural areas having to treat patients with little or no information about resources in neighbouring areas and this according to (Vital Wave Consulting, 2009), impeded the doctors from providing optimum care. The project gave Kenyan health workers at Kijabe Hospital access to the Map of Medicine, a medical information database. Doctors participating in the pilot study were given PDAs and access to data on HIV/AIDS, TB, malaria, abdominal pain, diarrhoea, and typhoid fever. Results were promising and hospital staff reported that the data access and entry via the PDAs led to greater efficiency, more time with patients, and reduced administrative costs. (Mobile Map of Medicine pilot studies, 2007)

2.6 Impact of M-Health Projects

Formal studies and preliminary project assessments—in both the developed and developing world—demonstrate that mobile technology improves the efficiency of healthcare delivery, and ultimately makes healthcare more effective. The long-term goal, and expectation, is that m-Health programs will have a demonstrable and significant positive impact on clinical outcomes such as reduced infant mortality, longer life spans, and decreased contraction of disease. (Vital Wave Consulting 2009).

2.6.1 Some Benefits of m-Health

- i) Improved compliance with treatment regimes: A 2007 Thai study showed that TB patients who received daily text message medication reminders jumped to over 90% adherence. A device called SIMpill that uses mobile technology to monitor and direct medication adherence also proved effective.

- ii) Improved public awareness outcomes: In South Africa, Project Masiluleke, which promotes an AIDS hotline through SMS messages, resulted in a 350% increase in phone calls to the hotline.
- iii) Improved disease management: A recent United States study on the use of wireless-enabled PDAs by Type 2 diabetes patients found greater improvements in blood sugar indicators among regular users than among less frequent users (Vital Wave Consulting, 2009). This has resulted in a general improvement of patient health.

2.7 Existing Mobile Application Architectures

2.7.1 Mobile Agent Platform

This mobile agent based framework is designed for mobile ubiquitous applications (Lee, 2010). This framework is made up of hierarchy management for multi-layered mobile agent, coordination management and event notification. It provides a life cycle of mobile agent as well as access control to various resources of a system.

One of the major features of this model is a shared object and access control. In this case, mobile ubiquitous agents can access common objects with hierarchical role based coordination and access rights. These are controlled by the common object and access control manager. The manager defines objects which will be used in ubiquitous applications as object group unit based on role in the group.

A working agent group in this model is able to register a group as well as register and delete objects dynamically. The model also contains a communication manager which provides a communication channel among agents using a multicasting method. This is made up of a local communication which aids in communication among mobile agents and an event distributor which manages communication in the local communicator. Figure 2.6 shows the model's communication manager, indicating the flow of information between the event distributor and the agents.

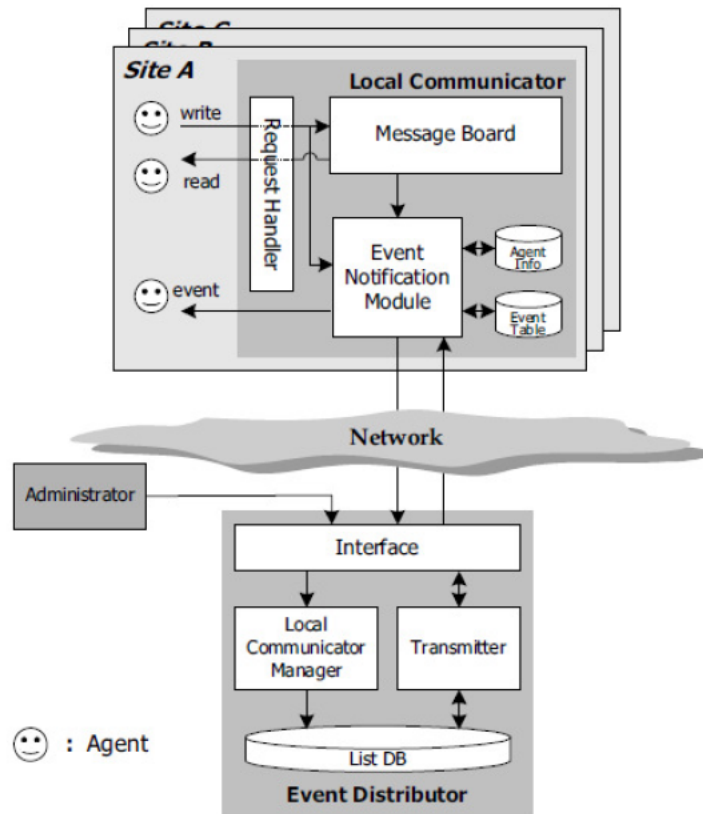


Figure 2.6 Communication Manager (Lee, 2010)

The event notification module assists in receiving events to and from the event distributor. This module supports the synchronized communication while the message board supports asynchronous communication. The request handler is an interface that allows the agent to communicate with the local communicator. However, if the agent wants to communicate with other agents using asynchronous methods, the message board is employed. Several implementations of this model have been done to validate it and test its usefulness in the development of mobile applications. One such example is shown on Figure 2.7. The model was used to create a simple information searching system.

To validate the model using the information searching system, the system underwent tests on registration of events, provision of a proper multicasting and also reliability in providing asynchronous communication.

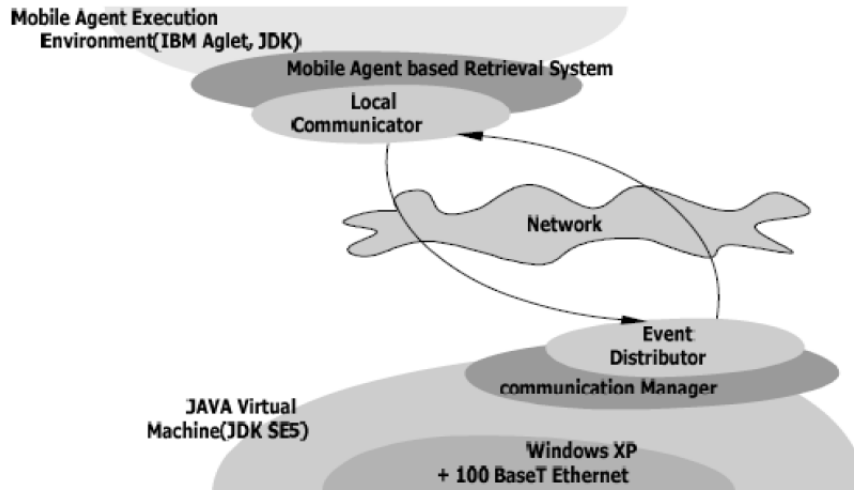


Figure 2.7 Information Searching System (Lee, 2010)

The mobile agent based retrieval system above is composed of five mobile application modules. The first gets information from the environment, so that it can send a message to the second module to start a task. The second module requests the third module to gather context information, while the fourth and fifth modules are used for transmission of information across the network.

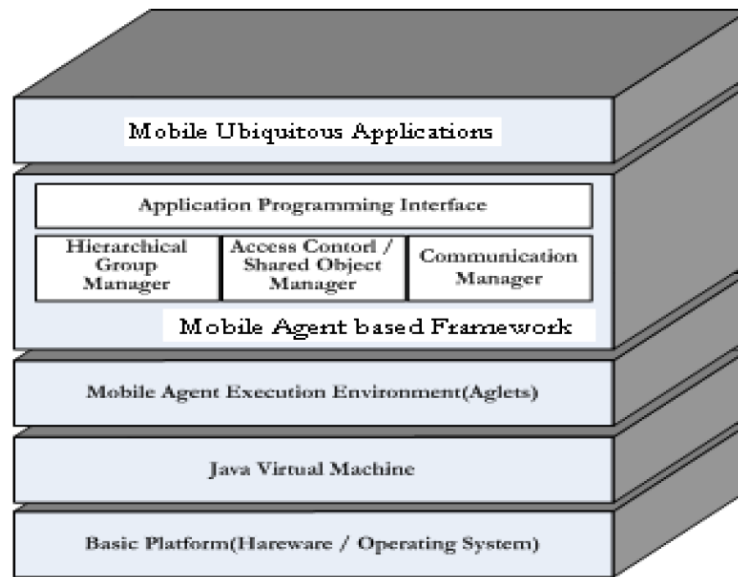


Figure 2.8 Overview of Mobile Platform Agent (Lee, 2010)

The mobile agent platform provides a lifecycle (Creation / Interpretation / Execution / Destruction) of a mobile agent.

This platform is then extended to perform a co-ordination of mobile ubiquitous applications. In this platform, a mobile ubiquitous agent can access objects with a hierarchical role based coordination model as shown in Figure 2.8

2.7.2 Mobile Applications Development Framework (MADF)

Unhelkar and Murugesan (2010) developed a framework to be used for enterprise mobile applications. This framework is meant to provide a systematic and comprehensive solution to mobile applications development and maintenance. Figure 2.9 shows the MADF architecture.

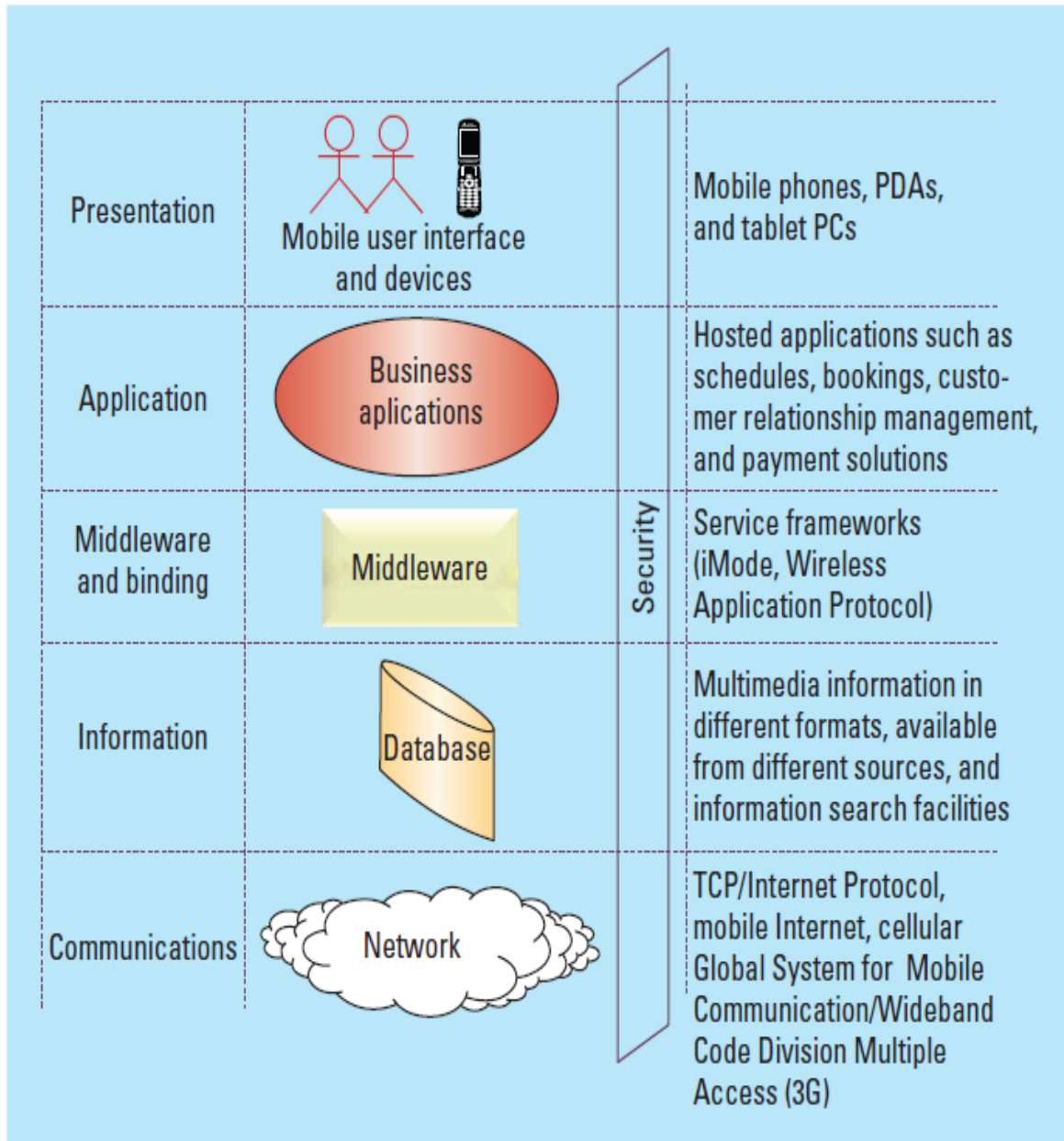


Figure 2.9 The Enterprise Mobile Applications Development Framework (Unhelkar & Murugesan, 2010).

According to Unhelkar and Murugesan (2010), the MADF framework brings together elements of software architecture and design and the required supporting communication infrastructure (network and protocols) and different types of information accessed across multiple sources.

MADF considers the usage of communication infrastructure e.g. TCP and IP protocol, WAP, PAN and also MANs. Depending on the range of communication, the model also suggests the usage of mobile telecommunication standards (2G, 2.5G, 3G or 4G), Bluetooth and also Wireless VoIP technologies. Mobile application developers can use the MADF framework to model and incorporate the application's execution location, interface for third party deployments and security interfaces. This relates to the fact that networks and communication capabilities directly affect a mobile application's QoS.

The MADF model requires the programmer to implement security measures in all the layers of the model. This is due to the vulnerability of attacks in mobile and wireless networks. In case of lack of security measures, data within the enterprise model may be tampered with, stolen or maliciously removed. There are various ways that security can be implemented in any of the MADF layers. Some of the methods include cryptography, encryption, authentication measures and using secure communication protocols.

CHAPTER 3: RESEARCH METHODOLOGY

The research methodology section will mainly consist of the following key aspects. These are:

- The research design
- The target and sample population
- Methods of Data Collection

3.1. Research Design

This research seeks to determine the usage of mobile health applications in Kenya, as well as determining the best design requirements for mobile health architecture. Since the Health Industry is very broad, this study focused on designing a mobile health architecture that was used to provide health care information to patients. It is mostly important to people who require information to assist them in managing a given medical condition in terms of nutrition, medical check-ups, conducting self-examinations, adherence to drugs and many more.

The architecture involves various stakeholders. Breast Cancer awareness was used as a case study for this research. The resulting architecture was used to provide health care information for various diseases. It was also made to be extensible to accommodate any other stakeholders who directly or indirectly play a role in the health industry.

A research questionnaire was designed to produce results that would be helpful in coming up with the mobile health architecture that would assist patients, the Community Health Officers, as well as medical practitioners. Through the questionnaire, the answers given by the respondents were crucial in determining the components of the architecture as well as the technology that would be used in implementing the mobile application.

3.2 Methods of Data Collection

3.2.1 Document Reviews

A review of existing documents addressing health issues and mobile technology was done. The essence of this was to understand the history, philosophy and operations of various aspects of health and mobile technology.

Extensive reading and analysis of written materials on health related issues both in the developed (especially America) and developing countries was carried out regarding mobile health. This was done in order to review mobile applications in the Health sector, their usage and limitations in their various areas of implementation.

Most of the mobile applications which have been used for health purposes especially in Europe and America already have tangible benefits to the users. Most of the applications are used for personal purposes while others are normally integrated to a certain hospital record management system. As technology has evolved, new applications have been developed to make use of current technologies. Most of the systems have been developed on an experimental or research basis, while others have been developed because of an arising need in the sector.

Other sources of information included annual reports by CCK which served as a good source to know the status of mobile technology in Kenya. The changes in mobile phone penetration, usage of mobile services, communication rates by different mobile operators were established from these reports.

Reports by international organizations for example World Health Organization (WHO) and International Non-Governmental Organizations (NGO's) that have accurate statistical data on Health from all over the world were also very useful in this research. There is evidence of extensive investigations in these reports, therefore giving them credibility and accuracy. Information from local organizations that deal with Health Care provision was also useful. These were mostly in terms of magazines, blogs and company websites.

3.2.2 Questionnaires

The questionnaires that were distributed were used for self-filling while the others were used during the interview sessions. The research questionnaire was designed to produce results that are objective. The use of a questionnaire enabled the researcher in capturing data that is not documented in any other source. It was also an effective tool for analysing the respondent's attitude

concerning the questions or the topic. Through this, it was easy to test the respondent's preparedness for the deployment of a given mobile technology.

Reasons for using the questionnaire:

The first part gives the general demographic data which indicates general overview of the location, gender, occupation and age bracket of the respondents. This section gave statistics of who the respondents are.

The next section was about the usage of mobile phones. This part was used to collect information whether the respondents own a mobile phone, the type of phone the respondents have i.e. whether it is a feature phone or a phone that has internet capability. This information was crucial in determining the most popular phone used by a majority of the people which in turn was important in determining the platform to be used.

To determine end user readiness of mobile applications, questions regarding whether the respondents have had previous experience with other mobile phone programs /applications were addressed.

The questionnaire also had open-ended questions which were targeted mostly for the medical practitioners. The aim for this was to find out the kind of information that could be sent to the patients or the general public. The knowledge and usage of other mobile health programs was also addressed to determine the level of awareness of mobile Health programs to the users.

3.2.3 Interviews

Interviews were used to collect data from various people, these are namely; mobile phone users, Community Health workers, Patients, and General Practitioners and some Cancer Specialists. The interviews were useful since through them, one was able to access the respondent's attitudes as well as values concerning the topic. The Interviews were conducted in both formal and informal manner.

3.3 Target and Sample Population

120 questionnaires were prepared for distribution to the various stakeholders involved. This is because the estimated population of Ndakaini and its environs is 150,000 people with the confidence interval (marginal error) of 6.0.

The participants of the research were selected based on their role in the health sector and also their potential benefit in a mobile Health system implementation. Information was collected from the following stakeholders in the health sector, Community Health Workers, Patients affected by Cancer, General practitioners, Mobile phone users (Lay Users) and Nurses. The questionnaires were distributed at Thika District Hospital which is located in Thika town, as well as the outskirts of Thika town –Ndakaini Health Centre (Dispensary) which is a rural town located 45 Km from Thika town.

Information collected for this research was also sourced from libraries, the Internet, document reviews, medical journals, individuals and other stakeholders in the health sector. Individual Purposive sampling was used to select participants for the study. In this sampling method, the researcher chooses participants because of their specific knowledge in the research topic.

CHAPTER 4: RESULTS AND FINDINGS

This chapter focuses on the findings of the research undertaken through the examination of the overall data collected on the selected variables.

4.1 Gender Representation

According to the collected data, 64% of the respondents were female, while 36 % were male.

Figure 4.1 below shows the distribution of the respondents based on their gender.

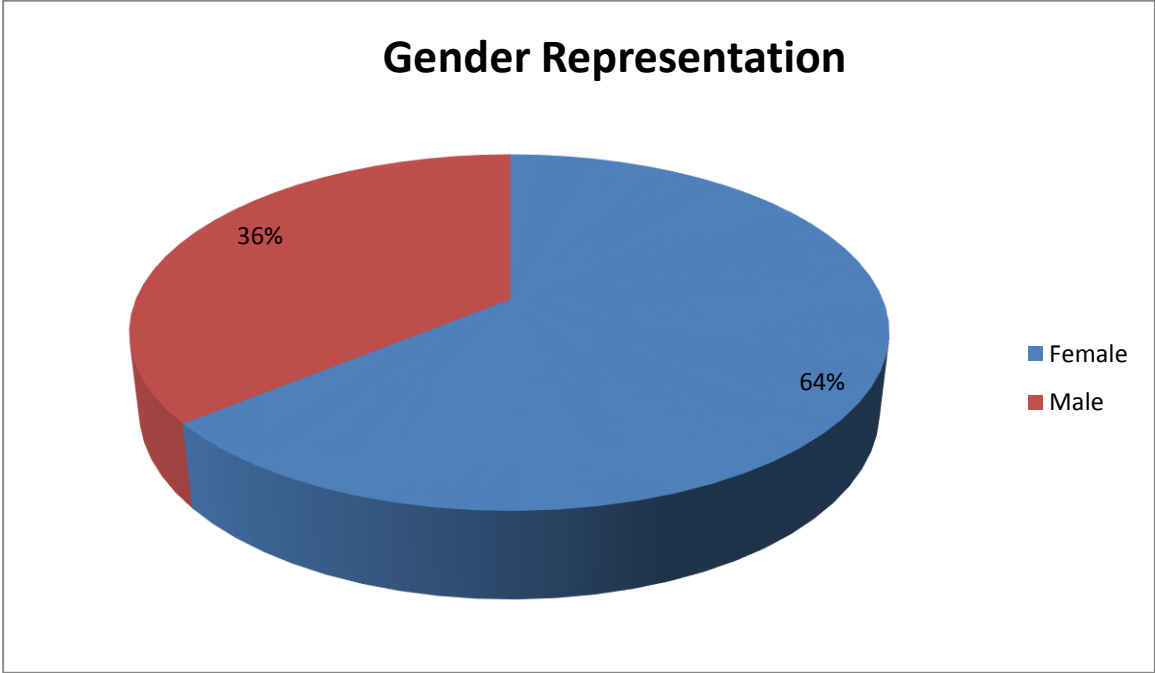


Figure 4.1 Gender Representation

The figure shows that there were more female respondents compared to the male respondents. This is because the majority of the respondents were largely female community health workers.

Figure 4.2 shows the level of education for most of the respondents.

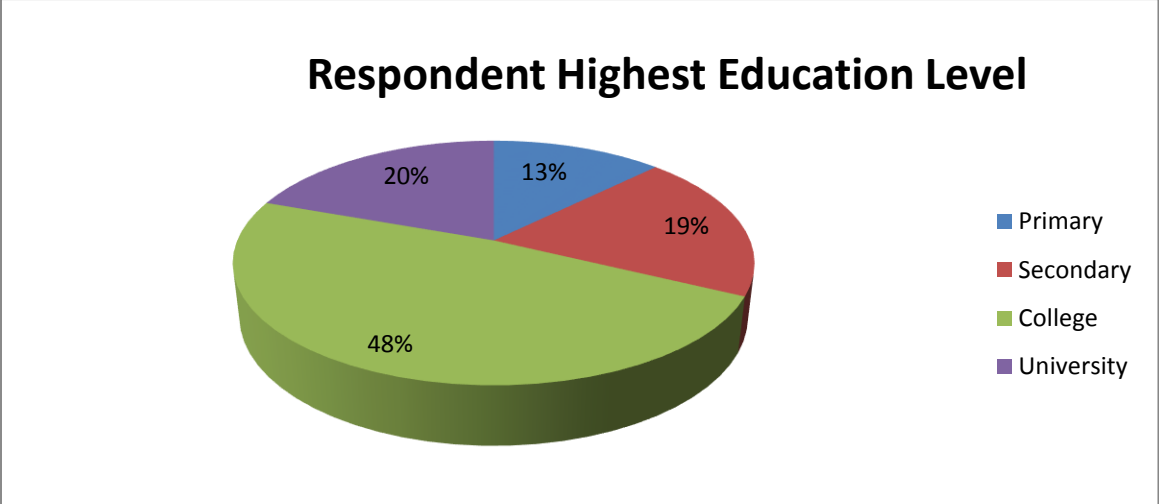


Figure 4.2: Respondents education level

According to Figure 4.2, with respect to the different percentages, it indicates that majority of the respondents have had college education and they are literate. This chart is representative of respondents ranging from normal mobile users, Community Health Workers, General Practitioners, and Cancer Specialist.

4.2 Occupation of Respondents

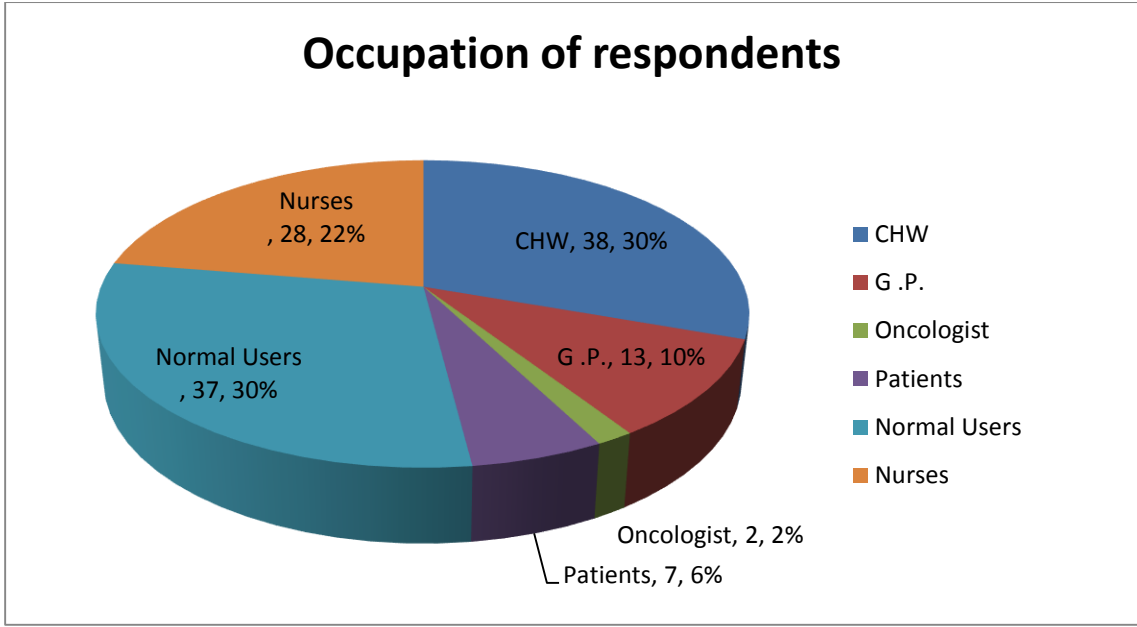


Figure 4.3 Respondents' Occupation

The chart shows the different occupations of the users. 41% of the respondents indicated that they are normal mobile phone users who neither work as medical practitioners or as CHW (Community Health Workers). The statistics on patients included people who have recovered from Cancer related cases before. The statistics on normal users included some medical students interviewed at Thika General Hospital.

4.3 Age of Respondents

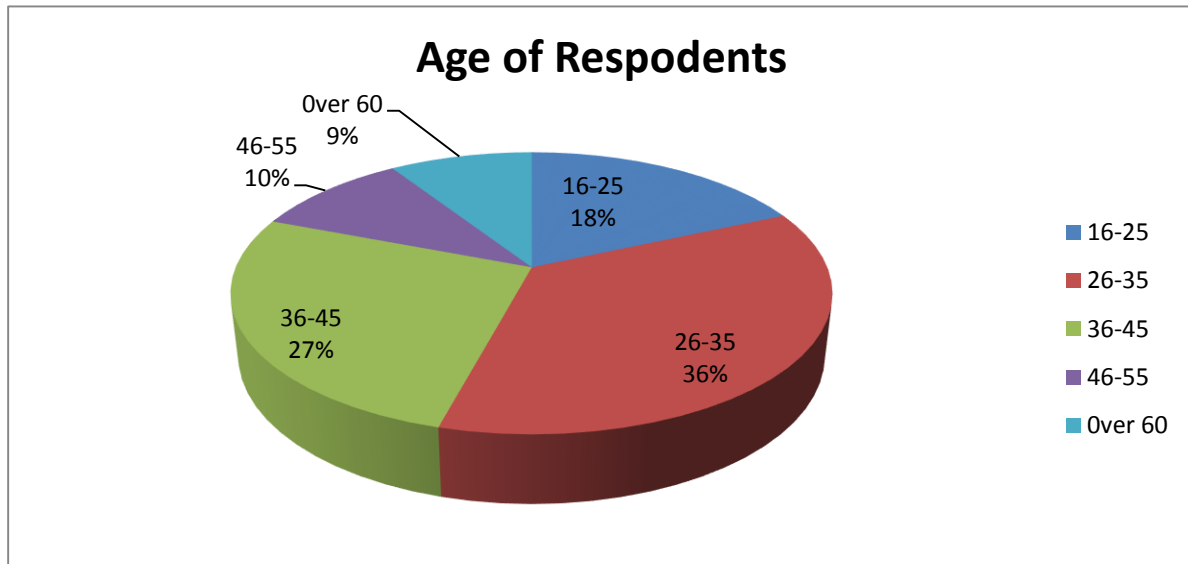


Figure 4.4 Age of the respondents

From Figure 4.4, majority of the respondents fall in the mid 20's to mid-40's age category. This is the majority of the population that are highly active and productive. Majority of the people in this age bracket are working and they own or have access to mobile phones.

4.4 Mobile Phone Ownership

Majority of the respondents owned mobile phones. However, a few of the respondents did not own mobile phones. Figure 4.5 shows the distribution of the respondents based on the mobile phone ownership.

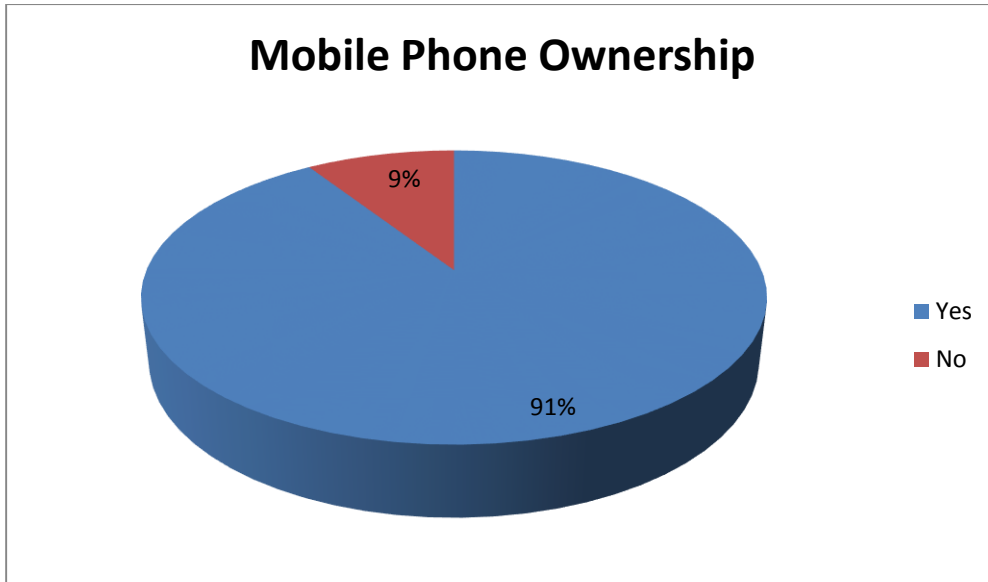


Figure 4.5 Chart showing mobile phone ownership

91% of the respondents owned mobile phone while 9% of the respondents didn't own a mobile phone. This is an indication that majority of the users also have the knowledge of operating a mobile phone.

4.5 Phone Models

The Chart below shows the phone models from various major manufacturers.

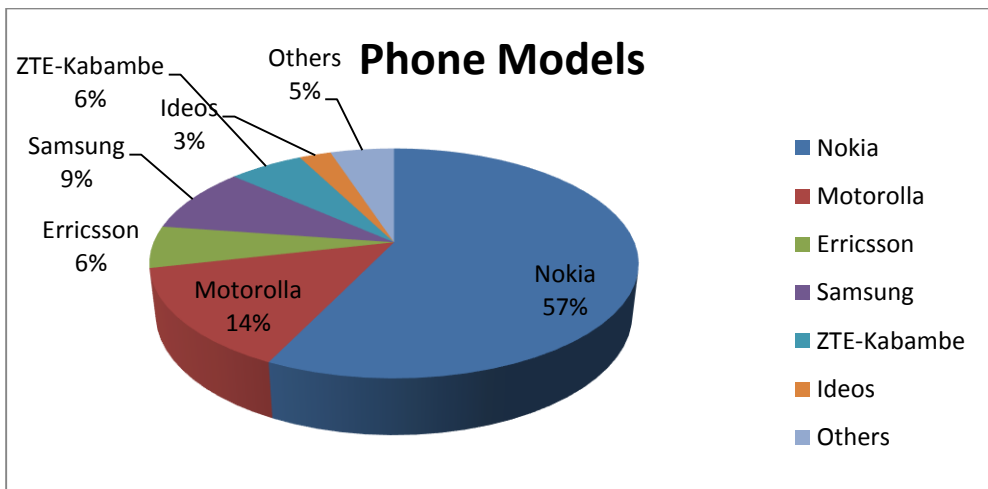


Figure 4.6 Different Mobile Phone Models

The Nokia mobile phones were owned by the highest percentage of the respondents. The second most popular phone model owned by the respondents was Motorola followed by Samsung, Ericson and ZTE respectively. Other types of mobile phones formed 5% of the total number of respondents interviewed.

From the statistics given, it is clear that majority of the respondents own Nokia phones and if a mobile Health application was developed in this platform, it would highly benefit the majority.

4.6 Internet Capability

The chart shows the internet capability of the phones of the respondents.

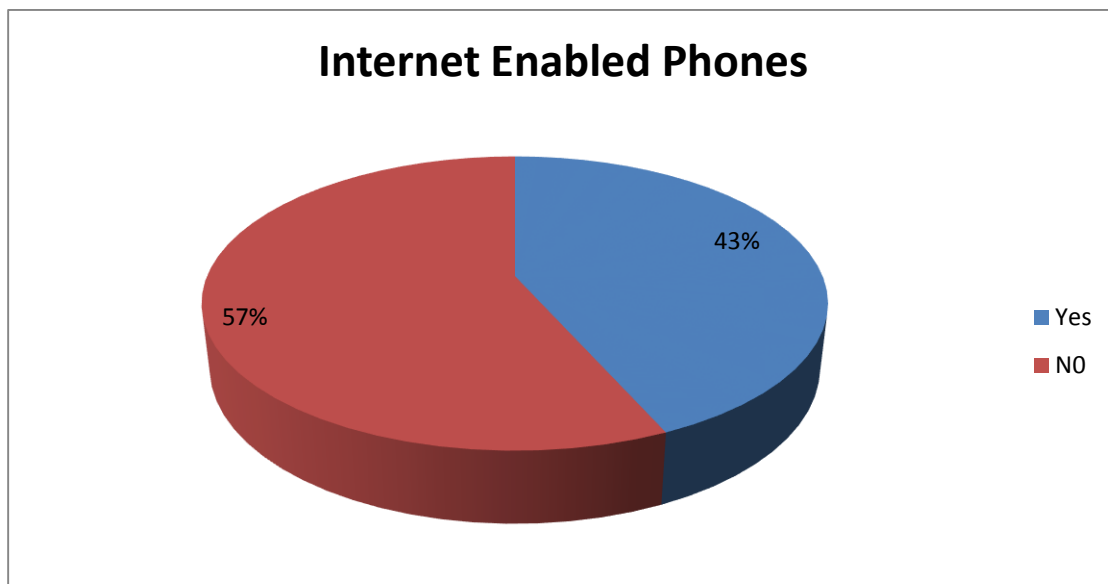


Figure 4.6 Data Capability

Most of the respondents especially those living at a close proximity to the town, majority of them had Internet enabled phones. While the rest -majority of who were in the rural areas (Ndakaini Village) did not have data enabled mobile phones. Most of the respondents who had Internet enabled phones were medical students at the Thika District Hospital. They used their phones mostly to access social sites.

These statistics indicate that if the respondents were to access a mobile health application via their handsets online, only 43% of the respondents would enjoy these services. This would result in locking out a major portion of the population.

Consequently, there is need to build applications based on other technologies e.g. SMS to accommodate the other population of respondents without internet enabled mobile phones. The statistics also indicate that there is huge potential for internet enabled mobile applications.

The adoption and usage of a mobile Health application would be more successful if the target population has prior experience in using other mobile applications, e.g. games, social network applications and money transfer applications or any other information oriented application e.g. weather, sports or news. According to the collected data, 57% of the respondents who owned mobile phones had used another mobile application e.g. a game, or money transfer services. Figure 4.7 shows the distribution of respondents based on their experience with mobile applications.

4.7 Mobile Application Experience

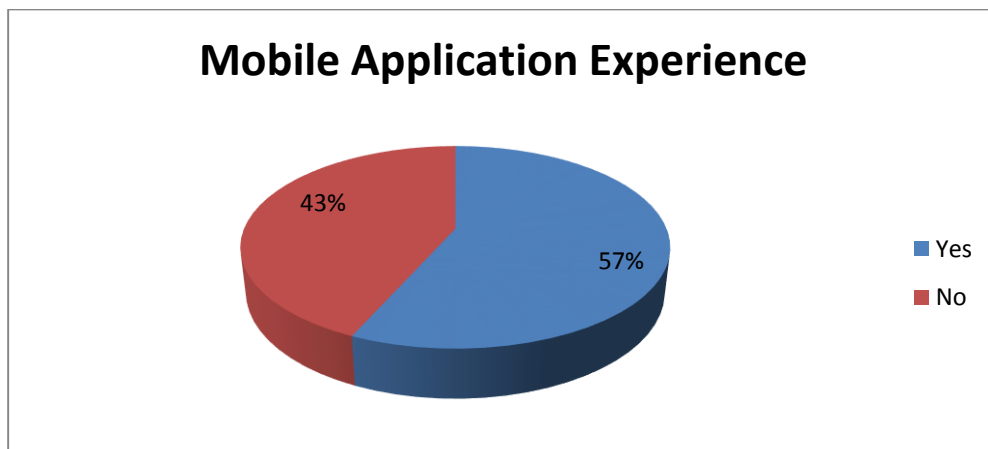


Figure 4.7: Experience of Respondents with Mobile Applications.

With the above statistics, it implies that the deployment of a m-Health application among the respondents would likely have a positive reception. Since they have had experience with other mobile applications, training them to use a mobile health application will not be a hard task.

From the above statistics, it is possible to conclude that there is a co-relation between respondents who have Internet enabled phones and those who have mobile application experience. This is possibly because the respondents utilize the Internet to access other mobile applications.

The successful deployment and adoption of a mobile application also depends on the mobile service provider. This is because of considerations such as data capability and the cost of sending and receiving information in the network. Figure 4.8 shows the distribution of the respondents among the local mobile service providers.

4.8 Mobile Service Providers

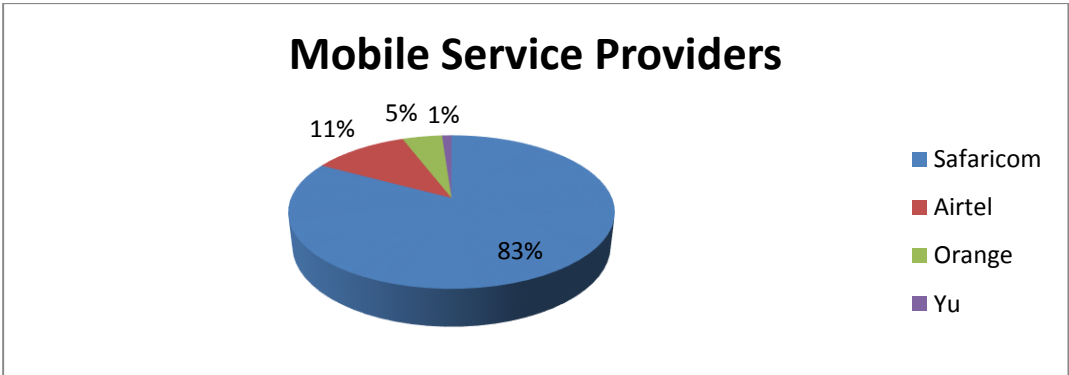


Figure 4.8 Chart Showing Major Service Providers

According to the above chart, Safaricom had the highest number of respondents followed by Airtel and Orange respectively. Yu- (Essar Telecom Kenya Limited) had the lowest number of subscribers among the respondents which was recorded at 1%.

The chart above implies that if the mobile application was designed with Safaricom as the main service provider in mind, majority of the respondents would have easy access to the application as well as enjoy cost effective services.

4.9 M-Health Applications Usage

The popularity of mobile health applications was low among the respondents, with only 15.1% reporting that they had ever interacted with an m-Health application. Consequently, 84.9% of the respondents had never used any mobile health application. This implies that the popularity of mobile health applications is low as compared to the respondents' experience with other mobile applications. The reason for this is because there are very few m-Health applications which are

available. Another reason is that people majority of the population are not aware about their existence.

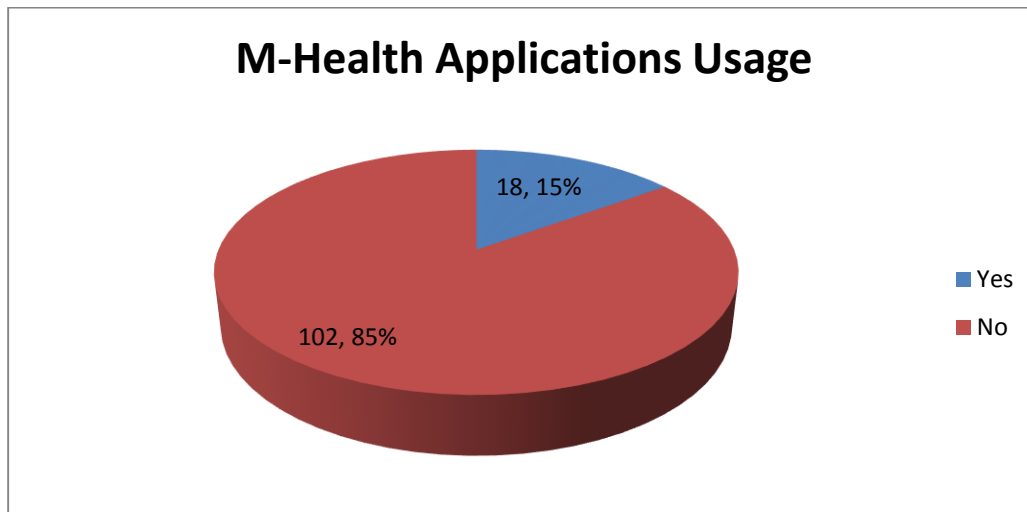


Figure 4.9 Mobile Health Applications Usage.

Even with the low exposure of mobile applications to respondents as shown in Figure 4.9, some of the respondents were already using their mobile phones to book for doctors appointments, while others were using the Internet to get knowledge about medical information. The doctors who were respondents also admitted that they use mobile phones to communicate with nurses and other staff regarding health related issues.

In addition, the respondents gave suggestions on how they would like to use their mobile phones to access health related information. These included getting access to nutritional information, education about common ailments and diseases that can be easily avoided like Typhoid, Cholera, information on how to best manage diseases like Diabetes and Cancer. Some of the respondents also suggested if it was possible, they would like to access their laboratory results via the phone.

Some of the respondents who were in the medical fraternity suggested that it would be a good idea to have a platform whereby Doctors/Nurses can be able to broadcast information to the general public as well as get feedback from the users. This would promote an interactive forum between the Doctors and Patients in a cheap and cost effective manner. The Community Health workers

who interact one-on-one with the patients suggested that they would like a platform whereby they can be able to collect information on the ground and then submit this information to a central server whereby the Doctors or Medical Officers can access the information easily and fast. This means of communication could have tremendous positive effects in managing outbreaks of diseases as well as alerting mothers with young children about a certain vaccine that is being administered in the nearby health centre or mobile clinic.

4.9.1 Summary of Findings

From the above information, it is evident that the usage of mobile phone as a tool of delivering health care information has a huge potential. Since the majority of the population are literate and have the capability to operate a mobile phone, this is an indication that deployment of an m-Health application would have positive reception to the respondents.

The occupation of the respondents varied from skilled to semi-skilled levels. This means that implementation of an m-Health application would be easy to use for the respondents. The phone model owned by a majority of the respondents is Nokia. This means that if the m-Health application was developed on a Nokia platform, majority of the respondents would have access to the application. The findings also revealed that majority of the respondents had low end phones, meaning that their phones didn't not have internet capability. In order to come up with an application that would best meet the needs of the population, a technology that can be used by all the phone devices would be the best preferably SMS(Short Message Services).

The network infrastructure is also crucial in determining the network to use when developing the m-Health application. From the statistics collected from the respondents, majority of the population interviewed used Safaricom as their service provider. When choosing a service provider, it is necessary to consider its coverage and reliability.

CHAPTER 5: ANALYSIS AND DESIGN

5.1 Identification of Mobile Health Architecture Components

The available network infrastructure, type of devices and user experience are among the things that determine the most favourable components of the m-Health architecture. The most appropriate mobile device should be selected based on the information which is being transmitted from and to the mobile device. For example, multi-media files such as images and video require mobile devices to have more memory and processing speed, than mobile phones that are supposed to handle text only.

As a result of conducting the research, the study revealed that the typical users of a Mobile Health application have different mobile devices that support varying technologies. This means that there is need to combine various communication technologies in the architecture in order to accommodate the different targeted users.

The mobile health architecture should rely on the existing communication infrastructure, using communication channels that are already existing. These include SMS, data and voice. The cost of these modes of information transmission may vary. In the recent past, CCK has made efforts to lower the cost of SMS in Kenya, making SMS a favourable mode of information transmission in mobile based systems.

Table 5.1 shows the current SMS rates among the four mobile operators in Kenya, namely Safaricom, Airtel, Orange and Yu.

Table 5.1 Current SMS Rates Among Mobile Operators. Source: (CCK Report, 2011)

Network Operator	Within the Network (Ksh.)	To other Networks (Ksh.)
Safaricom	1	2
Airtel	1	1
Orange	1	2
YU	0.50	1

From the information on Table 5.1, it is noticeable that the average SMS cost within a network is Ksh.0.875, while the average cost of sending an SMS to another network is Ksh.1.50. On the other hand, the usage of data among mobile subscribers is growing in large numbers. This is because of the continuous affordability of data enabled mobile devices, as well as the introduction of low data rates by mobile operators. Moreover, the Kenyan mobile operators have invested in network technologies that enable the mobile subscriber to enjoy high data transfer speeds, thus encouraging internet access via the mobile phone. For example, Safaricom allows its mobile subscribers to use data services via GPRS, EDGE and 3G. Table 5.3 shows the current data rates among the four mobile network operators in Kenya for 2GB of data.

Table 5.2 Current Data Rates of Major Network Operators in Kenya

Network Operator	Cost per 2GB (Ksh)
Safaricom	2499
Airtel	1000
Orange	1500
Yu	599

From Table 5.2 the average cost of 2GB of data is Ksh.1399.50.

In addition, the type of data which is being transmitted within the mobile network should be handled by the underlying network and be supported on the various mobile devices that are using the application.

Moreover, the Kenyan mobile operators have invested in network technologies that enable the mobile subscriber to enjoy high data transfer speeds, thus encouraging internet access via the mobile phone. For example, Safaricom allows its mobile subscribers to use data services via GPRS, EDGE and 3G. Plans are underway to install a 4G network, which will allow very high data transfer rates. Also, Orange acquired its 3G license in November 2010 (CCK, 2010).

The components of the mobile Health architecture must include choices that will make it easy to integrate with other platforms (web, mobile and desktop) on Health related issues. The available bandwidth is also a determining factor that affects the type of data that is transmitted within the network. For example, to transfer a video file, more bandwidth is required as opposed to text which requires far much less data to send. The business and technical requirements of the application need to be considered and the necessary adjustments done to accommodate any specific needs of the whole mobile health architecture.

5.2 The Proposed Mobile Health Architecture

The proposed mobile health architecture was designed to accommodate the stakeholders in the health industry, whose needs were identified in this research.

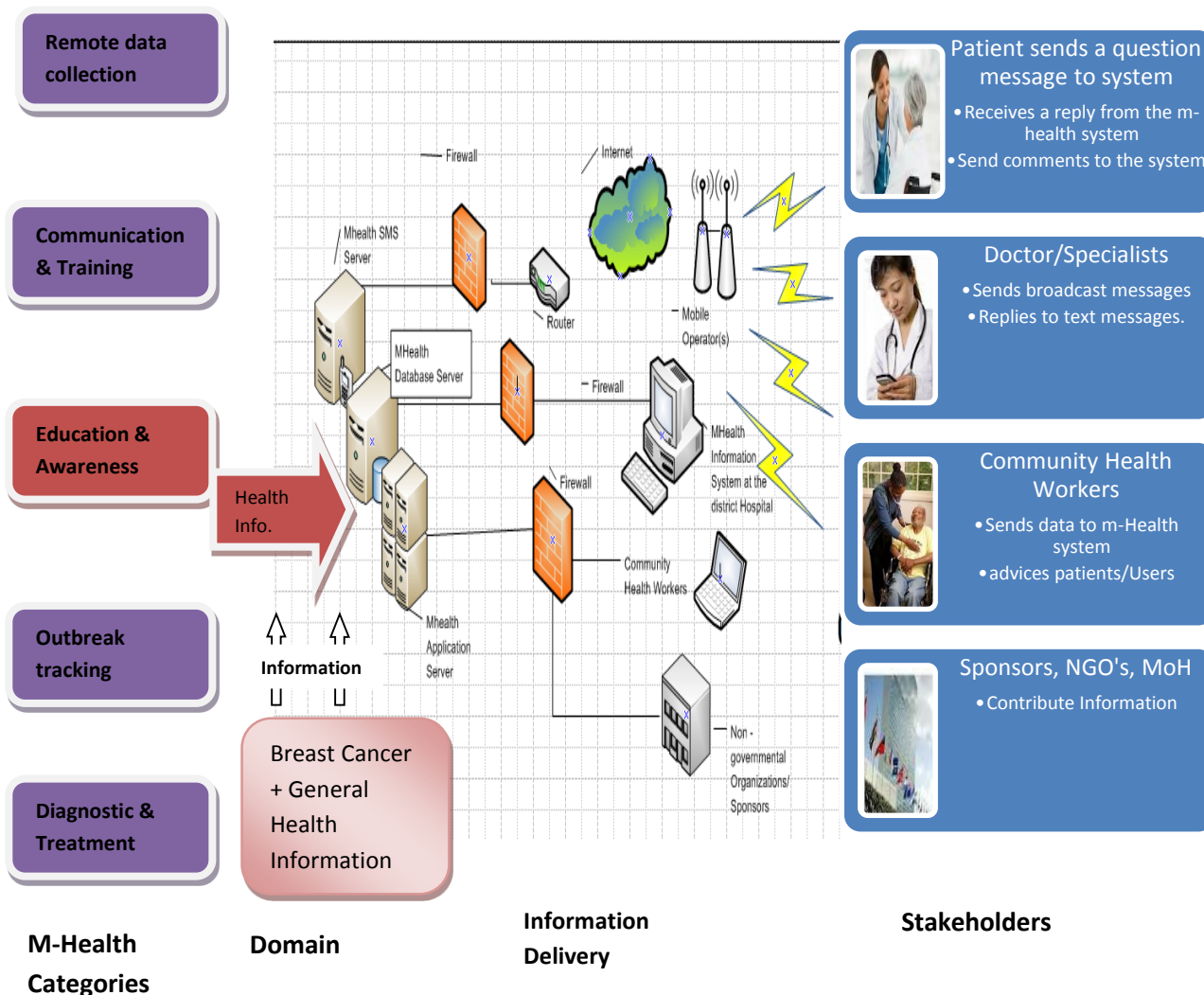


Figure 5.3 Proposed M-Health Architecture.

The flow of information between all the involved entities in the architecture is bidirectional. As shown above, the patients/users, the community health workers and doctors/specialists, access m-Health services from their phones through SMS or data connection. The mobile operator is responsible to route the communication between the Mobile Equipment (ME) (e.g. mobile phone) with the application server.

The communication protocol between the ME and the application server via the mobile operator's network is HTTP (Hyper Text Transmission Protocol). The data services provided by the mobile operator, e.g. EDGE and UMTS allows this to take place via a mobile phone's GPRS capability. Secure network connections are established between the application server and other entities accessing information on the platform e.g. the Health Information System, and access by Non-Governmental Organizations.

5.3 DFD Models

Data flow diagrams were used to show how data flows through the m-Health system. Figure 5.5 shows a DFD of the m-Health system.

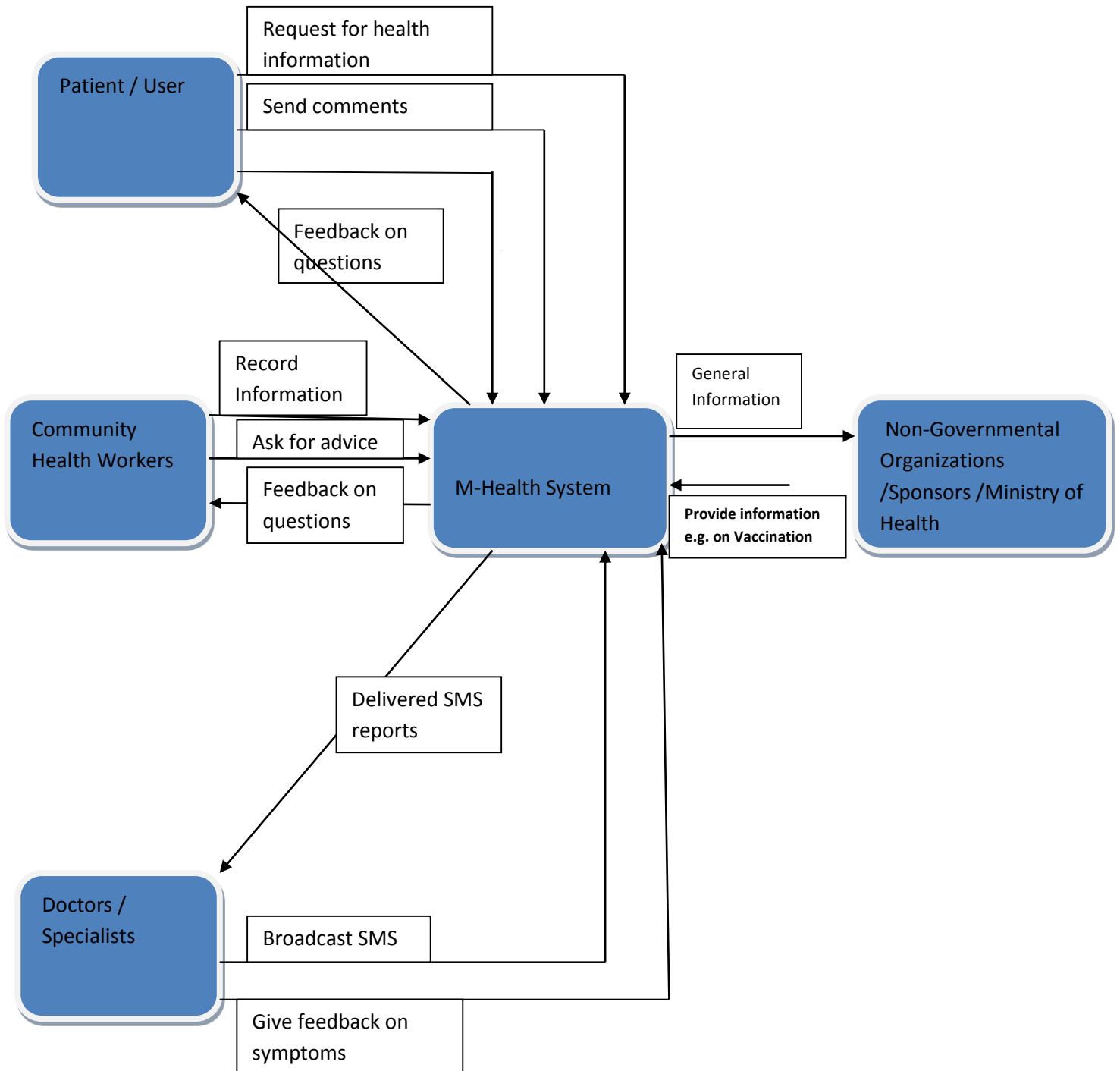


Figure 5.4 Data Flow Diagram of the M-Health System.

5.3.1 Use Case Modelling

The interaction between the external entities and the various processes in the M-Health system are illustrated using a use case diagram. The main actors of the system are patients/users, the CHWs and Doctors.

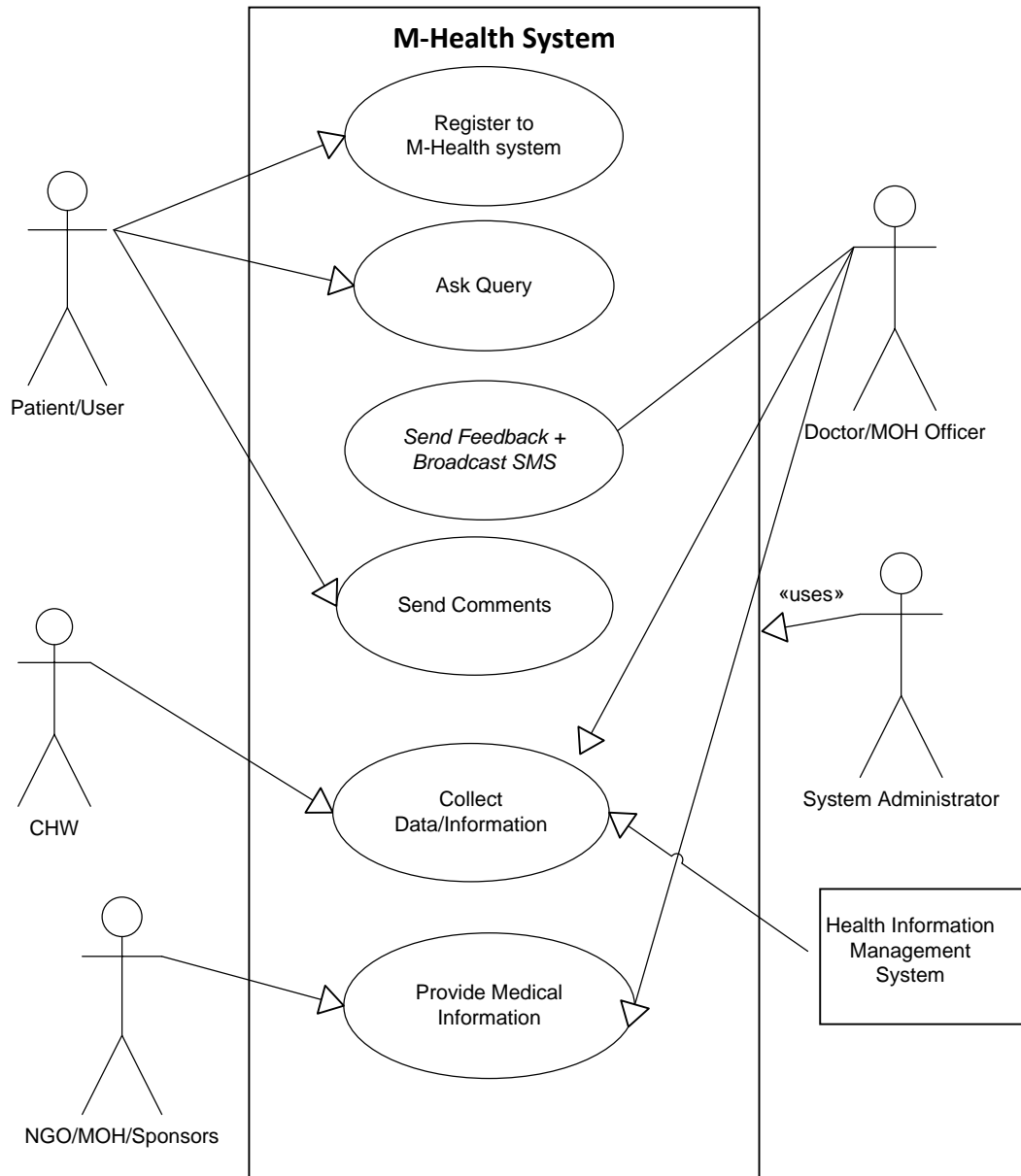


Figure 5.5 General Use Case Diagram M-Health Information Application.

When the patient visits the health centre, the medical officer registers the patient in the M-Health system. After which the patient can be able to request for information as well as receive information from the M-Health system. After this, the users can start sending and receiving information text messages. Once they send the text messages, they will get an automatic response that the system will respond to their query shortly. The patient will later receive a text from the m-health system with the appropriate response.

The Community workers when they are on the field, if they are registered on the system they can send information to the system as well as receive text messages from the Ministry of Health Officers. They should give their work number, area/location followed by the details.

5.3.2 Domain Modelling

The domain object model in Figure 5.8 was used to model the various entities involved in the system and their relationships. The diagram shows a conceptualization of the system interaction already explained in the previous sections.

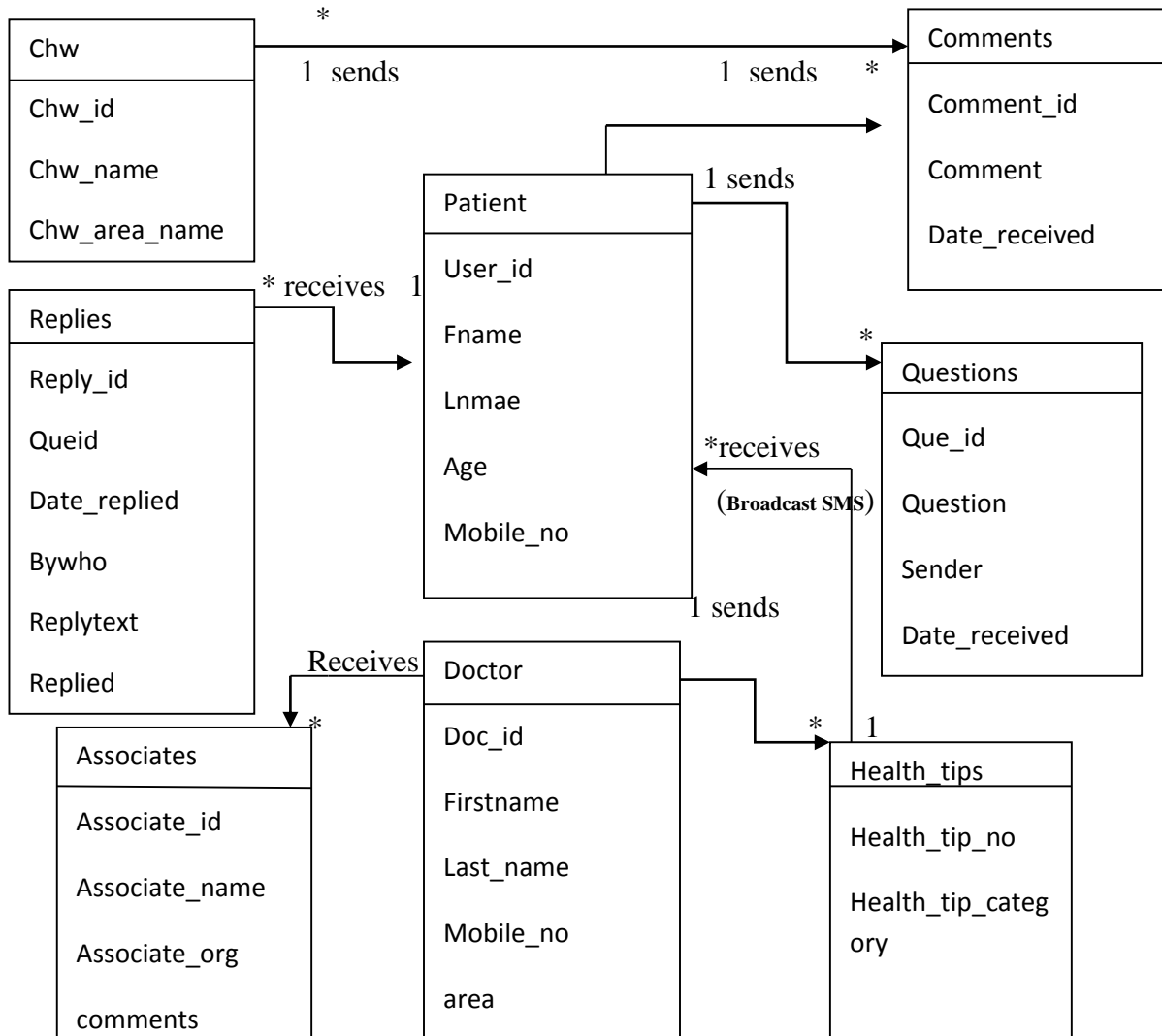


Figure 5.6 Domain Model Diagram for M-Health Application.

Note:

In the Domain model diagram, the associates refer to other organizations affiliated with the m-Health system. These include Non-Governmental Organizations, Sponsors and the Ministry of

Health. They can access the system and give health care information. They can also use the m-Health system for getting information collected by the Community Health Workers.

5.4 Security Design

Security of health related data is of general concern across the board and hence there is a need to ensure that an m-Health system takes this into consideration. The protection scheme will depend on the device type in light of their computational power and battery life. Several measures have been put in place to ensure maximum security of the data.

5.4.1 Database Security

At the database level, the database management system required the creation of users and various roles assigned to them. Sensitive information such as stakeholders passwords were encrypted in the database.

5.4.2 SMS Security

The security of an SMS is controlled by the mobile service provider. In most cases, different technologies are applied by the network service provider to ensure that the SMS transmitted in the network are safe. The most common type of technology used to ensure SMS security is the approximate one time pad encryption.

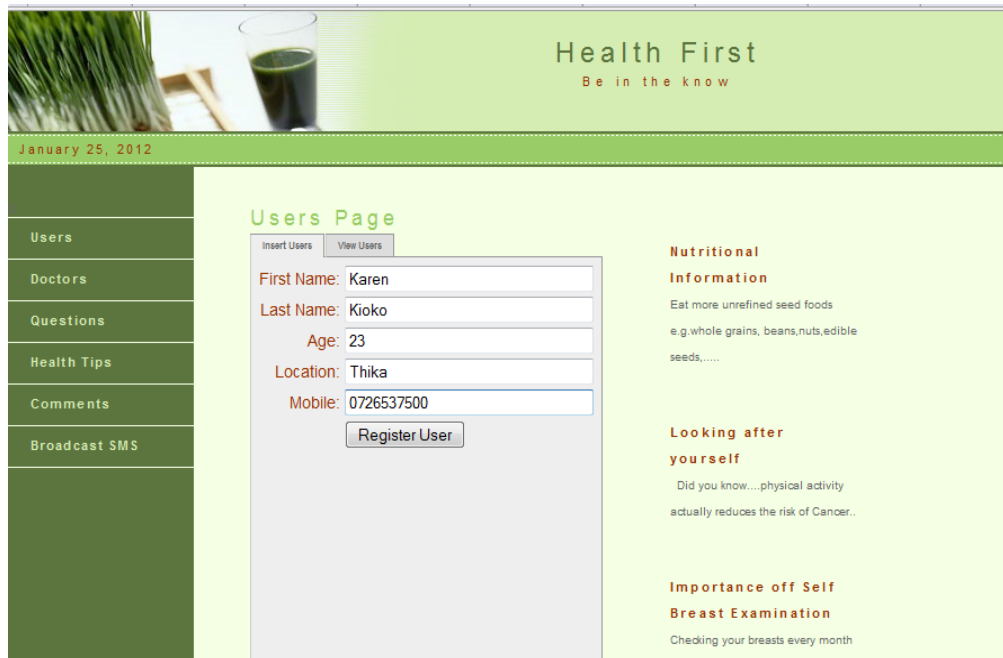
5.5 Development

Analysis and design of the simulation was developed using the Object Oriented approach. The system was developed to work on mobile and web platforms. The mobile application was developed using Java Micro Edition, while the mobile applications server side and web application were developed using PHP. SMSLib - a library for sending and receiving SMS messages via a GSM modem or mobile phone was used to emulate the sending and receiving of messages using a GSM Modem. The database used for this simulation was MySQL 5.0.

CHAPTER 6: IMPLEMENTATION AND TESTING

6.1 Patient Registration

The Patient visits the Health Centre and the Medical Officer registers the patient to the m-Health system. This is after the patient agrees to be receiving health care information via the m-Health system.



Once the patient/ user are registered into the system, they can start sending and receiving messages from the system. The Community Health Workers are also registered into the system in a similar way. Once they are registered, the users' get a number through which they can be sending their questions and comments to. The next page illustrates the interface of mobile application in an emulator.



Figure 6.1 Initial user interface screen.

The user types the question on the screen and sends it to the M-Health system.

6.2 Patient Sends Query

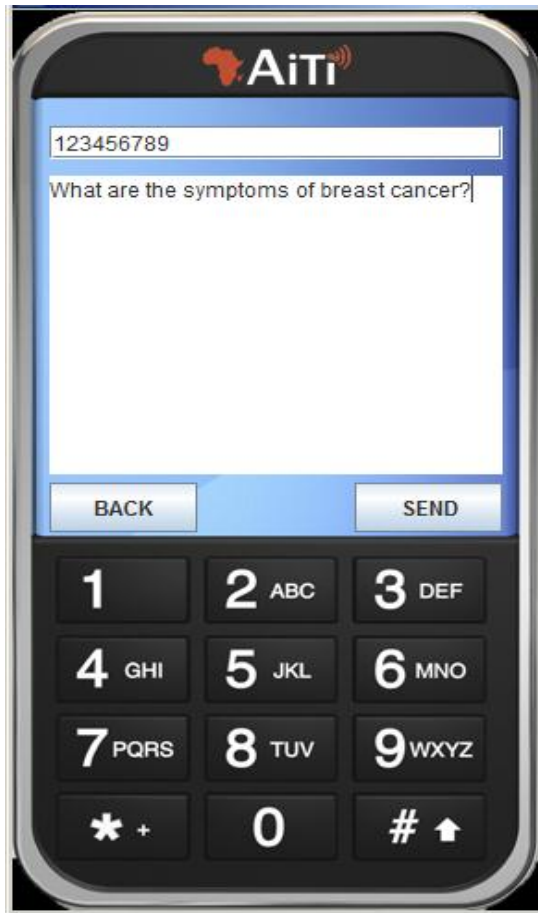


Figure 6.2 Patient Sends Query to M-Health SMS Enquiry Number.

6.3 System Auto-Response



Figure 6.3 System Responds Feedback Message

Once the Patient sends the message, it is relayed to the m-Health system whereby the Doctors or Medical Officers are able to view the questions sent and respond to them appropriately.

The screenshot shows a web browser window with the following elements:

- Browser Tabs:** Home Page, localhost / localhost / mhealth | phpMyAd...
- Header:** Health Be in
- Date:** January 22, 2012
- Sidebar Menu:**
 - Users
 - Doctors
 - Questions
 - Health Tips
 - Comments
 - Broadcast SMS
- Main Content:** View Questions Page
- Table:**

question	sender	date_received	
I have a lump under my armpit	2	2012-01-07 19:22:15	Reply
Please help	2147483647	2012-01-16 20:57:12	Reply
What are the symptoms of breast cancer?	123456789	2012-01-22 18:55:06	Reply

Figure 6.5 The Doctor /Medical Officer Question View.

6.4 Feedback



Figure 6.6 The Doctor's Response.

Once the Doctor clicks on the send button, the SMS is received on the Patient's phone.



Figure 6.7 M-Health System Response.

Note: The length of the SMS is limited to 160 characters.

6.5 Broadcast Information

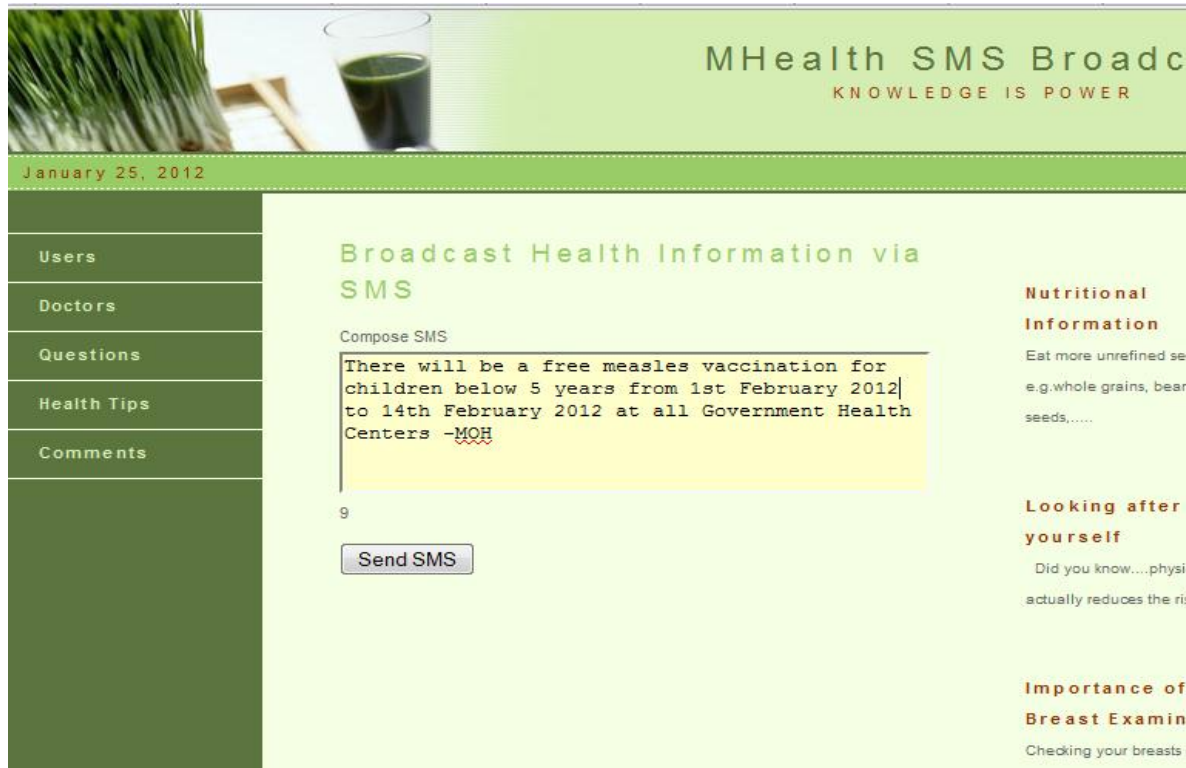


Figure 6.8 The M-Health System Broadcast Information to the General Public.

This facility is mostly useful for sending information to those residents living in remote areas where there is a shortage of medical practitioners. This facility will also come in handy when sending periodical reminders to visit the health center and periodically perform self-breast examination. The residents also recommended that it would be appropriate if the text messages would be sent in the local language. This would be easily implemented by the health officers when they are registering the Patients at the Health center.

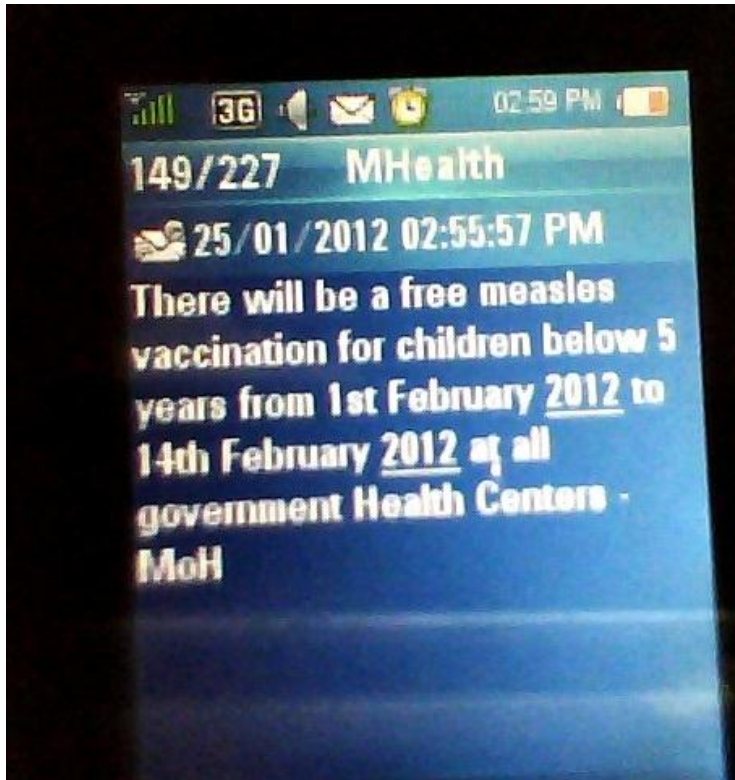


Figure 6.9 Receipt of the Doctor's Message by Subscribers.

6.6 Testing

6.6.1 Deployment

After the m-Health application was developed, the system was deployed at the health centre for a period of six weeks. A sample questionnaire was distributed to collect representative views from the people using it. The system was to be used in parallel with the existing system. From the response given by the users of the system, it was evident that the m-Health application would definitely have positive effects in the long term. This is because of the following reasons.

- i) It would result in reduced costs of accessing health care information on the side of the patients/users. It would cost them less to access health care information as well as getting information from the medical officers.
- ii) The m-Health application made data collection on the part of Community Health workers much easier and convenient since they would only be required to send messages to the central system. This would assist in replacing bureaucratic processes.

- iii) Dissemination of Health related Information by Health officers to the underserved sections of the population was relayed in an efficient and timely manner.
- iv) Use of the m-Health system resulted in raising awareness among the general public about important health issues. For example information regarding an upcoming vaccination drive or nutritional information to new mothers was transmitted through the system. This was achieved through the use of broadcast SMS.
- v) The Ministry of Health officers used the m-Health system to alert the general public about the causes and symptoms of Breast Cancer. This consequently resulted to an increased number of people visiting the hospital for checkup.
- vi) Through the use of the m-Health system, it emerged that the system could also be used by the community health workers as a tool to encourage patients to take medication. This would lead to positive consequences in terms of drug adherence, treatment and follow-up.

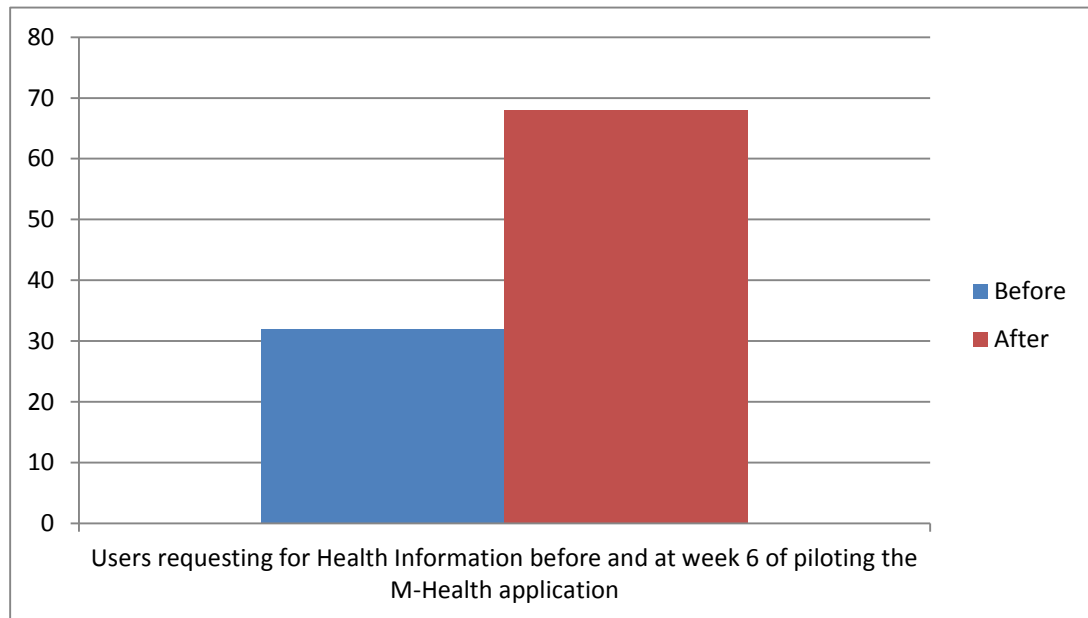


Figure 6.10 Chart showing the number of users requesting for information before and after M-Health Application.

Figure 6.10 shows the number of patients accessing Health Care Information before and after the m-Health application was piloted for six weeks. The Broadcast messages especially proved to be helpful in disseminating information to many people who live long distances from the health centers and dispensaries. This is an indication that the use of m-Health systems can bring the underserved populations under the umbrella of health systems. This makes it easier for people in the remote areas to be informed as well as have access better health care. The m-Health application also proved to be beneficial to the Community Health workers since they could easily give and get feedback from the medical officers at the Health Center.

The following section highlights the technical considerations and business considerations in implementing m-Health systems as experienced in this study and also discusses the some factors to consider when developing an m-Health application to make it usable and suitable to the local environment.

6.6.2 Technical Considerations

Technical considerations can broadly be classified to encompass the communication infrastructure, device type, and data display/type and data protection. The communication infrastructure must support the business requirements from the application purpose and domain. The devices to be used and the data display/type to be used will depend upon the type of communication infrastructure in place and they will also be variables to be considered when selecting a suitable communication infrastructure. On the other hand, in determining the devices to be used in a m-Health scenario, one must consider the inherent design features: display size, processor speeds and memory capacity and how they affect the other technical choices made.

6.6.3 Business Considerations

Business requirements will be determined by the Application Purpose and the Application Area/Domain for which the m-Health application is intended for use. Both the application purpose and application domain/area can be defined as clinical or nonclinical with the application domain/area referring to the specific clinical or non-clinical domain. When developing the m-

Health system, it was evident that text messaging was the most appropriate way of delivering the Health Care information because of the target population.

6.6.4 Implementation Considerations

The patient when registering at the clinic or health centre for the first time would have to give their mobile number which they will use for sending and receiving Health Care information from the m-Health System. This was important because the mobile phone number was used to uniquely identify the patients.

6.7 Design Requirements

Key design requirements that need to be in consideration when developing m-Health applications include security and usability. Because health data is generally considered confidential, any m-Health application must incorporate some security measure. M-Health applications need to be usable because they generally target a large population that is mostly in the unreachable areas and is mostly illiterate.

6.7.1 Usability

The proposed design architecture used text messaging which is a GSM service used by most people who own mobile phones because besides from the fact that it is supported by all mobile phones, it is also cheap and easy to use. The web interface was also important for disbursing information.

6.7.2 Security

This study also sought to achieve security of the data transmitted using text messages. The Ministry of Health officials each have secure access to the system which ensures security. The programming language used to build the application took into considerations possible web attacks that would compromise the security of the information and took appropriate measures to safe guard against this for example prevention of SQL injection. The use of passwords and MD5 algorithm was also used to ensure security.

7.0 CONCLUSION

It is true that Tele-consultations will greatly reduce the need for patients to attend hospitals, saving them time, reduce the financial burden and also saving the health providers of the already scarce resources. However, Kenya is still traditionally an oral culture. Findings suggested that in as much as text messaging was successful in most scenarios, patients still preferred some information to be relayed via telephone calls or face to face communication. Thus to be able to use mobile technologies successfully to promote health, implementation should be done in such a way that this aspect is promoted which means both community and mobile solution developers together with other stakeholders must collaborate to ensure m-Health solutions appropriateness to the local environment. Moreover, though Kenya has recorded some usage of mobile devices in health which have shown tremendous success, they remain very few.

The key technical considerations and business considerations were incorporated into the sample m-Health application and key design requirements were proposed to be usability and security. The research proposed the use of a m-Health architecture which was tested through an m-Health application that was used to deliver health care information on Breast Cancer. The application makes use of both SMS and Web based technology.

It is also acknowledged that hard decisions remain, particularly for policymakers and other decision makers faced with many competing priorities and limited budgets. However, it is the harsh reality that for m-Health to succeed in Kenya, it will be important that there is support from the government of Kenya, the Ministry of Health and other stakeholders. Besides decentralization to ensure decision making at the grass root level and increased health budgetary allocations, it will be important to ensure that m-Health stakeholders collaborate and that information is shared amongst them.

7.1 Recommendation

The research recommends the following:

1. The Ministry of Health should encourage the use and development of more m-Health applications this is because they can be used to achieve broad outreach to large populations.
2. The potential of mobile phones to bridge the ‘digital divide’ should not be ignored but it should be embraced. Initiatives to encourage development of mobile applications should be encouraged by stakeholders in the IT industry.
3. Support m-Health initiatives by providing guidance and tools to ensure proper impact and success assessment.
 - Little work has been published to illustrate the social, clinical or economic impact of m-Health services on its recipients or participants. Yet, impact studies are a critical aspect of interested parties such as investors and other regulatory bodies. The resulting published models would benefit the application developers, program managers and governments responsible for the design, development and maintenance of m-Health programs.
4. Stakeholders in the Health industry should drive strategies that build seamless integration between new m-health care services and existing health care IT systems at the national level. This can be done by ensuring proper co-ordination of the health care IT programs
5. Stakeholders in the health industry should develop two parallel paths for m-Health, one focused on today’s health needs, another anticipating future health needs evolving from demographic and technological changes.
 - Since technological changes are inevitable, it is important to have solutions that address the current health needs as well as the future health needs which will be brought about as a result of increased life expectancy, aging population and lifestyle changes etc.
6. Literacy and Training- m-Health services will have greater effects on health outcomes when their users have high levels of literacy—and for health workers, training—in ICT and health. Knowledge about medicine and health creates the context for successful interventions.

There are many ways to achieve improvements in these areas: dedicated training institutions, public information campaigns, programs in schools, and even software for mobile devices that trains people in their use and in treatment methods. This should be in accordance to best practices and health system priorities.

7.2 Future work

As new innovations keep coming up, the future of m Health applications remains bright. The mobile application was developed using Java Micro Edition, while the mobile applications server side and web application were developed using PHP. Future work can be done on cross-platform and cross-devices, this is because mobile applications are no longer limited to single platforms. A good example is the Android and iOS platform.

Other areas of research and advancement is the use of wearable devices. These wearable devices can be connected with smartphones and be useful in delivery of healthcare information. This technology is already in use. Internet of Things (IoT) is another technology which can be explored.

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Appendix A - List Of Acronyms

mHealth – (noun) for **Mobile Health**

GSM – Global Systems for Mobile Communications

GPS –Global Positioning System

GIS –Geographical Information System

GSM - Global System for Mobile Communications - A standard for mobile telephony specified by ETSI

GPRS - General Packet Radio Service - A packet oriented mobile data service used by GSM

HTTP –Hypertext Transmission Protocol

ITU –International Telecommunications Unit

MoH - Ministry of Health

SMS –Short Message Service

WHO - World Health Organizations

Appendix B- Sample Questionnaire

TITLE:	MOBILE-HEALTH RESEARCH QUESTIONNAIRE
RESEARCHER:	CAROLYNE GAKINYA
INSTITUTION:	STRATHMORE UNIVERSITY
PROGRAM:	Master of Science in Mobile Technology and Innovation

A: GENERAL DEMOGRAPHIC DATA

1. Region / Area of Respondent	
2. Residential Area	

2.

Gender	<input type="checkbox"/> Male <input type="checkbox"/> Female
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3.

Education Level	<input type="checkbox"/> Primary School <input type="checkbox"/> Secondary School <input type="checkbox"/> Tertiary <input type="checkbox"/> University
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4.

Occupation	<input type="checkbox"/> Student <input type="checkbox"/> Business Person <input type="checkbox"/> Professional <input type="checkbox"/> Other Please Specify-----
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5.

Age Bracket	<input type="checkbox"/> 16 -25 Yrs <input type="checkbox"/> 26 -35 Yrs <input type="checkbox"/> 36 -45 Yrs <input type="checkbox"/> 46 -60 Yrs
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	<input type="checkbox"/> Over 60 Yrs
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B: USAGE OF APPLICATIONS

6.

Do you own a mobile phone?	<input type="checkbox"/> Yes <input type="checkbox"/> No
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7.

Is the phone Internet enabled?	<input type="checkbox"/> Yes <input type="checkbox"/> NO
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8.

Do you use mobile phone programs such as games, social network applications, communication applications?	<input type="checkbox"/> Yes <input type="checkbox"/> No
--	---

Health Related questions

9.

How do you get health care information?	<input type="checkbox"/> Local Dispensary <input type="checkbox"/> From Radio <input type="checkbox"/> Mobile Clinic <input type="checkbox"/> Hospital If other Specify-----
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10.

Have you ever used any mobile Health application?	<input type="checkbox"/> Yes <input type="checkbox"/> No
---	---

11.

Do you use your phone to request for information or services related to Health?	<input type="checkbox"/> Yes <input type="checkbox"/> No If yes Specify-----
---	--

12.

Which health services would you like to access from your phone? ----- -----

13.

If you are a medical professional, which services or information would you like patients to access through their mobile phones?

