The Use of Mobile Application for Antenatal, Delivery and Postnatal Care: The Case of Oromia

A Thesis Presented

by

Teshale Daba

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In Partial Fulfillment of the Requirements

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ACCEPTANCE

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July-2019

DECLARATION

I, the undersigned, declare that this thesis work is my original work, has not been presented for a degree in this or any other universities, and all sources of materials used for the thesis work have been duly acknowledged.

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July-2019

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Abstract

This thesis is all about the use of Mobile Application for Antenatal, Delivery & Postnatal Care given to mothers deep in the remote areas of the Oromia Region. The health information related to pregnancy, delivery and care for their babies in the afterwards that are customizing the application for access to health services using information technology.

The study is focused on the use of mHealth application and proposing a solution the way to reducing maternal mortality in the community and at health facility. To this end, care providers and clients were communicated for interview on mHealth application. In this regard, basic questions were forwarded to these providers and clients to provide information as to how to fix additional features. The agile process model was used for propose, develop and integrate a prototype with new features appended. There are various kinds of software tools used in the research in different instances including platforms, programming languages, database server, and related AVD (Android Virtual Device) tools.

The results of this study show that expectant women can access maternal and child healthcare information on their phone while, Health extension workers (HEWs) and Health Development Armies (HDAs) and other concerned bodies such as ambulance service management are communicated when any complication arise on mother and their babies. Based on the assurances of the informants, the app was useful since it improves their job an eases service provision in general.

The researcher ends up with concluding remarks and few recommendations on the implementation of the application, enriching the application by expand the way more to accessible, making the application platform-independent, enriching the database with variety of messages, and integrating the mobile application with cloud technology as well.

Keywords: mHealth, mobile application, platform, maternal health, antenatal, delivery, postnatal

List of Acronyms

ADT	Application Development Tool
ANC	Antenatal Care (Pregnancy Continuum Care
API	Application Program Interface
AVD	Android Virtual Device
CHW	Community Health Worker
DHIS2	District Health Information System version two
eCHIS	Electronic Community Health Information System
EDHS	Ethiopian Demographic Health Survey
HER	Electronic Health Record
EDD	Expected Date of Delivery
FCM	Firebase Cloud Message
FMOH	Federal Minister of Health
GCM	Google Cloud Messaging
GDP	Growth and Transformation Plan
GPS	Global Positioning System
HC	Health Center
HAD	Health Development Army
HEW	Health Extension Worker
HIA	Health Information Administration
HIT	Health Information Technician
HIS	Health Information System
HIV/AIDS	Human Immune Deficiency Virus/Accrued Immune Deficiency Syndrome
HMIS	Health Management Information System
HP	Health Post
HSDP	Health Sector Development Program
HSTP	Health Sector Transformation Plan
IEC	Information, Education and Communication
ICT	Information Communication Technology
IPD	In patient Department

IVR	Interactive Voice Response
LMIC	Low and Middle-Income Country
MCH	Maternal and Child health Department
M & E	Monitoring and Evaluation
MW	Midwife
MOTECH	Mobile Technology for Community Health
MYSQL	Microsoft Structured Query Language
OPD	Out Patient Department
ORHB	Oromia Regional Health Bureau
OS	Operating System
PHCU	Primary Health Care Unit
PNC	Postnatal Care
PHR	Patient Health Record
SDG	Sustainable Development Goal
SDK	Software Development Kit
SMS	Short Message Service
SQL	Structured Query Language
UI	User Interface
WHO	World Health Organization
XML	Extendable Markup Language

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CHAPTER ONE:
INTRODUCTION

1.1.Background

Health conditions refer to state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [1]. With a view of fulfilling these health conditions, countries do formulate policies and devise strategies that could be implemented over the years. Hence, the Ethiopian government has put in place a three-tier health system, primary, secondary and tertiary level to impact on the general health needs of the population [2]. The health system primarily entertains maternal health among others so that it could be able to meet targets set by Millennium Development Goals within specified period of time.

Maternal health is the health of women during pregnancy, childbirth, and the postpartum period [3]. This implies that a care given to mothers upon preconception, prenatal, and postnatal times in order to ensure reduction in maternal as well as child morbidity and mortality. In order to achieve this, technology is playing a vital role in assisting the execution of the program at health post and health center levels. Here comes the contribution of mHealth as a reality that has been used since a couple of years ago all over the world.

World Health Organization, WHO, asserts the expansion of mobile health in its survey conducted in2011, mHealth [4], new horizons for health through mobile technologies: second global survey on eHealth. This interest has manifested into a series of mHealth deployments worldwide that are providing early evidence of the potential for mobile and wireless technologies. mHealth is being applied in maternal and child health, and programs reducing the burden of the diseases linked with poverty [4].

A mobile health application is a computer program running on a mobile device with a view of capturing, aggregating, analyzing and presenting sensitive health data. Mobile computing is

getting more and more attention these days, though selecting a suitable development methodology is a key towards achieving the objectives supposed to be met [5].

It is unquestionable that the availability of complete and quality of data at a given point in time helps to measure performance and results achieved in a certain environment. With this in mind, the Ethiopian health sector implemented a data collection, aggregation, processing and analyzing mechanism called Health Management Information System (HMIS) which was first crafted in the Health Sector Development Program (HSDP) [6], a twenty-year plan concluded in 2015.

According to the 2015 Health Sector Transformation Plan (HSTP), the health data collected via HMIS is mainly feeding the monitoring and evaluation (M&E) system which is an action-oriented management tool that requires complete, relevant, reliable and timely analyzed data to evaluate programs/projects [2].

In addition to HMIS, there is another system called mHealth that gives a special emphasis to management of data generated in relation to maternal and child health services with a view of passing informed decisions. The system has been implemented in all facilities under the Oromia Regional Health Bureau [7].

Recently, the Ethiopian government has given significant attention in restructuring the healthcare system in order to cope with the technological advancements. The government is mainly doing this because it started to recognize the immense potential of ICT not only in its applications to the medical practices, but also its applicability towards improving administrative services that can greatly enhance overall efficiencies. One of the measures taken by the Oromia Regional Government include establishing an ICT Agency that govern all the practices of ICT that exhaustively works on selections of appropriate technology for specific needs and systems development like management information system [8].

Several applications such as District Health Information System, Electronic Medical Record, Human Resource Information System, Health Commodity Management Information System etc.

are currently running all along the structure of the health sector to meet the health needs and improve the general health care standards [7].

By its very nature, the process of serving patients is highly complex and varies from institution to institution that needs to be supported by technology. It mostly involves services at various departments that make patients to feel anxious by the complexity of the processes [6].

Mobile phones or smartphones become the most important communication devices in the lives of people from different walks of life. Nowadays, mobile technology allows to integrate different apps into existing mobile phone systems. Practical medicine and healthcare services supported by mobile apps are called mHealth solutions [9]. This field is growing faster recently letting mHealth applications to be delivered via online stores, such as App Store, Google Play, Ovi Store and others [10].

An estimated 216 women died per 100,000 live births in 2015, and 45% of the total deaths among children under five occurred in the first month of life. These deaths are disproportionately concentrated in low and middle-income countries, but maternal and child health in Europe and other high-income countries is similarly challenged by growing health inequities [11].

According to Ethiopian Demographic Health Survey (EDHS) 2016, the maternal mortality ratio accounts to 412 deaths per 100,000 live births in Ethiopia. Similarly, Maternal health, Child Health, preventable diseases and premature deaths still inflict a high death toll in Oromia too[12]. Inequity of access to basic health services affects distinct communities, and social groups. Under-financing of the health sector in most areas has led to quantitative and qualitative deficiencies in service delivery and brought about growing gaps in facility. Inefficient allocation of scarce resources and lack of coordination among key stakeholders have made duplication of efforts, overlapping responsibilities, and hence resource wastage that can be seen as troublesome problem [2].

The researcher believes that fair access to basic health services, efficiency and effectiveness in the utilization of the scarce resources as well as lack of coordination among stakeholders could

be improved by supporting it through modern technologies like mHealth so that the unreachable segments of the society would be reached.

Therefore, this thesis tries to assess the currently running mHealth application in health centers & health posts and its roles in improving the services to provide for clients. The researcher focuses on maternal health program which is included in the current HMIS (Health Management Information System), an integrated data management system, paying particular emphasis on antenatal, delivery and postnatal care services at facilities.

1.2.Statement of the Problem

In our country, health facilities like health posts & Health Centers are located in remote areas where services like maternal and child healthcare are provided by health extension workers [2]. The health extension workers are providing continual healthcare services to mothers either at health posts or house-to-house approach. The regular home-to-home travel makes the condition more tedious and difficult to serve the service-seeking mothers appropriately affecting the overall quality.

Most of the services given by HEWs are said to be manual. The manual patient record keeping system is obviously prone to error, time consuming and bulky while generating timely reports. The health care provision on the ground is found to be inefficient since it takes longer to access information for timely decision makings.

The delay in communication due to dispersed geographic environment and manual practices, in one way or the other, affects the endeavor to reduce maternal and child mortality by jeopardizing timely management of complications related to pregnancy, labour and delivery services are provided. Due to the absence of ambulance service mothers and their babies' lacks the service to provide early because of this it lacks proper communication facilities among attending professionals.

The existing mobile health technology somehow helped to alleviate these challenges through communicating any complication that may occur in relation to pregnancy involving senior professionals as early as possible [9]. This technology also contributed in minimizing complications and facilitating early access to health care through speedy communication between clients and their care providers. The application allows for health care providers to access the information of mother and their babes using own mobile phones.

However, according to the researcher's personal observation and information obtained from professionals and clients, the application lacks the health education features that would play a vital role in achieving the plan to reduce maternal and child mortality in the country specifically and globally in general. One of the major features missing from the existing tool is the segment that helps to conduct health education through which awareness of mothers could be shaped and attract them to health facilities before complication arise. This feature helps to generate text-based short messages and voice messages that are well educative and informative. Particularly, the voice messages are essential for illiterate mothers since they can listen to the regular messages that tell them their level of pregnancy and the services they sought to get with clear reminder of their next appointments.

In addition, the midwife at health center gets notifications the usual way, based on their predefined regular visits, in the existing situation. To this end, it is possible to generate emergency messages upon serious complications that are simultaneously copied to ambulance services for speedy support. Therefore, these gaps could be narrowed down by updating the system with minor modifications that incorporate the aforementioned features.

1.3.Research Questions

1. What are the existing the mHealth applications currently running on health center and health post?
2. Which features have great importance and would be possible extensions?
3. What is needed to enhance the existing mHealth application?
4. What are the external factors that may affect proper functionalities of mHealth application?

1.4.Objectives

The main objective of the study is to improve service provision of m-Health system. The general objective and specific objectives of the study are described in the following subsections.

1.4.1. General Objective

The general objective of the study is to improve service provision of m-Health system.

1.4.2. Specific Objectives

Specifically, the study attempts:

- To review the deployed mHealth application
- To explore the bottlenecks of mHealth application by involving users of the system
- To develop a prototype of the mobile health application
- To enrich the existing system of mHealth application as per the gap identified
- To evaluate the newly developed prototype of mHealth apps
- To propose the possible integration of the application with cloud service

1.5.Significance of the Study

The research is primarily significant to protect women in reproductive age groups through early detections of danger signs that can occur in mothers and their baby during pregnancy, labor and postpartum that let them not to miss follow up visits. This in turn helps in reducing maternal and neonatal morbidity and mortality. Using mobile health application also helps to establish a communication system among health professionals themselves and facilitates the linkage with the ambulance services.

In addition, the study helps for developer that they can work on it to improve the mHealth. Moreover, this paper may be used as for scholars who are interested to conduct a research on a

similar topic particularly in the context of Oromia. Also, other academicians may use the paper as a reference in their work in the time ahead.

1.6.Scope

The mHealth assist to communicate the health extension worker at health post level with the midwife at health center in closely following changes during pregnancy, delivery & afterwards and take necessary actions to prevent an unexpected circumstance. It's included the communication between health centers and health posts but excluded the communication between the health center and hospitals. This means that the scope of mHealth application is between the health posts and health centers only.

Hence, the study only goes up to developing the prototype that shows how this mHealth could work. In other words, it is practically challenging to develop mHealth application within such a short period of time.

1.7.Limitation

The study is limited to discuss the use of mHealth applications in reducing the maternal and child mortality through health education on issues like pregnancy, delivery and postpartum. In addition, it needs to be clear that this study is limited to exploring mHealth application that can run over android platforms and could be accessed through web-browsers

1.8.Operational Definitions

- **Mobile Health** – The term used for the practice of medicine and public health supported by mobile devices such as mobile communication devices for health services.
- **Maternal Health Services** – Various facilities and programs organized for medical and social services for mothers including antenatal, delivery and postnatal services.
- **Health Extension Worker**– health professionals providing health service at health post level

1.9.Organization of the Thesis

This thesis report is organized in six chapters. Chapter one presents the introduction, statement of the problem, significance, objective, scope and limitations of the thesis. Chapter two discusses literature review and related works on the use of mobile application in antenatal, delivery and postnatal care. Chapter three presents the research methodology used while chapter four discusses the proposed mobile health framework and architecture. Chapter five implementation and evaluation of the thesis and finally chapter six ends up by concluding the thesis and forwarding some recommendations.

CHAPTER TWO:
REVIEW OF LETRATURE AND RELATED WORKS

2.1. Overview

In this chapter of this study, a considerable description of mobile application will be given together with discussion on varieties of mobile applications. After assessing the global context, it will also touch upon the Ethiopian context and jumps over contemplating on the benefits of mobile health applications. The study also deals with the role of mHealth application for service providers and clients.

2.2.Mobile Application

Mobile applications are consisting set of programs that run on a mobile device and perform certain tasks for the user [13]. Mobile application is a fast-developing new segment of the global Information and Communication Technology which is easy, user friendly, inexpensive, downloadable and run able on most mobile phones [13].Mobile applications have widely been used in areas like calling, messaging, browsing, chatting, social network communication through audio, video, and games [13].

Some of the mobile applications are pre-installed while others could be downloaded by users from the internet to be installed on mobile phones. Thus, large mobile application market is being served by increasing number of mobile application developers, publishers and providers. From the technical point of view, the different mobile applications are runnable on different managed platforms like iPhone, BlackBerry, Android phone or Windows Phone [14]. Based on application area, communication, games, multimedia, productivity, travel and utilities are among the different categories of mobile application [13].

Originally mobile apps were offered for informational and productivity purposes that included email, calendar, contacts, calculator and weather information [14]. These mobile applications were just used for receiving call messaging, doing simple calculations and etc. In 2000, the

mobile application developers started talking about internet based mobile application. These mobile applications can connect people to internet for their daily importance [13].

Most Internet based applications served fantastic features and since then, access to the internet using mobile phones increased much [13]. Those mobile applications were designed to help us in our daily life and allow us to connect with internet, interact with the world, getting information from distance, social communication using facebook or twitter and etc. [13].

Mobile applications do run on various platforms like the "*Ushahidi Engine",* a platform that allows anyone to gather and distributed data via SMS, email or web and visualize it on a map or timeline. The organization's goal is to create the simplest way of aggregating information from the public for use in crisis response [15].

Many new mobile innovations actually begin in developing countries and spread later to the developed world. A few examples include: WIZZIT and M-Pesa are mobile applications that target users without bank accounts, allowing millions to have access to banking services without opening a bank account. Both applications are developed first in Africa and compatible with a wide range of mobile devices, including early generation cell-phones that are popular in low-income communities and work with pay-as-you-go plans [15].

2.3.M-Health

Although mHealth lacks a standardized universal definition, it basically covers "the use of portable electronic devices with software applications to provide health services and manage patient information" [16]. It is defined as the provision of healthcare services through the medium of mobile communications devices. Health comes in many different forms to serve different purposes in the global health sector. According to *United Nations Foundation,* common uses of mHealth applications include education and awareness, remote monitoring, communication and training, disease and epidemic outbreak tracking, diagnostic and treatment support and remote data collection [17].

2.4.Benefits of mHealth

Due to the fact that mobile health (mHealth) is an emerging field, many researchers have started devoting time to conduct studies and develop various mobile applications that are linked to health. In connection with this, only few studies have been carried out on mHealth applications in the developing world in general in comparison to those that have been done in the developed world. These researches conducted on developed communities may not be appropriate in exposing the health challenges in the developing world where resources are shared by the community at large.

*The African Progress Panel,*2010, says in countries with weak primary healthcare systems where access to care is limited, utilizing community health workers in partnership with facility-based health systems is the best way to maximize the benefits and reach the population with the greatest need [18].

Its further states citing various researches that, mHealth, as part of the delivery of maternal health care, aims to reduce the distance, whether it is financial, structural, or political so that the lives of women and children can be saved by addressing preventable health problems [18].

Similarly, other scholars believe that the benefits of mHealth projects can reach various stakeholders in the healthcare system. First, Health benefits the entire health system in the country from the intervention as it would increase direct communication among health workers throughout the country, but especially in rural areas, mHealth would increase the support for patient management in the healthcare system [16].

mHealth intervention benefits patients because it saves them from paying for a regular doctor consultation, bridges the communication gap between them and the community health workers, and because of mHealth that allows community health workers to utilize cell phones, communication has improved between them and the providers for they have better access to information. mHealth helps to narrow the gap between access to services in urban versus rural

areas attributed to the fact that health care providers are more likely to be located in densely populated cities where hospitals and clinics are more available [19].

This way, mHealth allows people to overcome geographic as well as economic barriers to attend health care services being at their home. Moreover, mHealth can also address the chronic shortage of healthcare workers especially in developing countries [19].

2.5.The Role of mHealth Technologies in Healthcare System

Health systems of nations are currently undergoing an unprecedented transformation as healthcare providers are under pressure to increase access and reduce costs without compromising the quality of their services. To achieve these goals, healthcare institutions are making significant investments in advancing information and communications technologies designed to support the collection and reporting of critical patient data that is used for decision making.

Public health research and electronic health record equip healthcare providers with real-time information that can improve the quality and timeliness of patient care while also increasing operational efficiencies that can reduce the cost of care. Mobile technologies are playing an important role in the overall effort to collect and maintain accurate and consistent patient data. Clinicians now use tablet computers, so-called smartphones and other devices to record and retrieve vital patient information in real time [20].

In addition, wireless monitoring equipment that reads and records patient vital signs such as heartbeat and blood pressure can automatically transmit data to tablet computers or smart phones via any number of wireless network technologies, seamlessly updating patient records. These and other electronic devices operate through specialized software applications designed to facilitate data exchange among various platforms [21].

The use of mHealth technologies provides multiple benefits to patients, healthcare professionals and healthcare institutions. Devices and products based on mHealth technologies can

automatically update relevant public health research and electronic health record in real-time, thereby providing healthcare professionals with the most current patient medical data and increasing the efficiency and effectiveness of patient monitoring and treatment. Such devices also provide patients with greater mobility and independence, allowing them to resume everyday activities outside of the traditional healthcare settings. Mobile applications have enabled medical consultancy, treatment, drug administration and the provision of laboratory results to take place outside the hospital [22].

Healthcare institutions using mHealth apps can improve the overall quality of patient care while also optimizing resource utilization and the effective and efficient use of caregivers. These and other roles of mobile technology are expected to drive growth in the market for mHealth devices and products.

2.6.Varieties of mHealth

Up until now, a number of mHealth applications have been developed and deployed mainly with the intention of assisting the health care provision particularly, the maternal and child health programme. The following are among the few ones.

2.6.1. My Pregnancy Today

My Pregnancy Today is a daily pregnancy application that guides women with expert info insights, and tips. Whether a woman is trying to conceive, pregnant, or already have little one, the app could be made a go-to source in every day parenting journey. It gives answers and prepares for baby's birth. The versions available are for smart phones, iPhone, iPod Touch and Android. This targets high-class user who have the money to buy smart phones and pay for the data charges. My Pregnancy Today app has other features like fetal development images that are developed by expert medical illustrators. Pregnancy checklist is an interactive to-do list filled with activities and reminders to keep you on track with decisions; doctor-appointments; and more. A nutrition guide gives the tips and recipes to help eat well and manage cravings [23].

From the description given above, one can understand that My Pregnancy Today is a mHealth application that contributed much in the field by informing mothers about their fetus and follow their nutritional status of their children. However, it is mainly inclined to providing expert-level information that tries to tell what mothers would do in their day-to-day activities. Besides, it is confined to cell phones meant for high-class users serving clients who are primarily literate and from well-to-do families.

2.6.2. Wawa Net

Wawa Net uses text messaging via mobile telephones to enhance the health of mothers and infants by enabling them to receive customized advice on nutrition and potential problems during pregnancy. This mobile solution seeks to solve the problems of maternal mortality in Peru, emphasizing that an improvement in the health of mothers and infants would also contribute to Peru's attainment of the Millennium Development Goals. However, Wawa Net is solely textual as its main focus is on rural women it is more information based making the approach different to this research. The mobile application for detecting risks during pregnancy will determine based on the expectant mothers' information whether she is at risk or not [24].

Despite the fact that Wawa Net contributed to the reduction of maternal and child mortality in Peru, it is only designed to broadcast textual pieces of advices regarding child feeding as well as signs and symptoms occur during pregnancy to candidate mothers. It is almost similar to My Pregnancy Today except that their geographical coverage, the former focusing on rural women while the later meant for high-class urban dwellers. Hence, both of them are aimed at educating and awaking mothers in the overall activities related to parental practices.

2.6.3. Text4Baby

Text4baby is a program designed to educate pregnant women and new parents regarding their baby. Text messages are sent three times a week with information on how to have a healthy pregnancy and a baby [26].

The text messages were framed in accordance with the pregnant woman's due date or the baby's date of birth. The free text messages provide tips on subjects including breastfeeding, car-seat safety, developmental milestones, emotional wellbeing, exercise and fitness, immunizations, labor and delivery, nutrition, antenatal care (ANC), safe sleep, and stop smoking [26].

Mobile Health for Mothers similar to **Text4Baby** includes free mobile text messages on antenatal care (ANC), appointment reminders and phone calls from health coaches. This will have a great impact and reach to the users since all mobile phones are enabled to receive text messages [26].

As elaborated above, **Text4baby** is another mHealth application program developed to educate pregnant women by sending tailored text messages that goes along with their gestational age three times a week. The contents of the text messages are said to be for antenatal care, reminding appointments and goes up to making phone calls by health coaches. Thus, **Text4baby**reachesmore users living in the wider rural community with any kind of mobile phone at hand.

2.6.4. Mobile Midwife

Mobile Midwife was a mobile phone-based health education program for Indonesian pregnant women and recent parents. It uses mobile technology to send antenatal (ANC) and postnatal (PNC) health information to community health workers so that they can collect and share health data. Women registered for the program receive either SMS or voice messages with health information [25].

The messages were designed to be applicable to both men and women, as it is anticipated that both partners would listen to the messages. The messages were designed to tell women what to expect during pregnancy, dismiss tradition and cultural practices, and provide general health information [25].

The midwife mobile phone project was first implemented in 15 health centers in Aceh Besar, Indonesia involving 223 midwives. The study group used project cell phones to transmit health statistics to a central database, contact coordinators and peers for health advice and information, and communicate with doctors and patients [25].

Unlike to the previous apps, Mobile Midwife is a mobile technology meant to send antenatal and postnatal information to community health workers with a view of collecting and sharing health data. Expectant mothers registered in the database do receive SMS or voice messages applicable to both men and women. Mobile Midwife is a little more advanced in its features, coverage as well as involved bodies that help to work on eliminating traditional harmful practices.

All in all, though all these are varieties of mobile health applications, they in general could be shown using the following architecture given in figure 1.

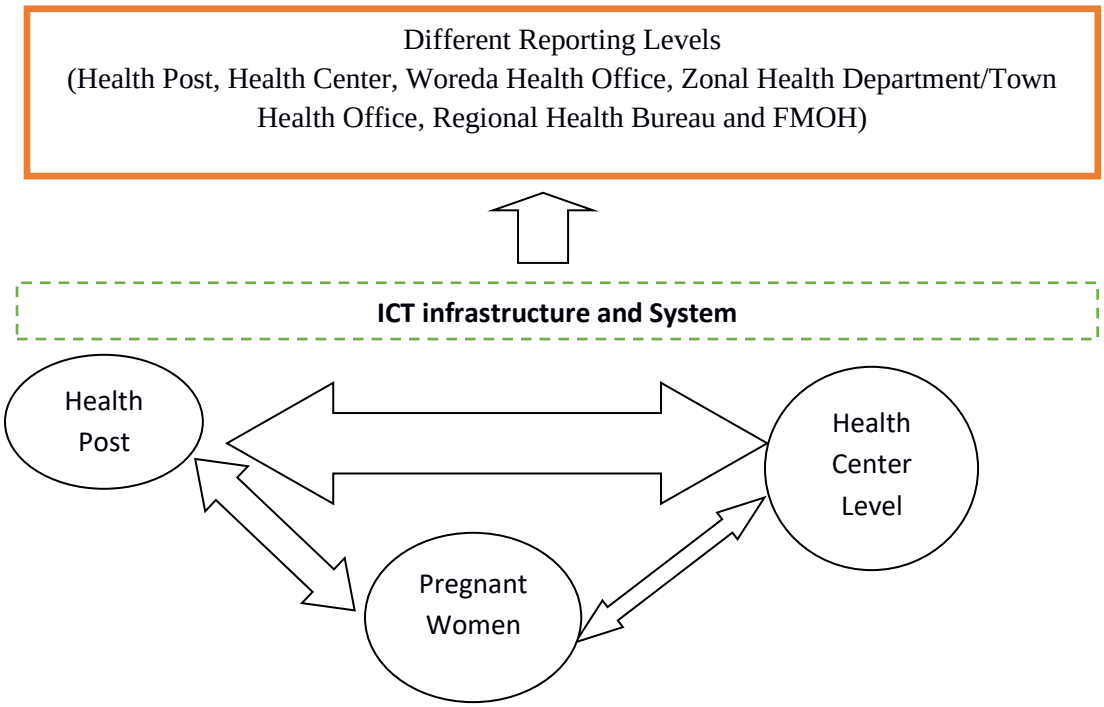

Figure 1: System architecture/work flow [25]

Procedures:

- Direct communication between health centers and health posts
- Both health facilities communicate with pregnant women
- Pregnant women communicate with both health facilities

One of the primary advantages of mobile health applications is to facilitate communications among concerned parties. The figure below demonstrates the end-to-end communication process among the devices, service providers and service seekers

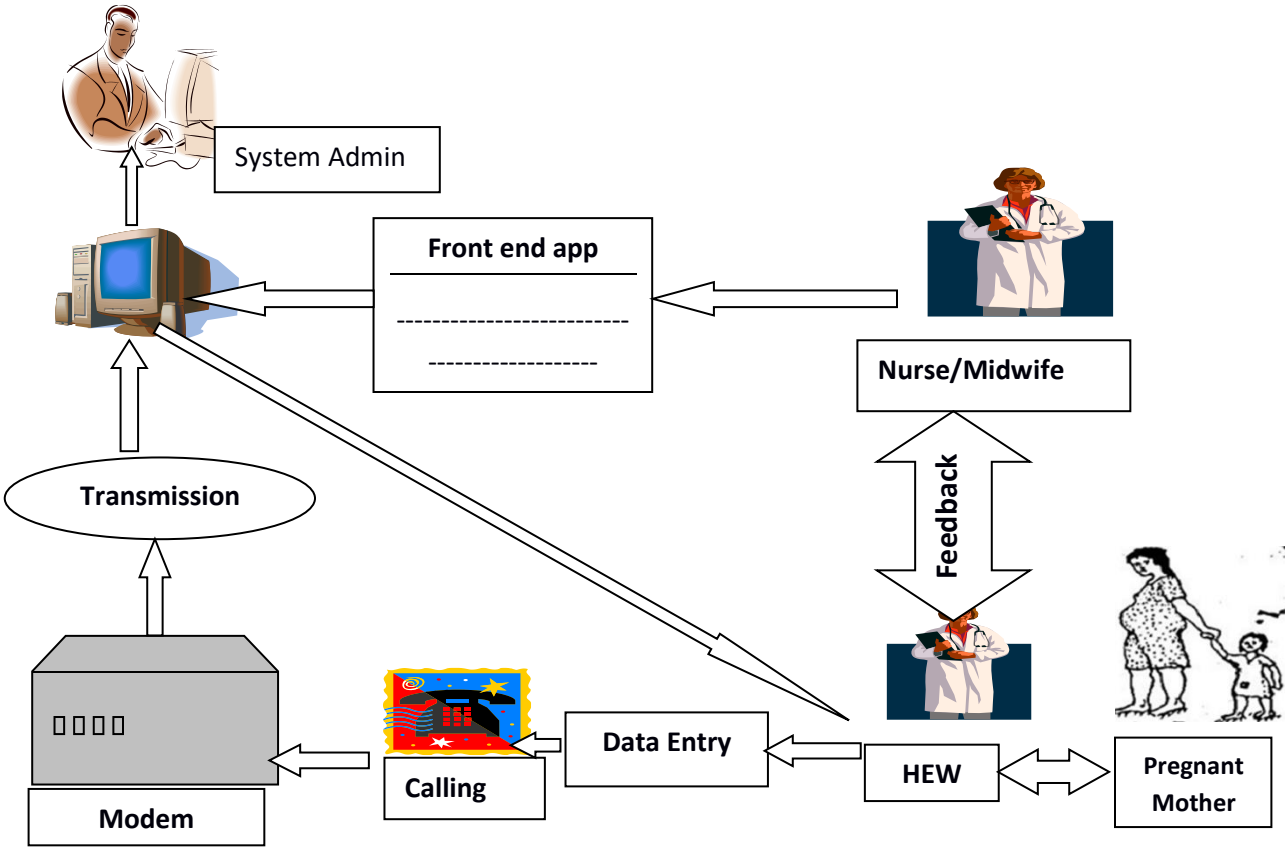

Figure 2: End-to-End Communication in mHealth [25]

Procedures:

- Interaction between the health extension worker and pregnant mother
- Collecting the required data from the interaction
- Entering the data in to the application
- Calling to connect to a computer at health center via modem
- Data will be transmitted and stored in to the database
- The Nurse/Midwife access the data through front end application
- The Nurse/midwife reviews the data and will give the feedback to HEWs

Table1: Major Actors in mHealth

S. N	Actors	Description
1	System Admin	Manages and monitors the overall mHealth system
2	Midwife/Nurse	Health professional providing health service at health center level
3	Health Extension Worker (HEW)	Another health professional providing health service at health post level
4	Pregnant mothers	Mothers who seek healthcare service

2.7.M-Health Application in Ethiopian Context

The sustainable development goals (SDGs) dictate "reaching the unreachable", with an intention to address inequalities. As mobile technology is becoming more and more affordable, powerful, and accessible also in low-income regions, it brings real opportunity for governments to achieve the objectives and goals set in the area of public health [27].

Digital transformation has seen the telecommunication sector to shift its view on telephony from just voice calls, SMS and communication to connectivity which has become a tool for development. Mobile can increase the quality, reduce the cost and extend the reach of healthcare. mHealth, as defined by the World Health Organization (WHO), is "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices". These devices have the potential

to generate significant impact by reaching women and children who lack access to essential healthcare and nutritional information and services [27].

The "*Technology Enabled Maternal and Child Health Care* (TEMACC)", an Ethio-Austrian joint project launched in 2015 to support and contribute to efforts to address development needs through effective utilization of ICT in maternal and child health programs, is established to develop an appropriate ICT-based service, which enables mothers to receive public health and related information without the need to travel long distances [28]. In addition, the health extension workers receive health education online or on their mobile devices by interacting with a specialist elsewhere without leaving their hometown. It also allows collaboration and consultation among healthcare professionals, and creates virtual professional communities for improving maternal and child healthcare [27].

Despite the coverage and energy constraints, HEWs are already using mobile phones to facilitate their work. They use mobile devices to communicate with supervisors, professionals at health centers, kebele heads and other HEWs to discuss emergency situations and protocols. In cases of emergencies related to delivery, they are contacted on their mobile phones, and when vaccines are running out of stock, they sometimes call health centers for refill.

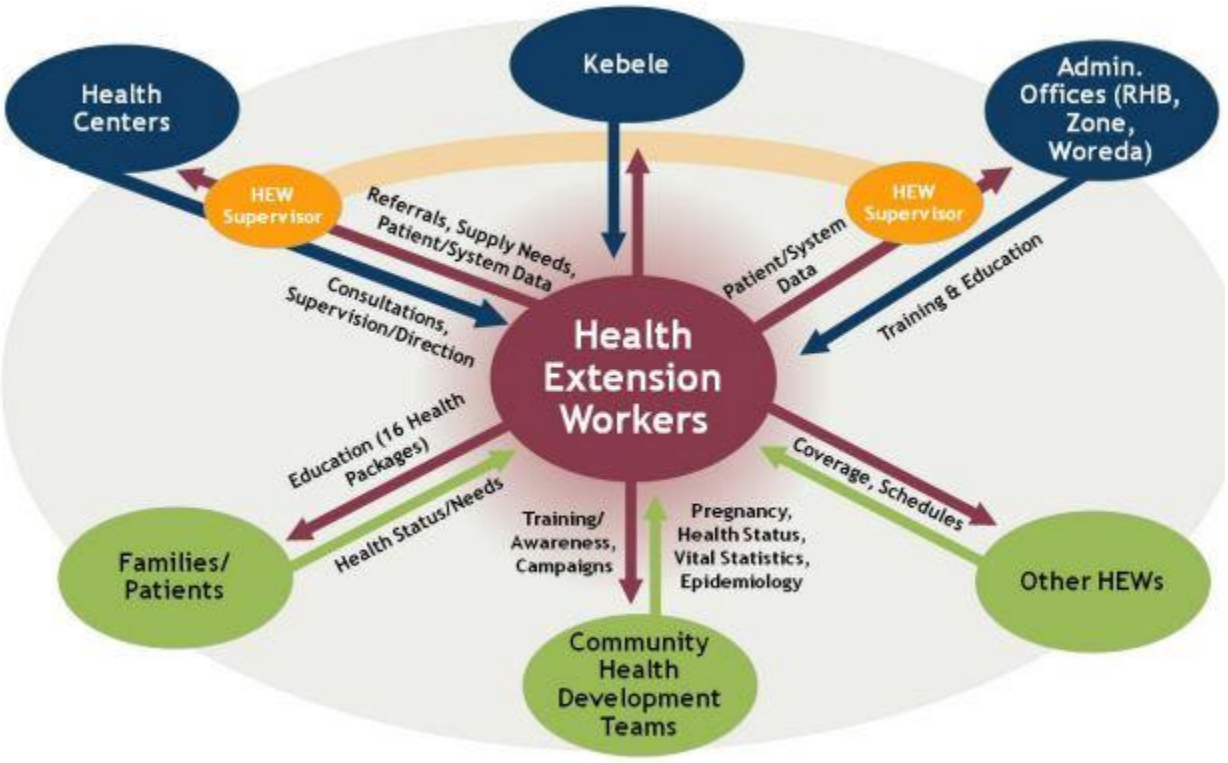

Figure 3: HEW Information and Communication Relationships [27]

Particularly, in the Ethiopian context, communication is essential to combat misinformation, and improve the reliance on non-professionals for treatment and support. Communication also provides Information, Education and Communication (IEC) services that are critically needed in preventing infection, encouraging testing, and facilitating access. The realization of the potential of mobile devices to improve healthcare system has resulted in many initiatives that are running on mobile devices in Ethiopia [29].

Health initiatives have attempted to utilize mHealth tools to deliver or/and improve health services to rural Ethiopia, and many have suffered from challenges ranging from poor network coverage, limited technological literacy of health workers and government commitment. Hence,

the TEMACC-Ethiopia project specifically explores these challenges and work on how they can be overcome to facilitate significant improvement in maternal and child healthcare practices using information and communication technologies [27].

2.8.Conceptual Framework

The existing conceptual framework has four distinct modules namely: Registration/Vital Event Tracking, Data Collection and Reporting, Provider to Provider Communication Facility, and SMS and Voice Communication.

The Registration module is the initial point where basic demographic data is captured for identification of clients of maternal health services for subsequent follow ups and tracking of progresses over time. The Data Collection and Reporting module helps to capturing clinical data resulted from daily services in accordance with the schedules dictated in the guidelines and program protocols for latter reporting.

Next, Provider to Provider Communication module establishes effective communication between the heath extension workers in the community and the midwives at health center with a view of exchanging information and facilitation of other related services. The SMS and Voice Communication module is used to generate tailored voice and short messages to inform the midwives and facilitate communication with HEWs.

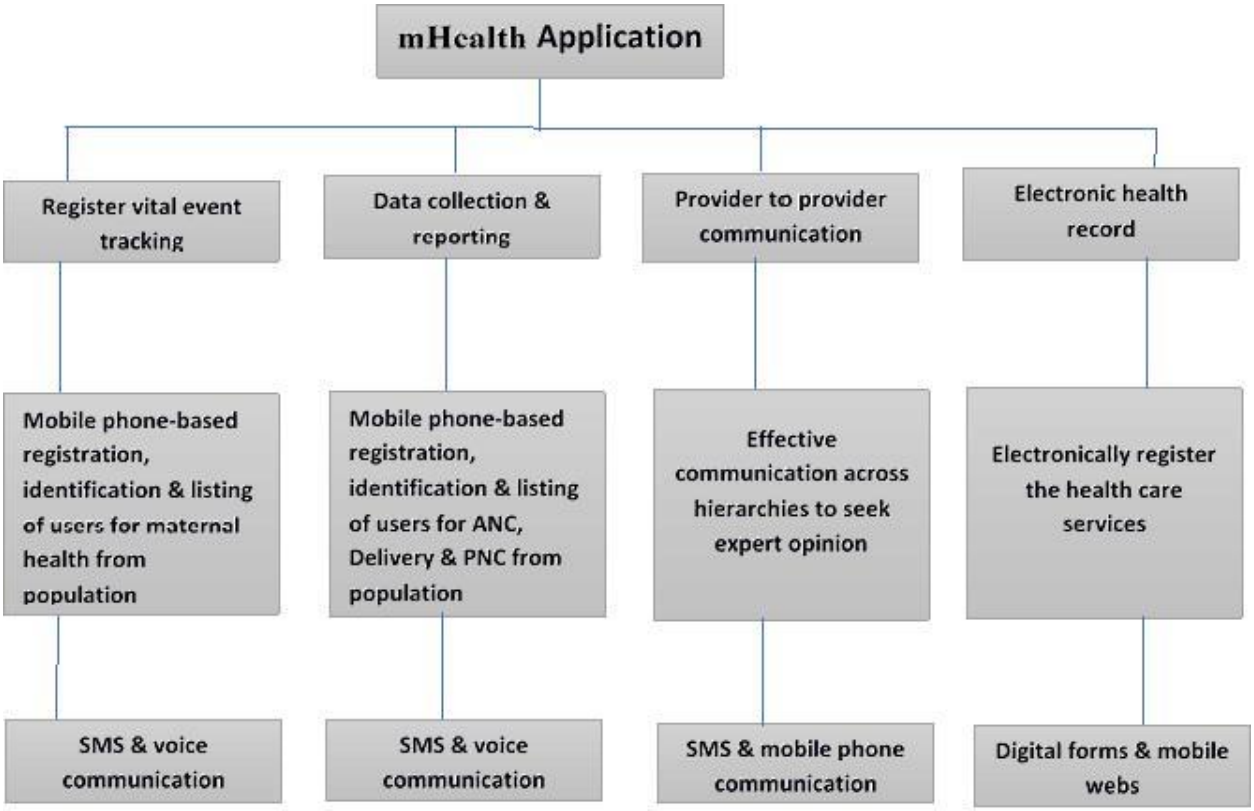

Figure 4: The existing Conceptual Framework

From the above framework, it is possible to conclude that there may be other modules that could be included to it so that the functionalities of the application would be more robust. Taking this as a pretext, one key module seems to have been missed from the existing framework, i.e., Client Education and Behavior Change Communication.

Client education and behavior change communication module focuses on generating time-bound text and voice messages that are full of health information aimed at educating pregnant mothers about complications during pregnancy, birth preparedness, symptoms of delivery and issues related to it, as well as postpartum conditions in addition to child care and nutritional advices with a view of bringing attitudinal change.

Besides, critical messages generated as a result of emergency situations reported by HEWs or midwives may be parallelly copied to HDAs to work on possible assistant and facilitators of ambulance services so that a delay, which is one of the factors for maternal mortality, could considerably be minimized. Moreover, professionals at health centers could get ready for the delivery procedure while the expectant mother arrives at the facility.

CHAPTER THREE:

Research Methodology and Tools Used

3.1. Methodology

The Cambridge Advanced Learner's Dictionary and Thesaurus defines methodology as a system of ways of doing, teaching, or studying something [30]. Hence, beyond scrutinizing the application through observation, the researcher has to interviewed 48 informants including midwives, nurses, health extension workers as well as clients have been involved in the system from Sebeta Hawas Woreda where mHealth has been piloted and implemented and expanded to the remaining ones.

A total of three Primary Health Care Units (PHCUs), with an average of five satellite health posts under each because of short period of time and lack of budget to did the study, has been identified to select the informants. Random sampling is one of the simplest forms of collecting data from the total population and the reason to use the random sampling is ease of use and its accurate representation of the larger population. Selecting one health professionals from each primary health care unit have been selected for this interview. In addition, selecting two clients who are pregnant, registered and not registered in the database using systematic random sampling technique by lottery method approach.

Moreover, in compiling this thesis, the researcher also tried to explore the existing system based on the crafted framework so that the gaps could easily be identified and thereby included in the proposed one. In doing so, the overall system has been explored, the components and features are evaluated, the problems of mHealth application.

Therefore, few components have been incorporated in the proposed framework of mHealth application to be physically modeled and ways to integrate with cloud services. By involving health professionals and clients to evaluate the existing system, available process models have been examined and used as well.

3.2. Process Model

As there are different components to be proposed that are meant to be integrated to the designed system, analyzing mHealth application at a time critically was impractical. In order to manage the dynamicity of analyzing and integrating the components, agile process model was used. The rationale behind utilizing this process model is that it permits iterative prototype development to make certain changes on the system aspects [31]. Unlike to this, the other approach, like waterfall process model, enforces a complete specification of all the requirements.

Therefore, in the process of developing a prototype for the suggested antenatal, delivery and postnatal care application, the agile approach was used to add health education features on the existing mobile health application. The researcher then proposed on the possible way to integrate the app with cloud messaging. Finally, the approach was also used for linking the components with mHealth app.

3.3. Software Tools Used

There are different kinds of software tools used in this study at different instances. This software includes platforms, programming languages, database server, google cloud server and related AVD (Android Virtual Device) tools.

3.2.1. The Platform Used

Currently, there are several operating systems being used on different mobile devices. These operating systems include iOS for Apple, Symbian for Nokia and Android for other devices. Out of these, Android is the most popularly used one. Furthermore, it is available for free as an open source with many important features and functionalities for the development of prototypes.

Generally, android is an OS based on Linux kernel that uses Java as a programming language to interface the components. The major components include: a stack of OS, middleware and applications, Android SDK (Software Development Kit) which provides all the necessary tools to develop Android applications (Compiler, Debugger, Device emulator, virtual machine, and

rich user interface library) [32]. Furthermore, it supports 2-D and 3-D technologies using Graphical Libraries, web kit, access to file system and provides an embedded SQLite database.

From the available ranges of android versions, Android 3.1.3 was used since it can support a wide range of users as indicated in figure 5. With regard to this research, communication, push notification and messaging are used in the development of mobile health application. These could be accomplished using its features, more specifically, elements indicated on the platform architectural layers presented in figure [32].

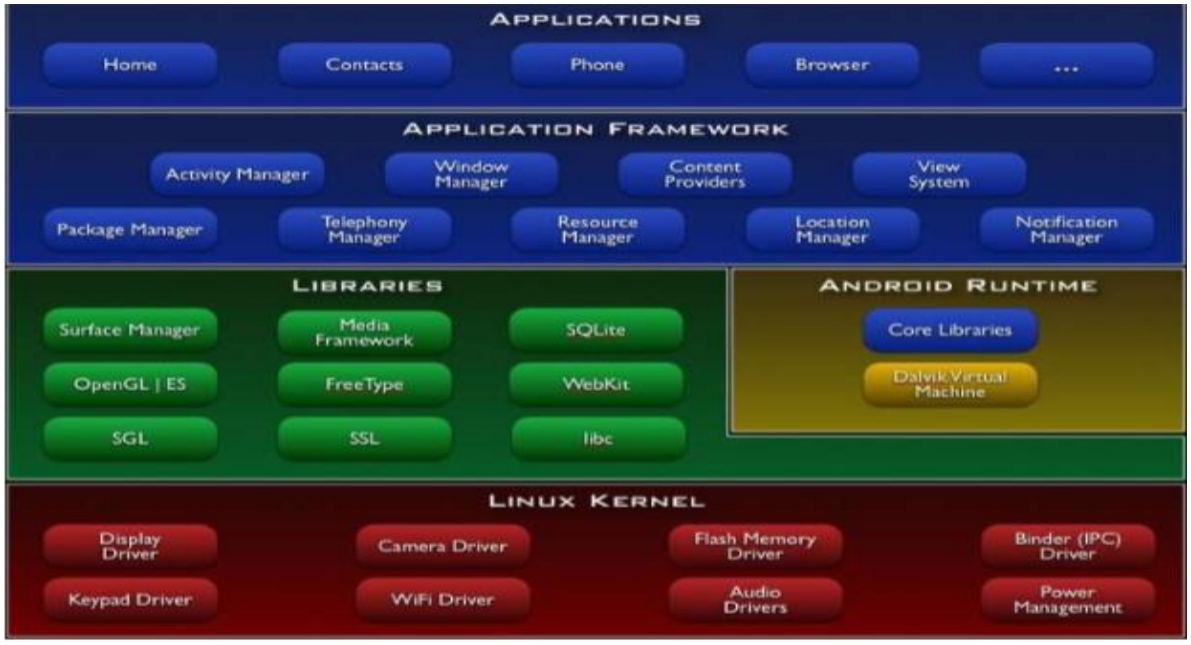

Figure 5: Android OS general structure

Application Layer

It is the most upper layer in android architecture. All the applications like camera, Google maps, browser, SMS, calendars, contacts are native applications. These applications work with end user with the help of application framework to operate. In this layer, there are managers which enable the application for accessing data. These are as follows: Activity manager: It manages the lifecycle of applications. It enables proper management of all the activities. All the activities are

controlled by activity manager. Resource manager: It provides access to non-code resources such as graphics etc.

Notification manager: It enables all applications to display custom alerts in status bar. Location manager: It fires alerts when user enters or leaves a specified geographical location. Package manager: It is use to retrieve the data about installed packages on device. Window manager: It is use to create views and layouts. Telephony manager: It is use to handle settings of network connection and all information about services on device [33].

Application Framework Layer

Android applications which are developing this layer contain needed classes and services. Developers can reuse and extend the components already present in API. The application framework consists of the various services that implement the Android app API. Every framework service is responsible for providing access to one specific system resource.

System apps, such as Contacts, Dialer, or SMS complement the application framework with commonly requested functionality. However, in contrast to the application framework services that are fixed parts of any Android deployment, system apps are exchangeable or omit table and, more importantly, are simply apps that are programmed against the same application framework API as third-party applications [34].

Libraries Layer

Android has its own libraries, which is written in C/C++. These libraries cannot be accessed directly. With the help of application framework, we can access these libraries. There are many libraries like web libraries to access web browsers, libraries for android and video formats etc. [35].

Android Runtime Layer

In this section, all the android applications are executed. Android has its own virtual machine i.e. DVM (Dalvik Virtual Machine), which is used to execute the android application. With this DVK, users are able to execute multiple applications at the same time.

The runtime executes byte code generated from Java-based applications and Android's SDK components. The runtime provides the code executed within its environment with the necessary hooks to interact with the rest of the system, such as the operating system, the application framework services, or the native Android user space. Every process executing an application runtime environment is usually forked from a warmed-up [36].

Linux Kernel Layer

This layer is core in android architecture. It provides service like power and memory management, security etc. It helps in software or hardware binding for better communication. Linux Kernel abstracts and mediates access to the hardware resources, including the CPU.

The Linux kernel presents a virtual machine interface to user processes. Processes are written without needing any knowledge of what physical hardware is installed on a computer - the Linux kernel abstracts all hardware into a consistent virtual interface. In addition, Linux supports multi-tasking in a manner that is transparent to user processes: each process can act as though it is the only process on the computer, with exclusive use of main memory and other hardware resources. The kernel actually runs several processes concurrently, and is responsible for mediating access to hardware resources so that each process has fair access while inter-process security is maintained [37].

3.2.2. Android Development Environment

It is one of the main sub-parts of android architecture that runs on mobile devices used to develop mobile health application. On Android, there are specific features intended to facilitate application development by a developer. These include: -

- **Eclipse**- is a separate multi languages software development environment containing a base workspace and an extensible plug-in system for customizing the environment for the development on Android platform.
- **ADT** (Android Development Kit) is a plugin for Eclipse IDE (Integrated Development Environment) that is designed to:

    - Provide a powerful, integrated environment in which Android application is built.
    - Extend the capabilities of Eclipse for quickly setting up of a new Android project, create an application UI (User Interface), add packages based on the Android Framework API and
    - Provide debugging utilities
- **SDK** provides the API (Application Program Interface) libraries and developers tools space necessary to build, test, and debug apps for Android.

By integrating those platform components, it is possible to develop the required mobile health application. On the other hand, a full functional Android Studio is designed for developing Android apps. In this research, the Android Studio Version 3.1.3 that contains feature to integrate apps with the internet and cloud service is used. Furthermore, the development studio consists of all the required components like Eclipse ADT and Gradle scripts.

3.2.3. AVD and API level

For the purpose of testing the proper functionality of the prototype of mobile health application in this study, several AVDs with range of API levels were used. The AVD software emulates the real device sharing of the hardware resource of the hosting device. Generally, the sample of AVD used with the corresponding APIs is specified in figure 6.

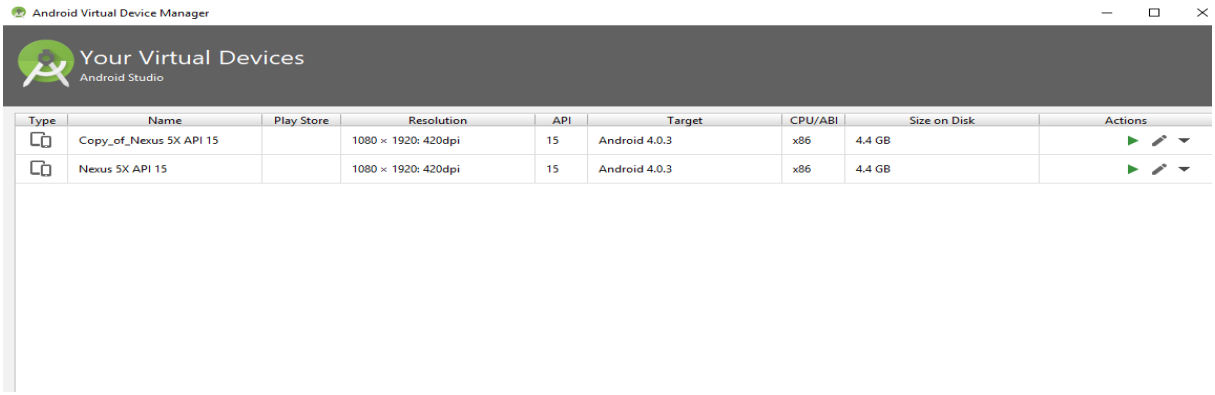

Figure6: Sample of virtual device used for the prototyping

3.3.4. Web Technologies Used

The architecture of mobile health application in the study consists of a web application used to communicate online. In order to enhance the access to the system through mobile devices, several web development technologies like jQuery Mobile and Bootstrap had been used. Web technologies like jQuery Mobile and Phone Gap intend to enhance the functionalities of web app to use local device resources. However, in the app under investigation, Bootstrap was preferred since the major emphases were making the mobile health application a responsive one.

3.3.5. Bootstrap

Bootstrap is a simple HTML, CSS and JavaScript framework for developing a responsive and user-friendly app. A responsive website is that with a property of a site to automatically adjust itself for better user experiences on all devices, from smart phones to desktops.

Finally, for the prototype implementation, Notepad++ editor and the PHP script language for Server-side scripting was used. The reason behind using PHP was it allows us to encode and decode JSON (Java Script object notation) by the help of **json_encode ()** and **json_decode ()** functions. In this manner, the JSON which is an open standard for exchanging data on the web was utilized for relaying messages from the web server to the FCM server.

3.2.6. Data Management

Obviously, mobile health application in this work requires back end permanent data storage. To this end, database servers like SQL, MYSQL etc. are commercially available. MYSQL is used for the prototype test in the study. In relation to the management, the data registered by the HEW from the expectant mother would be stored in the database at the health center with the help of communication facility deployed where continual monitoring of the progress based on subsequent follow up schedule is being conducted as per the service protocol. It is from this warehouse the required regular as well as customized report will be generated and disseminated to the parties in need of it.

3.4. Method of Evaluation

Finally, the evaluation of the prototype application in the real environment has been conducted by installing the application on mobile devices for 5 health professionals and 5 clients registered in the database to check whether it sends and receive the text as well as voice messages to the client and service provider. Hence, as far as the result is concerned, to test the performance of the prototype application has been witnessed as encouraging and a successful one. As a general practice, it is possible to deploy the source code of the mHealth application on a cloud server for central accessibility where seam-enabled device is attached to it to facilitate the intercommunication to this server

CHAPTER FOUR:
PROPOSED MOBILE HEALTH FRAMEWORK AND ARCHITECTURE

Up until now, the thesis tried to introduce mHealth in general and gone through available literature that helps to assess the existing mobile application being implemented in health posts and health centers under the Oromia Regional Health Bureau. In addition, the methodology used has been discussed in line with available models in developing a software that have laid the ground for the proposition made hereafter. Moreover, the architectural linkage with the cloud technology is also going to be proposed in this chapter.

4.1. Mobile Health Models

As it is discussed earlier, there are two prominent process model types called Waterfall and Agile. In order to manage the dynamicity of analyzing and integrating additional components to a system, agile process model was used. Contrary to this, the other approach, waterfall process model, requires a complete specification of all the components.

Hence, in the process of developing the prototype for the suggested antenatal, delivery and postnatal care application, the agile approach was used to add health education features on the existing mobile health application.

With a view of coming up the proposed framework of mobile health application under the study, the overall mobile health system was revisited as shown in figure 7 below because it can't involve the health education feature. The application is meant to serve the communication process with mothers, HEWs, Midwives, Ambulance system and also improve the referral linkage between health posts and health centers as well as hospitals.

Therefore, based on the literature review discussed in the section above, research topic and objectives, as well as the known use of mHealth application, the following proposed framework has been developed based on agile process model.

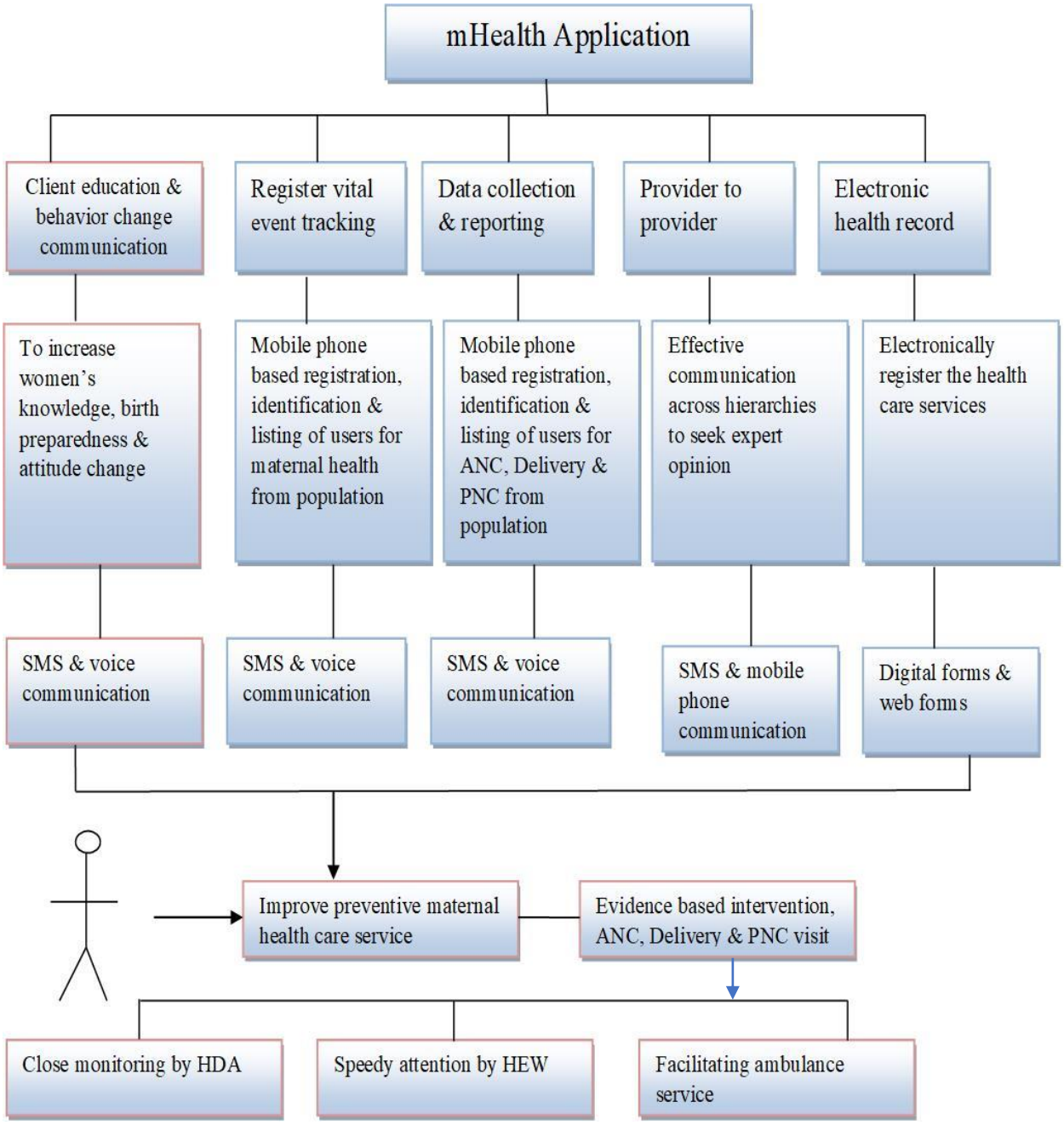

Figure 7: Proposed mHealth framework for health education andmaternal health care services

The full description of the proposed mHealth Framework:

1. Client education and behavior change communication
    - Generally, messages full of health education to pregnant mothers during pregnancy, at times approaching to delivery and afterwards are regularly generated and sent through SMS and voice for birth preparedness and attitudinal change
2. Registration/vital event tracking
    - This helps for initial registration to capture basic demographics for identification of clients of maternal health services for subsequent follow ups and tracking of progresses
3. Provider to provider communication
    - This part is used to establish effective communication between the heath extension workers in the community and the midwives at health centers with a view of exchanging information and facilitation of services
4. Electronic health record
    - This helps for capturing clinical data resulted from daily services in accordance with the schedules dictated in the guidelines
5. SMS and voice communication
    - This is a module that generate tailored voice and short text messages to inform the mothers and facilitate communication between care providers and subordinate facilities such as ambulance.

4.2. Integration to Cloud System

A certain system is nothing unless it is widely accessed and met the primary objective it actually developed for without any constraint. The booming volume of data over time need not be a hindrance on the proper interoperability of the system. Thus, the proposed architecture of mobile health application shown in the figure 8 was specified independently through agile approach in

order to achieve the proper functionality of all the features and show the method of interaction of every component.

As the core value of this thesis was developing a prototype followed by a sequential integration of the remaining components of mobile health application, the application follows the MVC (Model View Controller) pattern. This was applied to manage separation concern so that when modifying one aspect, the other should remain unchanged. In general, the proposed architecture to link mobile health application with cloud computing is shown in the figure below.

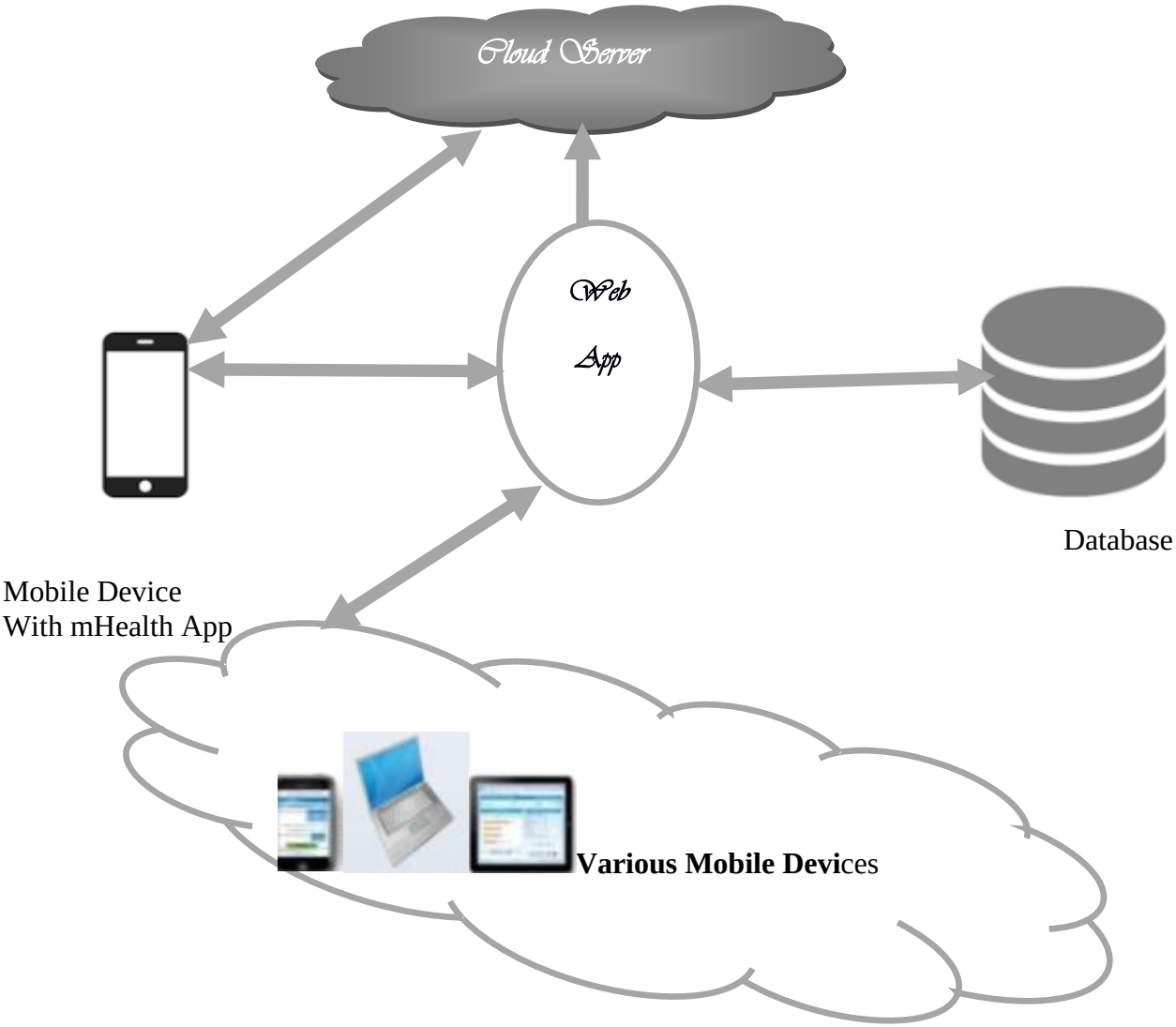

Figure 8: The proposed architecture linking mobile health application with cloud system

4.3. Description of the Physical Architecture

The general architecture of the mobile health application of this research has represented the major subcomponents described above. It represents the whole physical system architectural framework that could somehow ensure the benefits of mothers and children involved in the system as discussed below.

- **Mobile Device**

According to the context of the study, mobile devices are those devices that are android powered and used to deploy the mobile app that could let mothers get information related to maternity and child care. These mainly include hand-held cell phones and tablets that clients of antenatal, delivery and postnatal care do receive educative and alerting messages. In the system architecture, these devices have the highest interaction and wider usage. As the topic itself is concerned with mobile and mobile features, these devices play a central role in interacting with the remaining segments like databases and clouds.

- **Mobile App**

Here comes the core concept of the study as the app under the study bases on mobile architecture. It resembles any application that runs on mobiles devices either offline or online. The mobile app defines the data types, interaction between segments, data presentation and the whole architecture of information flow at the backend of the application. In addition, the basic client records taken upon registration and stored in the database is used to periodically create auto-generated tailored messages to be dispatched to pregnant and lactating mothers. Since the app could be accessed through a certain network platform, it can also be integrated with cloud services in order to maximize the scope of its availability.

- **Cloud Server**

Cloud server is a high capacity storage to carry large volume of data that users can be connected to it through a network architecture. In the suggested mobile health application, both the mobile

app and the web application are integrated to the cloud server for all involved parties could easily access it from anywhere. This was intended to enhance the functionality of mobile health applications by technically including the available services appropriate to the context.

- **Web App**

These include web browsers that help to access data stored in a specific location from anywhere where Internet connection is available in the online environment and locally in when the accessibility is offline. This is a segment that could interface the users (care providers, clients, ambulance drivers and managers) with the database. Web App is also the component that facilitates and manages the communication between the frontend interface with the back-end storage to realize access to information of maternal and child health service clients. The whole component can only be accessed through it. Apart from this, the mobile health application can be accessed through different devices using web applications. In this regard, it is possible to say that the application has good portability and accessibility features. Thus, this part could be seen as a bridge to interfacing to communicate between users and storages.

- **Database**

It is a container used to store crucial data of antenatal, delivery and postnatal care clients in the database. In the physical architecture, the database is used to store all the data related to the mobile health application. For more illustrations of the necessary logical steps undertaken in the overall operations, the sequences of interactions are stated in the implementation subsection.

CHAPTER FIVE:
IMPLEMENTATION AND EVALUATION OF THE PROTOTYPE

In this study, the envisioned mobile health framework consists of external and internal components. The users of the system are considered as outsiders while the actual mobile health application architectural framework is analyzed and designed separately as internal aspects of the system. Therefore, this chapter entertains the users with respect to the actors involved and the application's architecture from its development environment as well as implementation perspective before it ends up with evaluation mechanisms. In addition, for evaluation interviews conducted and available models in developing software that have laid the ground for the proposition made hereafter

5.1 mHealth Application Prototype Development and Implementation

5.1.1. Design of Basic Functional Requirements

For the prototype development agile process model was used for some major and basic functional requirements. Since the suggested mobile app is for android platform, the following contents were defined in the android studio project app fill. These are: -

- **Activity classes**

These represent the user interface components of the app that do appear on the screen of a mobile terminal. It can hold several subcomponents as themes, views etc.

- **Views**

It is a single element of activities on a screen and can be considered as a building block of the activities. Examples: Button, Image View, Text View, Web View

- **Services**

Used to handle functionalities that run at the background

- **Intents**

This is the part that handles the mechanisms of navigating between activities through intent messages relaying.

- **Firebase base messaging management and services**

This part is intended for capturing the functionalities of integrating the mobile app with the google cloud service, fire base cloud messaging. By applying the mobile health on android studio, all the necessary functionalities of the mobile app have been accomplished. The required functionalities are used for interfacing with the whole components. Thus, the basic requirements are user interfaces for interacting with the mHealth. These include registering a user to the database, accessing mobile health, receiving and sending push notification. Besides, the functionality of navigating within the system component is also an important issue.

5.1.2. Development of the mHealth App

This mobile health application was developed for android platform using android studio version 3.1.3 development environment. In the category of mobile applications, mHealth applications are installable apps that can utilize local device resources efficiently.

In the context of this study, one of the reasons to propose the integration with cloud service is to expand the accessibility of the mHealth application. Correspondingly, the other rationale behind making the app an ISP enabled is to acquire the capability of sending and receiving push notification to the service providers and clients from cloud messaging service.

5.1.3. Deployment of the Mobile Health Application

The mobile health application under the study has two major components namely called installable .APK file of the mobile app and device-side messaging web application. The two components are integrated and abled to communicate through cloud messaging service. In the following subsections, the detailed specification of these components is going to be discussed.

5.1.4. Actors Involved

The potential users that interact within this application, specifically in the mHealth app configuration, exploration and management with their respective roles they might possess are categorized as follows.

System Admin: Configures, manages and monitors the overall mHealth application.

Midwives: Health professionals providing health services at health center level

Health Extension Worker: Another health professional providing health services at health post level

Pregnant mothers: Women who seek healthcare services related to pregnancy

All in all, these are among the users of this mHealth application with varying roles and responsibilities that extend from ordinary user to the level of application administration that would let the components work together in an integrated manner. The System Admin is a built-in user while the others are created by the admin assigning the necessary rights and privileges they ought to have.

5.2Implementation of the Prototype

5.2.1 Messaging Management

The main agenda in implementing a mobile health service lies in persistently improving the access, quality and equity of the health services on the ground. In line with that, controlling the interaction of the user with the system needs a great attention. To deal with such a crucial aspect of this study, the messaging management subcomponent of the mobile health application was considered separately. This subcomponent basically is intended to interlink the backend persistent large volume of data with the hosting app that interfaces users with the system.

Thus, in this approach the system architecture would take client-server platform. As the messaging component is a normal web-enabled application, it could be accessed by different ranges of terminals including desktop computers and mobile devices. Therefore, for the messaging management in this study, the bootstrap web development technology was used so that it could be accessed by users from all range of devices with varying screen size.

5.2.2 Implementation of Prototype Application Interfaces

In order to realize the basic requirement functionalities in the design specification discussed in the earlier section, within the mobile app project package, several android files were included. Basically, in android application development on android studio, app development project structure always takes the model view controller form for customization and development.

Thus, the prototype of the app was developed and implemented on the android studio by the project package name "**com.example.mhealth application**" to have the entire required interface functionalities. Some of these file directories are:

- **App**

This is the core directory which holds all the source code files for the MVC within the src→sub directory. The internal library, **build.Gradle,** is also included in this directory. Moreover, the directory contains the dependency file "**google-services.json**"for synchronizing the app to the cloud service FCM. To facilitate the communication between the android app and the FCM, the **.json** file should sync with the android studio library files.

- **External Library**

This part of the project file is responsible for issues regarding the platform and the SDK. It also contains the detail of associated files and the emulator properties.

- **Model View Controller Structure**

In android studio, model view controller is the inherent structure for every app project file. This way of organizing files has several advantages like avoidance of certain concerns. In doing so, it is possible to modify one aspect of the project without affecting the other. For example, the view part of the file can be updated or changed in separate of the model and control part. The prototype design of the mobile app in this study followed the MVC project file structure

- **Model**

The model represents an application's data and contains the logic for accessing and manipulating that data. Any data that is part of the state of the application should reside in the model objects. The preview layout of the whole element is seen in design view. For the mobile app in this study also there were a couple of model layouts: design view and text view.

- **View**

It is java class file that is used to define the actions and events we can apply on the widget elements of an activity. In the design of this prototype, a number of view files were included. As it is illustrated in the figure 14 below, a sample screenshot of the view file was taken. The activity is mainly responsible for accessing contents from mobile health management app.

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayoutxmlns:android="http://schemas.android.com/apk/res/android"
xmlns:app="http://schemas.android.com/apk/res-auto"
xmlns:tools="http://schemas.android.com/tools"
android:layout_width="match_parent"
android:layout_height="match_parent"
tools:context=".MainActivity"
android:layout_marginLeft="10dp"
android:layout_marginRight="8dp"
android:background="@color/colorLayoutBackground">

<TextView
android:id="@+id/txtv_intro"
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:layout_marginTop="30dp"
android:textSize="20sp"
android:textStyle="bold"
android:text="@string/txtv_intro"/>

<TextView
android:id="@+id/txtv_login_instruction"
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:text="@string/txtv_login_instruction"
android:layout_alignParentLeft="true"
android:layout_below="@id/txtv_intro"
android:layout_marginTop="30dp"
android:textSize="20sp"
android:layout_marginLeft="10dp"
android:layout_marginRight="8dp"/>
<TextView
android:id="@+id/txtv_enter_uname"
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:layout_alignParentLeft="true"
android:layout_marginTop="30dp"
android:layout_below="@id/txtv_login_instruction"
android:textSize="20sp"
android:text="@string/username" />

<EditText
android:id="@+id/etxt_uname"
android:layout_width="match_parent"
android:layout_height="wrap_content"
android:layout_below="@id/txtv_login_instruction"
android:layout_toRightOf="@id/txtv_enter_uname"
android:layout_marginTop="20dp"
android:layout_marginLeft="10dp"
android:layout_marginRight="8dp"
android:singleLine="true"  />

<Button
android:id="@+id/btn_register_user"
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:layout_below="@id/txtv_password"
android:layout_marginTop="30dp"
android:layout_alignParentRight="true"
android:background="@color/colorButtonBackground"
android:text="@string/register_user"
```

Figure 9: Sample of model in text view

```
package com.example.ad3mk.mhealth;
import android.content.Intent;
import android.support.v7.app.AppCompatActivity;
import android.os.Bundle;
import android.text.Text.Utils;
import android.view.view;
import android.widget.DatePicker;
import android.widget.EditText;
import android.widget.ListView;
import android.widget.PopupWindow;
import android.widget.RadioButton;
import android.widget.AdapterView;
public class RegistrationActivityextendsAppCompatActivity {
private EditTextmEditTextName;
private EditTextmEditTextAge;
private EditTextmEditTextMobileNo;
private EditTextmEditTextLMP;
private TextViewmEditTextEDD;
private EditTextmtvANC2ApptDate;
private RadioButtonradANC1ServiceSelected;
private ListViewlv;
private DataAdapteradapter;
private Mother dataModel;
@Override
protected void onCreate(Bundle savedInstanceState) {
super.onCreate(savedInstanceState);
setContentView(R.layout.activity_fcm_registration);
mEditTextName= findViewById(R.id.editText_name);
mEditTextAge= findViewById(R.id.editText_age);
mEditTextMobileNo= findViewById(R.id.editText_mobileNo);
mEditTextLMP= findViewById(R.id.editText_LMP);
mEditTextEDD= findViewById(R.id.editText_EDD);
mtvANC2ApptDate = findViewById(R.id.etxt_anc2_appt_Date);
//mEditTextEDD.setText(dateString);
mEditTextMobileNo.setText("");
mEditTextLMP.setText("");
mEditTextEDD.setText("Exp. Date of Delivery:");
radGroupPregTest.clearCheck();  }
@Overrid
public void onClick(View view) {
pw.dismiss();
```

Figure 10: The sample view part of MVC

- **Controller**

This file is also ***.xml*** file and it is used to control the sequence of execution of the activities. The main xml file of the prototype that launches the application on emulators screen is shown in figure 16 below.

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
package="com.example.ad3mk.mhealth">

<application
android:allowBackup="true"
android:icon="@mipmap/ic_launcher"
android:label="@string/app_name"
android:roundIcon="@mipmap/ic_launcher_round"
android:supportsRtl="true"
android:theme="@style/AppTheme">
<activity android:name=".MainActivity">
<intent-filter>
<action android:name="android.intent.action.MAIN" />

<category android:name="android.intent.category.LAUNCHER" />
</intent-filter>
</activity>
<activity android:name=".RegistrationActivity">
android:label="@string/registration_activity"
android:parentActivityName=".MainActivity"
<meta-data
android:name="android.support.PARENT_ACTIVITY"
android:value="com.example.ad3mk.mhealth.MainActivity" />
</activity>
<activity android:name=".UserregistrationActivity" />
<activity android:name=".ListActivity"></activity>

</application>
<uses-permission android:name="android.permission.RECEIVE_SMS" />
<uses-permission android:name="android.permission.READ_SMS" />
<uses-permission android:name="android.permission.SEND_SMS" />
</manifest>
```

Figure 11: Sample of controller of mobile health management

For testing the output display and behavior of the program, the prototype was tasted on a couple of android's devices virtually. The app has got its own icon in an app menu of the devices as shown below. Thus, the sample use case interface of the prototype is illustrated in the emulator system image.

Figure 12: The sample emulators used to access mobile health

5.2.3 Integration of the App with Cloud

Currently, various telecom service providing enterprises do give a cloud messaging services that works on different platforms such as iOS, Android and also web apps. This service is mainly intended for delivering push notifications which is a way of broadcasting and delivering notification messages from the servers to a registered and online mobile user.

To get these functionalities in the development of the prototype, the option for creating a firebase project in Google FCM dashboard that is integrated with the package of the android studio project. For the prototyping of the mobile health app under focus, a firebase project was created by the name "***mHealth***" and assimilated with the android studio application project package

name ***com.example.teshale.mhealth application'.*** The dashboard also provides several other options including:

- Setting up authentication methods
- Sending simple messages to the client application on the mobile device
- Supporting real time database.

Finally, after the dependency file called ***'google-services.json'*** was downloaded and included to the android project, the above library file is included to the '***Gradle'*** files of the project and synchronized with all the remaining project files.

In this study, the core part is settling an architectural framework and the mechanism for sending/receiving push notifications and messages from mobile health management component. Therefore, the mobile health management component incorporated a web app that works with the various formats of data such as text and light weighted graphics while addressing the following issues.

- Sequences of messages
- Notification to be broadcast
- Other relevant communications.

Hence, for the mobile health application dealt in this study, the messaging service is the major component to broadcast a notification message to the active users involved keeping the appropriate sequences of the messages as well as the roles of each individual actors registered in the database.

5.3 System Evaluation and Validation

The proposed mobile health application system was tried to be implemented through a prototype approach. Hence, evaluating and analyzing data collected from respondents through interview questioners from service providers meaning: Midwives, Nurses, HEWs and clients.

5.3.1 Results of the Interview

As it is discussed earlier in the research methodology, due to time limitation and lack of budget it limits the sample size of the informants which means it takes a total of 48 informants including midwives, nurses, health extension workers as well as clients have been interviewed so that the gaps with the existing system could be identified and addressed in the proposition to be made. The demographic information of these informants is shown in the table below.

Table 2: Demographic data of informants

SN	Items	Category	Frequency	%age
1	Age Group	18-24	18	37.5
		25-35	20	41.67
		36-45	10	20.83
2	Work Experience	<1 year	3	6.25
		1-5 years	6	12.5
		>5 years	9	18.75
3	Education Level	Primary	15	31.25
		Secondary	18	37.5
		Tertiary	15	31.25

According the table above, 41.67% of the respondents are between 25-35 years old while some 37.5% of them are in their young ages (18-24) and 20.83% of the respondents are ages between 36-45 years old. With regard to the work experience of the informants, 18.75% of all have served over 5 years and 12.5% of the informants have served between 1-5 years with only 6.25% said

they have only been at office for less than one year. Nearly 37.5% of the informants are secondary school and 31.25% of the informants are primary and tertiary school, the interviewees expressed their level of education as Primary, Secondary and Tertiary respectively.

5.3.2 Data Analysis

Overall, the number of health professionals interviewed is 18 constituting 38% of the total participants. The findings show that 15 of the informants say that they are familiar with the application while three HEWs were identified with unfamiliar status for not attending training sessions due to social circumstances. Almost all these familiar informants have explained how mHealth app works appropriately further ensuring their knowledge about the system.

Being asked whether the application simplified the service they are providing, 16 of the health professionals out of 18 have assured that the system have helped them in saving time, realizing a well-documented record keeping practice, speeding up the service provision, and also making the accessibility of maternal and child care data easy. However, two respondents, say that due to absence of internet connection, power disruption, computer corruption and work overload the mHealth application isn't easily accessing the data. In congruence to the simplification, an equal number of respondents repeated their satisfaction in relation to the assistances they enjoyed from the application. Also, the remaining equal amount expressed that they are not satisfied that may have a link with personal skills.

With regard to communication facilities, they mentioned automatically generated text and voice messages from mHealth application installed on your phone and personal messages as a tool to communicate with their clients. Incorporating simplified health education materials by text and voice for those who can read and not, automatic linkage to ambulance services to reduce the current manual practice and HDA involvement in facilitating the relationship between care providers and clients in the community are among the features proposed to be included in upcoming releases of the application.

Continuing on criticizing the current manual referral system, all of them said the process involves informing the ambulance manager upon emergencies, calling for the drivers as well as HEWs and vice versa in almost one voice. Lastly, frequent database failures, network interruptions, power cuts that may result in computer corruptions are among the major challenges that could be mentioned in relation to the current mHealth application.

Table 3: Summary of the responses of midwives/nurses and the HEWs

SN	Items	Category	Frequency	%age
1	Familiarity on mHealth app	Yes	15	83.33
		No	3	16.67
2	Simplification of mHealth app	Yes	16	88.89
		No	2	11.11
3	Satisfaction on mHealth app	Yes	16	88.89
		No	2	11.11
4	Ease of Service Provision of mHealth app	Yes	15	83.33
		No	3	16.67
5	Means of Communication with mHealth app	Phone	11	61.11
		SMS	4	22.22
		Personal Messages	2	11.11
		HDA	1	5.56

In connection to responses of clients, the result of the findings shows that the data collected and analyzed from clients of maternal and child health care who are sorted out from the database of mHealth application that are currently active is presented in the following table.

Table 4: Summary of the responses of client mothers

SN	Items	Category	Frequency	%age
1	Satisfaction	Yes	20	66.67
		No	10	33.33
2	Ease of Service Provision	Yes	19	63.33
		No	11	36.67
3	Means of Communication	Phone	11	36.67
		SMS	8	26.67
		Personal Messages	4	13.33
		HDA	7	23.33

Table 4 above explains that 66.67% of the clients who were receiving services from these selected health facilities are satisfied with the services they are getting while the remaining 33.33% is not satisfied stood to the opposite. And yet 63.33% of the clients under the study confirmed that the access to services obtained at ease though a considerable portion (36.67%) compromised on the ease of access to health services. According to these clients, the majority of them (64%) mentioned phone calls and text messages as a mean to communicate with the service providers. And hence, personal messages and HDA involvement contribute in due course of the communication process as it can observed from the table above.

In addition, these clients listed the following services such as Family Planning, Antenatal Care, Postnatal Care, Delivery, Immunization and Treatment related to morbidity as the ones they obtain from care providers. In connection to the challenges they face, the clients said delayed ambulance service, absence of timely services due to busy schedules of providers, longer distance to reach the facilities as well as other infrastructural problems like poor telecom network are among the major ones.

All in all, this analysis implies that there needs to be some technological intervention that can alleviate those problems and make the systems more robust and up to the standard. In line with this, the researcher considered some improvement on the architectural framework by including additional features like the mechanism to dispatch messages full of health education for those communities in a detached localities, a technique to include ambulance services management by automatically generating and sending text messages to managers and drivers upon emergencies and expanding the involvement of Health Development Army in facilitating communications as well as assisting in fixing appointments and others.

CHAPTER SIX:
CONCLUSIONS AND FUTURE WORKS

6.1 Conclusions

In conclusion of this study, the researcher has tried to go through a number of steps with a view to achieving the objectives set and solving the problems identified. The primary task was specifying the research problem by appending additional features in the existing mHealth application and articulates few objectives to be met. The preliminary assessment conducted by interviewing care providers and clients also proved the gaps identified in statement of the problem. Assessing the available literature works in the perspective of mobile health in addition to other efforts contributed to their designing of the mobile health framework.

Agile process model was followed to deal with all the dynamicity of functionalities in the design and implementation of the proposed architecture of mobile health application. Tools like Android platform and programming language, independent web technologies such bootstrap and firebase were used in the practical implementation. For enhanced functionality like receiving and sending push notifications, the mechanism of integrating the app with messaging management has been entertained.

Basically, in the development and implementation, the application has mainly been dependent on android application. The application was developed using android studio and tested on virtual mobile devices and prototype emulators. The application has had the capability to send and receive notification and educative messages.

Generally, from the evaluation of the system functionality in the prototype implementation, it is possible to say that health education has been proved to solve the gaps by creating awareness and appending new functionalities to it. Hence, with respect to the specific objectives set at the beginning of the research, the proposed framework can be seen as a solution to the stated problem.

The result of this study shows that expectant women easily access maternal and child healthcare information from their own phone being at home. It also disseminates messages full of health education in their content could reach Health extension workers (HEWs) and Health Development Armies (HDAs).

As it has been grasped from the informants, the current manual referral system needs improvement by involving ambulance drivers by facilitating transportation system and reducing maternal mortality death upon emergencies as well as HEWs and midwife at a time. This happened to be one of the convincing arguments for this research to append health education on the existing mHealth application. Finally, the informants mentioned frequent database failures, network interruptions, power cuts that may result in computer corruptions as the major challenges that contribute in stopping the proper functionality of the system and require due attention in resolving these issues.

6.2 Future Works

Evidently, the benefits of the prototype application have been exhaustively elaborated earlier in the sections above. Therefore, based on the observed facts, it is highly recommended to enrich the application by way of integrating the proposed modules so that large-scale implementation would be possible in general. In addition, the following points are listed for further considerations.

- Working on producing a mobile health application framework that is platform independent and avoid restrictions.
- Enriching the database with clear, informative and sensible messages to either of the actors based on their level of understanding may also be hugely rewarding.
- Devoting time and committing resources to integrating the mobile application with cloud technology.

- Planning on availing backup power to prevent problems that arise from power interruptions such as database and network failures as well as computer corruptions.

As a final complement, the researcher recommends the full-scale implementation of the mHealth application in health posts, and health centers throughout the region in partnerships with non-governmental organizations to improve access to the maternal and child healthcare with respect to health events during antenatal, delivery and postnatal eras and thereby meet some of the Millennium Development Goals.

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APPENDICES

Appendix A: Dependencies

The other most important file included to the android studio app for the purpose of firebase integration was the dependencies file. The file is added to the app level Gradle script file of the application project file. The main purpose of this file is to integrate the necessary packages to be imported the app. Finally, for the proper functionalities, the dependency file is synchronized through command with the whole gradle script file of the project file. The major content of the file is as below.

```
apply plugin: 'com.android.application'

android {
compileSdkVersion28
defaultConfig {
applicationId"com.example.ad3mk.mhealth"
minSdkVersion15
targetSdkVersion28
versionCode1
versionName"1.0"
testInstrumentationRunner"android.support.test.runner.AndroidJUnitRunner"
}
buildTypes {
        release {
minifyEnabledfalse
proguardFilesgetDefaultProguardFile('proguard-android.txt'), 'proguard-rules.pro'
}
    }
}

dependencies {
    implementation fileTree(dir: 'libs', include: ['*.jar'])
    implementation 'com.android.support:appcompat-v7:28.0.0-rc02'
implementation 'com.android.support.constraint:constraint-layout:1.1.3'
testImplementation'junit:junit:4.12'
androidTestImplementation'com.android.support.test:runner:1.0.2'
androidTestImplementation'com.android.support.test.espresso:espresso-core:3.0.2'
}
```

Appendix B:Interview Questions

Dear Sir/Madam

The purpose of this interview is to collect primary data from purposely hand-picked informants (health professionals and service seekers) in Sebeta Hawas woreda of the Oromia Regional State. I am currently conducting a research to fulfill the requirements for **Master's Degree in Computer Science at St. Marry University**.

Your responses remain confidential and will only be used for academic purpose. And hence, I kindly request you to respond honestly. ***I really thank you for taking time to participate in this interview!***

Purpose: the interview question will help to assess the current system and suggest on the future design of the antenatal, delivery and postnatal care follow-up system.

Part 1: General information

Interviewee: _____

Name of Zone: _____

Name of Woreda: _____

Name of Health facility: _____

Date: _____

General Information of providers as well as women in reproductive age group indicating important determinants regarding maternal and childcare.

S.No	Items	Category		
1	Select your age group	18-24	25-35	36-45
2	Select your work experience	Under 1 year	1 – 5 years	Over 5 years
3	Select your level of education	Primary school	Secondary school	Tertiary level

Interview questions for midwife/nurse and health extension worker

Instruction: Please give appropriate answers for the following questions.

1. Are you familiar with mHealth application?
   A. Yes B. No
2. If yes, for how long have you been using it?
3. Would you explain how mHealth works?
   A. Yes B. No
   If yes, explain it

   _____
   _____
   _____
4. Has it simplified the service you provide to clients?
   A. Yes B. No
   If yes, in what way?

   _____
   _____
   _____
5. Are the sources of maternal and child care information easily accessible or available?
   A. Yes B. No
6. How do you communicate with clients?

   _____
   _____
   _____
7. Which segment of the system would you like to be improved and what more features you propose?
8. How do you explain the referral linkage system between health facilities using mHealth application?

   _____
   _____
   _____

9. How do you facilitate ambulance services during emergency situations? Did the system support you in this regard?
10. What challenges do you face while using mHealth application?

_____
_____
_____

Interview questions for clients in the database

1. Are you satisfied with all the services you are expected to get during ANC, Delivery and PNC?

   A. Yes B. No
2. Do you easily get the service you are seeking when you are referred to the health center?

   A. Yes B. No
3. Would you please tell me the services you frequently get from the service providers?
4. How do you communicate with service providers upon any complications occurred?

   _____
   _____
5. What challenges do you usually face during receiving the service you need on Maternal and child care?

   _____
   _____

Gaaffii Afaanii

Kabajamtoota hirmaattota gaaffii fi deebii kanaa, kaayyoon gaaffii afaanii kun tajaajila haadholee fi daa'immaanii waliin wal-qabatee kennamaa jiru fooyyeessuuf ogeessoota fayyaa fi tajaajilamtoota muraasa buufataaalee fi keellaawwan fayyaa aanaa Sabbataa Hawaas jala jiran irraa tajaajila argatan keessaa raga funaanuun qorannoo fi qo'annoo digirii 2ffaa Kompiyutar Saayinsiin Yunivarsiitii Seent Meeriitti barachaa jiru guttaachuuf kan qopha'eedha.

Deebiin isin nuuf kennitan iccitiin isaa kan eegamee fi haala amansiisaa ta'een kan taa'uu fi dhimma barnootaa qofaaf kan fayyadamnu ta'a. Dabalataanis qabxiilee isin gaafadhu haala iftoomina qabuun akka naaf deebistan isin gaafadha. Yeroo keessan fudhattanii gaaffii fi deebii kana irratti hirmaachuu keessaniif baay'ee galatoomaa.

Kaayyooijoo: gaaffiin afaanii kun tajaajila haadholee fi daa'immanii mosaajiin deeggaramu ilaalchisee sadarkaa yeroo ammaa irra jiru qorachuun hanqinoota muul'atan irratti yaadafurmaataa akeekuuf kan qophaa'eedha.

Kutaa 1ffaa: Odeeffannoo waliigalaa

Maqaa Nama Gaafatamuu: _____

Maqaa Godinaa: _____

Maqaa Aanaa: _____

Maqaa dhaabbata fayyaa: _____

Guyyaa:_____

Odeeffannoo walii gala ogeessotaa fayyaa fi dubartoota ulfaa tajaajila haadholeef daa'immanii argachaa jiranii fi daataabeezii keessa filatamanii.

Lakk	Gaaffii	Qoodiinsa		
1	Umriikee adda baasi	18-24	25-35	36-45
2	Muuxannoo hojiikee filadhu	Waggaa 1 gadi	Waggaa 1-5	Waggaa 5 ol
3	Sadarkaa barnootaa	Sadarkaa 1^{ffaa}	Sadarkaa 2^{ffaa}	Digrii 1^{ffaa} fi isaa ol

Qajeelffaamma: Maalloo gaaffiiwwan armaan gadiitiif deebii sirrii ta’e kennaa

Gaaffiifi deebii ogeessoota narsoota deessistuu/waliigalaa fi hojjattoota ekisteenshinii fayyaaf qophaa’e

1. Mosaajii ‘mhealth’ jedhamu kanaa beektuu?
   A. Eeyyee B. Lakkii
2. Yeroo hagamiif itti fayyadamaa turtan?
3. Akkaataa mosaajiin kun itti hojjatu naaf ibsuu dandeessuu?
   A. Eeyyee B. Lakkii
4. Tajaajila kennitan isinif salphisee jiraa?Akkamiin?
   A. Eeyyee B. Lakki
   Debiin keessan eeyyee yoo ta’e akkamiin?

   _____

   _____

   _____
5. Odeeffannoo tajaajila haadholee fi daa’immanii haala salphaa ta’een argachuun ni danda’amaa?
   A. Eeyyee B. Lakkii

6. Akkaamiin tajaajilamaa keessan waliin wal quunnamtuu?

   _____

   _____
7. Mosaajii kana keessaa qama kamtu akka isiniif fooyya’u barbaaddu ykn maaltu itti dabalamuu qaba jettu?
8. Mosaajii kana fayyadamtanii akkaataa itti tajaajilamaa tokko dhaabbata tokkorraa gara biraatti itti ergitan naaf ibsuu dandeessuu?

_____

_____

9. Yeroo waan muddamaa isin muudatu tajaajila ambulaansii akkamiin mijeessitu? Mosaajiin kun adeemsa kana keessatti waan isin deeggaru qabaa?
10. Yeroo mosaajii kana fayyaadamtan rakkoolee maal maaltu isin muudata?

_____

_____

Gaaffiifi deebii tajaajilamtootaaf qophaa'e

1. Tajaajila da'umsa duraa, da'umsaa fi da'umsa boodaa argattan irraa quuftanii jirtuu?
   A. Eeyyee B. Lakkii
2. Yeroo keellaa fayyaa iraa gara buufata fayyaatti ergamtan tajaajila isin barbaaddan hunda haala salphaa ta'een argattuu?
   A. Eeyyee B. Lakkii
3. Tajaajiloota yeroo yeroon ogeessotarraa argattan natty himuu dandeessuu?
   A. Eeyyee B. Lakkii
4. Rakkoon gara garaa yeroo isiin quunnamu akkamiin oggeesso tatajaajila isiniif kennan waliin wal quunnamtuu?

   _____

   _____

   _____
5. Tajaajila kunuunsa haadholii fi daa'immanii isin barbaaddan yeroo argachuu deemtan rakkooleen isin muudatan maal fa'i?