INTERNET OF THINGS BASED MODEL FOR PREECLAMPSIA MONITORING IN ANTENATAL CARE

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A Thesis Presented to the Institute of Postgraduate Studies of Kabarak University in Partial Fulfilment of the Requirements for the Doctor of Philosophy Degree in Information Technology.

KABARAK UNIVERSITY

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DECLARATION

This Thesis is my own work and to the best of my knowledge, it has not been presented for the award of a degree in any university or college.

Signed: ……………………………………. Date: …………………………….

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RECOMMENDATION

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The Thesis entitled "**Internet of Things based Model for Preeclampsia Monitoring in Antenatal Care**" and written by **Faith Mueni Musyoka** is presented to the Institute of Postgraduate Studies of Kabarak University. We have reviewed the thesis and recommend it be accepted in partial fulfilment of the requirement for the award of Doctor of Philosophy degree in Information Technology.

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DEDICATION

I dedicate this PhD thesis to my loving Husband Dr. Jonathan Mwau for the great support, training and, upbringing in my life and throughout my education.

To my children Samuel Mumo and Esther Mutheu, my parents, in-laws, brothers and, sisters for their continuous support and encouragement.

ABSTRACT

In the health sector, the health of women is a significant public health issue, which impacts the personal well-being, family reproduction, and societal development. Therefore, knowledge about the health of women has led to an emerging requirement for healthcare sectors to obtain the real-time status and data of various applications that can improve the performance and accuracy of the health production. Globally, it has been found that women die due to pregnancy and childbirth consequences. The major effects of maternal morbidity and mortality include haemorrhage, infection, high blood pressure, unsafe abortion, and obstructed labour. Some of the maternal challenges that cause long term effects when not controlled include preeclampsia, which is caused by hypertension, one of the leading identifiable risk factors in pregnancy. Hypertension also results in stillbirth, oedema, and even death. Hospitals in developing countries have been using several devices in the detection of blood pressure fluctuations, though not reading real-time data. This study, therefore, sought to implement an Internet of Things (IoT) based model for preeclampsia monitoring in antenatal care. To achieve this overall objective, the study identified suitable smart armband for measuring blood pressure based on functionality, hardware, software, and affordability. In addition, the study sought to develop IoT model and implement it to read pregnant mother's real-time data that can be accessed by a Health care provider and family caregiver in case of an emergency. The developed IoT prototype was tested with fifty pregnant mothers who were selected using purposive and simple random sampling. The sample size selection was done using Cochran formula. The study was undertaken using mixed research design that involved exploratory, rapid prototyping approach and a quasi-experimental research designs. The respondents were selected from Thika level 5 hospital and Embu Level 5 hospital in Kiambu and Embu counties respectively. The study used consistency, response rate, accuracy, reliability, and output as metrics to evaluate IoT system performance. The T-test was used to determine the significance of performance metrics. The study found out that the IoT based model for preeclampsia monitoring was feasible and practical during the testing and also performed as expected during its evaluation. Based on the findings, the study recommends the approach to be scaled up and adopted in maternal health care to address preeclampsia conditions while addressing issues of cost in its adoption. In addition, the study recommends fabrication of suitable smart armband for measuring blood pressure in pregnant mothers.

Keywords: Internet of Things, Preeclampsia, Antenatal Care, Prototype, Hypertension, Maternal Mortality, Maternal morbidity

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ABBREVIATION

ANC:	Antenatal Care
BP:	Blood Pressure
ERP:	Enterprise Resource Planning
IoT:	Internet of Things
ECG:	Electrocardiogram
JSON:	JavaScript Object Notation
M2M:	Machine to Machine
MMR:	Maternal Mortality Ratio
mHealth:	Mobile Health
MoMTECH:	Mobile Technology
PDAs:	Personal digital assistants
REST:	Representational State Transfer
RFID:	Radio Frequency Identification
SDG:	Sustainable Development Goal
SOAP:	Simple Object Access Protocol
UHF:	Ultra-High Frequency
WHO:	World Health Organization
WSN:	Wireless Sensor Network
XML	Extensible Markup Language

OPERATIONAL DEFINITION OF TERMS

Antenatal Care:
The period of affirmative pregnancy which offers a platform for significant health-care functions, such as health promotion, screening and diagnosis, disease prevention, communication, and support in order to improve and save lives (UNICEF, 2016).

Internet of Things:
An approach in which objects integrated with sensors, actuators, and processors communicate with one another to serve a meaningful purpose (Sethi & Sarangi, 2017)

Maternal health:
Health of women during pregnancy period, childbirth and the postpartum period (WHO, 2017)

Preeclampsia:
A pregnancy specific disorder that is characterized by hypertension of greater than or equal to 140/90 mm Hg which is strongly associated with foetal growth restriction, low birth weight, preterm delivery, respiratory distress syndrome, and admission to neonatal intensive care (March of Dimes, 2017).

Smart Armband Watch:
A wearing wrist device with an integrated clock and has a computational power to connect with other devices through short range wireless connectivity; provides alert notifications; collects personal data through a range of sensors and stores them (Cecchinato, Bird, & Cox, 2015)

<center>**CHAPTER ONE**</center>

<center>**INTRODUCTION**</center>

1.0 Introduction

This chapter gives a brief background of the main concepts and problems informing this study. It further proceeds to state the statement of the problem, outline the research objectives, list the research questions, define the scope, significance, limitation, contribution, assumption and the organization of the rest of the chapters.

1.1 Background to the Study

Women's health is considered a significant public health issue, impacting personal well-being, family reproduction, and society's development (X. Wang & Lu, 2017). Studies have shown that many women die yearly due to pregnancy cases, as reported by mHealth Alliance (2012). The study further showed that in a year, on a global scale, nearly 350,000 women lose their lives because of pregnancy and childbirth-related complications, and for those who die, approximately 20,000 others suffer from pregnancy-related consequences.

A study in India showed that, 67,000 women out of the 28 million pregnancies annually succumb to complications that are related to pregnancy and childbirth. Statistics show that about one million women suffer from chronic ill-health issues, and about one million neonatal deaths happen. It is evident that similar situations persist in many other developing countries (Maitra & Kuntagod, 2013). Therefore, maternal health is a global healthcare problem affecting developing and developed countries alike.

<center>1</center>

Pregnancy difficulties increase the risk of maternal and infant death and are associated with adverse outcomes such as miscarriage, stillbirth, and preterm birth (Penders, Altini, Hoof, & Dy, 2015). Maternal health is a positive experience; however, it involves suffering, ill-health, and at some level, death in large numbers. The direct rates of maternal mortality and morbidity comprise of hemorrhage, infection, high blood pressure, hazardous abortion, and frustrated labour.

Currently, there are maternal challenges that cause long term effects if not controlled, such as preeclampsia that is caused by blood pressure. Preeclampsia conditions represent one in three cases of severe obstetric morbidity, while hypertension is the major identifiable risk element in pregnancy associated with stillbirth. Preeclampsia is strongly related to fetal growth restriction, low birth weight, preterm delivery, respiratory distress syndrome, and admission to neonatal intensive care (March of Dimes, 2017). Mostly, blood pressure challenge does not cause signs or symptoms, and pregnant mother should go to all prenatal care visits for a check-up. To manage blood pressure levels, an expectant mother should go for antenatal care check-ups even if she is feeling fine.

Globally, the burden of preeclampsia has been a significant concern both in developed and developing countries causing its prevention and management is a primary concern (Musyoka, Thiga, & Muketha, 2019a). Currently, there are no well-established measures for the prevention of preeclampsia in the general population (Rudra, Basak, Patil, & Latoo, 2011). Preeclampsia community guideline has been laid down in developed countries. The guidelines involve: mothers to be presented for referral before Twenty weeks gestation for specialist input to their ANC plan. For those having no risk of preeclampsia to visit ANC care seven times, while mothers with high risk are

reviewed in the community at least once every three weeks before 32 weeks and at least once every two weeks until delivery for a check-up of any symptoms of preeclampsia. Recommendations have been prepared to improve the blood pressure measurement accuracy (Rudra et al., 2011).

Besides, technology has brought a significant improvement in preeclampsia cause (blood pressure) detection. Several applications have been developed to detect blood pressure measurements. Some of these applications include blood pressure tracker, where a patient has to enter information such as systolic pressure reading, diastolic pressure reading, heart rate, and when the reading was taken. In the application, when the color-coded calendar displays green then the blood pressure is normal, when the color displayed is orange then the patient is on the verge of hypertension, and when the color displayed is red then the patient has got a high blood pressure. Omron Health Management Software (OHMS) is an application for blood pressure readings. The software allows one to directly upload BP details from the blood pressure monitor or pedometer to their personal computer using the Health Management Software that keeps track of their health and fitness data in addition to providing essential updates to the health care provider (Omron, 2018).

In a study carried out by Bahl (2016) found out that maternal deaths due to preeclampsia are incredibly high. The research established that there was 14% of maternal mortality worldwide due to pregnancy hypertensive disorders. In sub-Saharan Africa (Kenya), the statistics of mortality was 16% while in the United States, death due to preeclampsia is as low as 4.8%. Therefore, it points out that there is a massive difference in the rates of maternal mortality and preeclampsia, which is caused by differential diagnosis and management of preeclampsia in Kenya and the United States. When preeclampsia is

left unmanaged, it is likely to progress into eclampsia. Hence, respiratory issues, acute renal failure, obstetric embolism, or maternal death occur.

To achieve the Millennium Development Goals (MDGs) and maintain better maternal health beyond 2030, researchers have critically examined new ways of using existing resources in the world to create improvements. Mobile technology infrastructure is one of the novel technologies that are being adopted with the aim of improving health care accessibility and saving pregnant mothers' lives. The growth of mHealth solutions to improve health outcomes is preferred based on their suitability, manageability, and relatively low cost of mHealth applications (mHealth Alliance, 2012). In recent moments, sensor technology is an advanced technology that is being used to monitor maternal data. Besides, Internet of Things (IoT) technology, in combination with modern sensor technologies such as RFID and ZigBee, are implemented for the realization of automated tracking systems for resources such as patients, assets, and records in a smart hospital environment (Alharbe & Atkins, 2014).

In a study by Santhi, Gandhi, Geetha, & Nirmala (2016), the proposal was established for a consistent system perception for maternal healthcare nursing that gives instructions during operation by video conferencing. Moreover, the proposed system aims to create an uninterrupted interaction with the attending doctor in the hospital on getting information on routine nutrition diet and vital monitoring parameters from a pregnant mother. Such parameters include infant heartbeat, labor delivery time, blood glucose level, temperature, pressure, a mother's electrocardiogram for the whole pregnancy period. Mobile fetal cardiotocography was proposed to allow conducting dynamic monitoring over the cardiovascular system of the fetus and pregnant woman

without the need for staying inside a medical institution and being under medical personnel's supervision (KhoKhlova, Seleznev, Zhdanov, & Zemlyakov, 2016).

In Mexico, a system called MAMICare was designed to ensure the proper monitoring and control of the patient's development. This was made possible by keeping satisfactory information and doing data follow ups that are required in primary maternity-infant care and reduce failure to detect risk situations (Lavariega, Cordova, Gomez, & Avila, 2013). Mi Bebe has also been developed in Mexico with the aim of remotely allowing health professionals and community health workers to monitor women who have high related disorder pregnancies and showing signs of abnormalities, then connecting them to specialized clinics promptly.

Kenya is not left behind; technology is being adopted to reduce MMR. mHealth Alliance (2012) showed a list of mHealth applications in Kenya. The applications include Mobile for Reproductive Health (m4RH) app which, is a text-based message service for providing evidence based information on family planning approaches. Changamka and m-Money For Women with Fistula apps that offer mobile financial services that help women to save money towards delivery and postnatal care (World Health Organization, 2013). ChildCount+ app that helps community health workers to use text based messages to register new births and also track community health events in pregnant mothers. Capacity project app is an application that supports operational communication with health workers positioned to remote regions.

Blood pressure is one of the vital measurements taken during antenatal care (ANC) visits. While a pregnant mother should visit healthcare at least four ANC visits, this is never a reality to many due to social, family, and community context, and beliefs hence a significant concern (Lincetto, Anoh, Gomez, & Munjanja, 2015). Poverty and low

education levels may make it more difficult for pregnant mothers to make better choices about when to seek health care. Even for those who manage, it may never be feasible to carefully detect hypertensive disorders within those four visits depending on the period of visits. Sometimes, women never get to have their blood pressure taken, and there is no opportunity to monitor even for women who are at risk of developing preeclampsia. Another cause of difficulty in testing hypertension is the accuracy of devices used due to environmental conditions such as stress.

During ANC visits, the devices that are typically standalone kits that a patient will collect data, record, and take the records to the health care provider for analysis and take of action. Mi Bebe and MamiCare are apps developed in Mexico which connect women to specialized clinics in Mexico area and not in Kenya. While in Kenya, there are over the counter devices that help one to read blood pressure then take it to a health care provider for analysis. Currently, there is no device in Kenya that automatically implemented for preeclampsia monitoring, which reads blood pressure fluctuations, analyses high blood pressure, and sends a notification to the cloud database for healthcare providers' and family caregivers' notification. However, few pregnancy-specific wearable health solutions have been introduced so far for self-management (Penders et al., 2015).

Although there is likely to be mass adoption of connected technology in the long term, the majority of consumers had not heard of the term "The Internet of Things" (Acenture, 2014). According to the study, the top barrier to mass adoption of this technology is a lack of both awareness and value perception among consumers.

Other potential barriers found out in the study include usefulness, price, security, and privacy (Miazi, Erasmus, Razzaque, & Bagula, 2017). This study established that in

developing countries, people face many problems to have access to the communication technologies due to poverty, lack of Internet speed, low levels of expertise, and overall lack of infrastructure. Besides, the study found out that the authorities face enormous challenges to improve the current systems in making the infrastructure capable of deploying IoT as a whole. Therefore, in developing countries, poverty causes the problem of IoT adoption of devices for blood pressure measurement and data transmission, payment of the purchase of the device, and its maintenance cost. Also, a low level of expertise inhibits the success of IoT devices, since the devices need importing. Lack of infrastructure in authorities is a challenge too since there is a need to have a model that incorporates IoT, data monitoring online dashboard, and mobile alerts for an effective IoT based system.

1.2 Statement of the Problem

Ante-natal care (ANC) is vital to pregnant mothers since it reduces pregnancy complications and foetus risks, which the Kenyan government has embraced through the beyond zero health care project. However, major pregnancy complications are still related to preeclampsia, which is strongly associated with foetal growth restriction, low birth weight, preterm delivery, respiratory distress syndrome, and admission to neonatal intensive care, among other complications. The minimum recommended number of ANC visits is four, which for many women, is never a reality. Even for those who manage, it may never be feasible to closely detect hypertensive disorders within those four visits because of environmental and social factors that some mothers face. Globally, wearable devices have been developed that sense any danger from the mother and save the data in a memory card. The data is, after that, transferred to the health care

provider for further diagnosis. Other systems aim to assist patients to self-manage their health and lifestyle behaviours which work in a standalone mode.

Nonetheless, this data is not real-time since the messenger has to carry the blood pressure readings to the health care provider or make a call to inform the provider. Therefore, this may lead to delay or data loss; hence, it lacks integration with the clinical process. Thus, little has been done to provide several health care providers and family members with timely and valid data about the pregnant mother despite hypertensive disorders and preeclampsia conditions being among the fundamental causes of maternal mortality and morbidity worldwide. Although the Internet of Things in health care is a well-studied field, there is limited research on preeclampsia condition from a developing country's perspective, especially given the many challenges such countries face. Furthermore, several MHealth IoT models have received much appreciation in literature and prototype developed based on them, but none has been utilized to create an IoT prototype for Preeclampsia monitoring, and even no evaluation has been conducted to measure the performance of the IoT prototype. Therefore, the study sought to develop an IoT model for preeclampsia monitoring in antenatal care, which involves the extension of data sharing with more than one user required, that is, the pregnant mother, health care providers, and family caregivers.

1.3 General Objective

The study aimed at implementing an Internet of Things based model for preeclampsia monitoring in antenatal care.

1.4 Specific Objectives

The following specific objectives guided the study:

i.   To identify a suitable blood pressure measuring smart band watches for use in preeclampsia monitoring in antenatal care

ii. To develop an Internet of Things based model for preeclampsia monitoring in antenatal care

iii. To implement the proposed Internet of Things based model for preeclampsia monitoring in antenatal care

iv. To evaluate the performance of the proposed Internet of Things based model for preeclampsia monitoring in antenatal care

1.5 Research Questions

The study sought to answer the following research questions:

i.   What is a suitable blood pressure measuring smart band watch for preeclampsia monitoring in antenatal care?

ii. What is a suitable Internet of Things based model for preeclampsia monitoring in antenatal care?

iii. How can the proposed Internet of Things based model for preeclampsia monitoring in antenatal care be implemented?

iv. How does the proposed Internet of Things based model for preeclampsia monitoring in antenatal care perform?

1.6 Significance of the Study

The study was significant to the following stakeholders:

i.   To expectant mother: the expectant mother will wear the smart armband device which will automatically keep reading blood pressure fluctuation and communicate the readings to the health care provider and family caregiver via alerts. The readings remain in a database which the health care provider will be able to retrieve and thus intervene in order to reduce preeclampsia complications. The outcomes include reassurance, empowerment, and self-management to pregnant mothers as well as the quality of life improvement. Therefore, this results in remote accessibility to assistance and early detection of worsening events.

ii. To Health care professionals: The system will provide for an integrated care approach, monitoring, and availability of real-time measurements of blood pressure. The health care professional will be able to make better-informed decisions due to the greater availability of data.

iii. To the government: The study findings will provide a solution to aid in reducing maternal and infant mortality in Kenya, which is as a result of undetected high blood pressure levels and therefore make a progress towards achieving the Sustainability Development Goal number 3.

iv. To researchers and policymakers: The study findings will provide a basis for knowledge development and enhance the image of the Internet of Things technology. The working IoT model will set the stage for development of easy to use maternal health mobile applications that have the potential to address maternal health issues.

1.7 Limitations of the study

The following were the limitations that researcher experienced while carrying out the research.

It was not possible to develop a web based interface for data visualization and analytics to be used by health care providers due to the time limit factor. In addition, the duration of the study did not allow full follow up on the pregnant mothers to make full use of the IoT system and get more detailed information about the system.

1.8 Contributions of the Study

The study has made the following contributions: the novel achievements that advance the state of the art in preeclampsia monitoring include:

i.   Identification of suitable smart arm band for use in preeclampsia monitoring. The categories used in identification were functionality, hardware, software, and affordability. This novelty of identification of categories made the study recommend a fabrication of suitable device that have few features specific for preeclampsia monitoring.

ii. Identification of components that are involved in the IoT based prototype in preeclampsia monitoring. This identification of how the components are integrated to form a model will enhance ease development of other health mobile applications.

iii. An evaluated IoT based model will ensure a system is performing as expected will drive towards the use of the developed IoT based prototype by the hospitals which will be a new practice to help reduce maternal health challenges caused by preeclampsia condition

1.9 Scope of the Study

This study focused on the development of the Internet of Things based model for preeclampsia monitoring in antenatal care, which dealt with the reading of blood pressure from pregnant mother's worn the smart armband, keeping the data as well as sending the real-time data to a health care provider as a notification. The health care IoT models considered were the ones that deal with real-time data analysis. The study also focused on the implementation of IoT based model for pregnant mothers in attaining real-time health data, which acted as a proof of concept. Geographically, the study was carried out in Kenya in two selected counties: Embu and Kiambu counties between February 2019 and July 2019.

1.10   Assumptions of the Study

The assumptions made in this study are enumerated below:

i.   The study assumed that in the regions selected for the study to be carried out, there would be Internet connectivity since the prototype relied on it.

ii. The study assumed that the selected sample within the geographical area was a representative enough of the country and respective counties to evaluate the performance of the Internet of Things based model.

iii. The study assumed that the smart armband device would work on all people of all skin colour. When the assumption was not found not to hold for dark skinned pregnant mothers, an index finger was used.

1.11   Organization of the Thesis

This thesis is organized into five chapters as follows:

Chapter One presents an introduction to what the study focuses on and expresses the problem statement and objectives of the study.

Chapter Two presents a detailed analysis of literature on maternal health on Preeclampsia condition, applications of the Internet of Things in health care, reviewing of existing health care IoT models, and highlighting gaps in the literature.

Chapter Three presents the methodology applied in the study. In discussion are the philosophical theory and the design approach supporting the study. Besides the techniques used in the research, such as sampling, instruments, and data collection, the different stages and processes in the study are also discussed in this chapter.

Chapter Four presents the results and discussion obtained after data is collected and analysed, including the results of the evaluated Internet of Things based model.

Chapter Five presents the key findings of the research, the general conclusion of the study, and recommendation from the research. This chapter concludes the study by giving an overall evaluation of the outcomes of the study and suggesting future work.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter presents a review of the critical points of current knowledge, among them being substantive findings of the literature related to the study. These include literature related to maternal health and preeclampsia monitoring, the Internet of Things based models used to design one for preeclampsia monitoring, existing mobile health applications, existing smart armband devices to help in selection of suitable device for the study, evaluation models for prototypes, theoretical and conceptual framework used to design the IoT based model.

2.1 Maternal Health

Maternal health denotes the health of women during the pregnancy period, childbirth and the postpartum period (Musyoka et al., 2019a). While motherhood is an encouraging and satisfying experience in the society, it is associated with suffering, ill-health and even death in some women (WHO, 2017) thus leading to maternal morbidity and mortality.

The importance of maternal health care is a very vital factor in the human aspect of the world since a healthy child needs a healthy mother. Studies have also shown that at least 20% of the disease burden in children under five years is related to problems in maternal health during pregnancy. Moreover, according to (UNICEF, 2016), a baby whose mother dies during childbirth is less likely to survive, and children who lost their

mothers are ten times more likely to succumb within two years after the death of their mothers.

The World Health Organization (WHO) recommends a minimum of four antenatal care (ANC) visits (WHO, 2016). The WHO portrays a world where every expectant mother receives an eminence care during the pregnancy period. Prenatal care is the period of a progressive pregnancy that offers a great platform for critical healthcare functions, such as health advancement, screening and diagnosis, and disease prevention, which with effective implementation of ANC visits, can save and improve lives. The Antenatal care practice also provides a chance to associate with and support pregnant women, families, and communities at a life threatening time in the progression of a woman's life. However, global approximations specify that only about half of all pregnant women receive this recommended amount of care (UNICEF, 2016).

According to WHO's report WHO (2017), the major causes of maternal morbidity and mortality are: haemorrhage, infection, high blood pressure, unsafe abortion, and obstructed labour. In a report by (WHO, 2015), in the year 2015, it was estimated that 303 000 women died from complications that are caused by pregnancy or childbirth. These complications included haemorrhage, infection, unsafe abortion, and eclampsia (very high blood pressure leading to seizures), or from health complications worsened in pregnancy in low-resource settings. The report showed that in all these cases, unreachable, inaccessible, high-priced, or poor quality care is primarily responsible.

According to Maitra & Kuntagod (2013), the key causes of high maternal and neonatal deaths have been associated with delays such as: delay in identifying the problem and pursuing care. These happen due to the lack of awareness of danger signs, unreachable health ability or lack of resources to pay for amenities and medicines; delay in reaching

the health facility due to improper logistics or lack of awareness of suitable referral facility in the region and; delay in receiving treatment once the expectant mother has arrived at the health centre due to insufficient health facility, lack of trained workforces or emergency amenities. These are the same delays that will probably occur to a woman with blood pressure issue especially for those in semi settlement areas. The two authors found out that requirement for the elimination of delays is a mutual approach of data collection, data relationship and data management in assisting healthcare providers to offer high levels of patient care, and also to empower personalities and their families for self care and health management thus presented a low-cost mobile handheld based decision support system.

According to a study by Dahdah, Lou, & Meadel (2015), worldwide, 500,000 women die annually, due to complications that are connected to pregnancy or childbirth, and 99% in developing countries. The majority of these pregnant women experience pregnant-related morbidity hence causing severe consequences that are avoidable through information and better monitoring. Clinicians report that the leading cause of death for pregnant women could be the nonattendance or late arrival in a health service due to distance, lack of transport, poor quality of primary health care services, poverty, lack of information or education, and women's social status.

2.1.1   Blood Pressure

Blood pressure has been established to be the amount of force exerted by the blood against the walls of the arteries while a human's blood pressure is considered to be high when the blood pressure readings are higher than 140 mm Hg systolic or 90 mm Hg diastolic (Suhasini & Sudarshini, 2015). Systolic tops the number in the blood pressure reading, while diastolic is the bottom number. Studies have reported that high blood

pressure in other terns hypertension contributes to other diseases such as coronary heart disease, stroke, heart failure, and kidney disease. To pregnant mothers, a hypertension disorder can be dangerous for both the mother and the unborn baby, and when left to get chronic, the disorder can come with other complications during pregnancy such as impairing the mother's kidneys and other organs, causing low birth weight and even causing early delivery. In severe cases, the mother develops preeclampsia condition that can threaten the lives of both the mother and the unborn baby.

There is a great importance of monitoring hypertension since high blood pressure leads to dysfunction of essential organs, like the brain, heart, and kidneys. Every pregnant mother with hypertension should be encouraged to make lifestyle amendments. Moreover, in its treatment, an expectant mother can use information technology that provides information to patients about their health condition. Hypertension is a common disorder that involves exerting too much blood pressure on blood vessels.

Hypertension is a blood pressure measurement above the normal scale (140/90 mmHg). According to JNC 7 (2004), there are four classifications of blood pressure: namely standard (<120/80 mmHg), prehypertension (<139/89 mmHg), stage 1 hypertension (<159/99 mmHg), and stage 2 hypertension (≥160/100 mmHg). Pre-hypertension is not a disease; rather, it is a selected description to identify individuals who are at higher risk of suffering from hypertension. Therefore, both patients and clinicians are alerted to the impending threat and are encouraged to intervene and prevent or delay the disease from developing (JNC 7, 2004). Individuals who have pre-hypertensive conditions are not candidates for drug therapy though they are advised to practice lifestyle changes to lower their risk of developing hypertension in the future. Moreover, individuals with prehypertension who also have diabetes or kidney disease undergo drug therapy

sessions, especially in events where there is a failed trial of lifestyle modification in reduce their BP to 130/80 mmHg.

Hypertensive disorder, being one of the causes of maternal mortality in pregnant mothers during ANC visits, has resulted in the measuring of a mother's blood pressure for level fluctuation. According to a study by Brown & Garovic (2015), hypertensive disorders represent significant causes of pregnancy-related maternal mortality worldwide, which was estimated to occur in about 6–8% of pregnancies. Moreover, in low-income and middle-income countries, preeclampsia and its convulsive form, eclampsia, are associated with 10–15% of direct maternal deaths. Preeclampsia is being a pregnancy-specific disorder is characterized by hypertension of greater than or equal to 140/90 mm Hg (Brown & Garovic, 2015).

In Kenya, the case is not different from other developing countries. In a report (UNPF, 2017), the maternal mortality ratio, the number of women dying of pregnancy-related complications, stands at 488 deaths per 100,000 live births, which ranks Kenya among the ten most dangerous countries, globally, for a woman to deliver a baby. UNPF reported that maternal mortality results from challenges such as limited use of skilled care, inadequate skills among health care providers and low health facility coverage. A study carried out in Kenya showed that the late appearance of a pregnant woman in the event of a complication, combined with poor quality care, contributes to high levels of maternal and perinatal mortality and severe morbidity (Orare, 2015). This study found out that awareness is a significant structural variable that could influence the decision of women to get health care services thus affecting the quality of free maternal health services in Kenya. A study carried out in Central Kenya showed that the direct causes contributed to the majority deaths included haemorrhage, infection, and pre-

eclampsia/eclampsia showing preeclampsia/eclampsia caused 12% of maternal deaths in the period between 2008 and 2012 (Muchemi, Gichogo, Mungai, & Roka, 2016).

2.1.2 Preeclampsia Condition in Pregnant Mothers

Preeclampsia is a disorder that usually starts after the twentieth week of pregnancy and is related to high blood pressure or hypertension and protein in the pregnant mother's urine due to kidney problems (Suhasini & Sudarshini, 2015). It generally affects the placenta, and it can affect the mother's kidney, liver, and brain as well. When the disorder advances, it causes tonic-clonic seizures, which is a condition known as eclampsia with or without the high blood pressure and protein in the urine occurring during or after pregnancy with or without other identifiable cause (Musyoka et al., 2019a). The eclampsia is said to be frequently multifactorial including cerebral vasoconstriction, ischemia, vasogenic edema, or other pathology (Koofreh, Ekott, & Ekpoudom, 2014).

Studies have indicated that eclampsia as the second principal cause of maternal death in the U.S., whereby Preeclampsia is the leading cause of fetal complications, which include low birth weight, premature birth, and stillbirth (Suhasini & Sudarshini, 2015). Although there is no established method of preventing preeclampsia conditions, pregnant mothers who develop preeclampsia are more tracked and taken care of to avoid health problems since the only way to remedy the preeclampsia disorder is by delivering the infant. Besides showing hypertension and protein in the urine, a pregnant mother can have persistent headaches, blurred vision or sensitivity to light, and abdominal pain as signs of the condition.

In a study about the prevalence of preeclampsia among expectant mothers in the University of Calabar Teaching Hospital, Calabar, it showed a high tendency in the occurrence of preeclampsia over the topical years, with overall prevalence being 1.2 %. A little less than half of the women were nulliparous, and the majority had a caesarean delivery. In the study, Preeclampsia was associated with iatrogenic preterm deliveries in a third of the women, while a generational hypertension condition was reported to be the underlying risk factor in several pregnant women. There is an intensifying trend in the prevalence of preeclampsia in that study area, therefore, emphasizing the need to strengthen the utilization of antenatal care to pregnant mothers in detecting and managing preeclampsia conditions early in advance (Musyoka et al., 2019a).

In the developed countries the maternal mortality ratios are relatively low while in low- and middle-income countries (LMIC), these ratios are still high, presenting that 99% of preeclampsia-related maternal deaths occur in in these low and middle income counties (Romero et al., 2018). This study showed that almost one over ten of all maternal deaths in Asia are linked with hypertensive disorders of pregnancy, whereas one-quarter of maternal deaths in Latin America are linked with the same, and 9.1% of maternal deaths in Africa are due to hypertensive disorders of pregnancy.

A different study conducted in Zimbabwe found out that a pregnancy-induced hypertension prevalence of 19.4% (Muti, Tshimanga, Notion, Bangure, & Chonzi, 2015). This ratio was extremely high, and these pregnant mothers were at higher risk of hostile pregnancy outcomes. Moreover, the study also found that preeclampsia condition was associated with an increased risk of perinatal mortality as well as preterm birth complications contributing to 39% percentage of under-five mortality causes.

The pregnant mothers with gestational hypertension and preeclampsia normally experience issues such as placental abruption, disseminated intravascular coagulation, cerebral hemorrhage, and hepatic and renal failure, preterm deliveries, and subsequent neonatal and long-term morbidity (Bokslag, Teunissen, Franssen, & Kamp, 2017). Additionally, cesarean section delivery is standard in pregnant mothers with preeclampsia. Bokslag et al., (2017) found out that expectant mothers with preeclampsia had a shorter gestational age, children with lower birth weight, and lower placental weight, including symptoms of metabolic syndrome.

Furthermore, after pregnancy, preeclampsia may lead to lasting effects whereby about 15% of women who have a history of preeclampsia are more likely to suffer from chronic hypertension and at high risk of cardiovascular diseases such as stroke, kidney disease, diabetes mellitus, thyroid disease, and even impaired memory, among others. These mothers have nearly high risk of cardiovascular events in the next 5 to 15 years after pregnancy compared to women who are normotensive during pregnancy. Bellamy, Casas, Hingorani, & Williams (2007) revealed that the condition of cardiovascular disease is reported to be even superior when the pregnancy tends to be premature and could probably also affect the one adult health while the babies born by mothers who have had preeclampsia during their pregnancy could also be at high risk of cardiovascular disease.

2.1.3   Blood Pressure Reading Techniques

Blood pressure is interpreted in a standardized fashion, and repeated readings are recommended to reduce wrong interpretations (Eckner, 2014). The current ESH/ESC guidelines (Mancia et al., 2013) suggest that for a patient to be taken blood pressure readings, one should consider the following: be allowed to sit for 3–5 minutes before

beginning blood pressure readings, be made at least two blood pressure readings in the sitting position, and spaced 1 to 2 minutes apart. The health care practitioner should also consider the average of the two blood pressure readings if estimated to be appropriate, use a standard bladder that is 12 to 13 cm wide and 35 cm long, and have the cuff at the heart level, whatever the position of the patient. Besides, a quiet, comfortable location at average room temperature is ideal. Preferably, the patient should not have eaten recently, or smoked, or exercised, or taken caffeine. The one helping in taking the blood pressure readings should be well trained in the techniques of blood pressure measurement and use an accurate and properly maintained device. The guidelines were followed by (Shahbabu, Dasgupta, Sarkar, & Kumar, 2016) during their study to know out of the digital and aneroid sphygmomanometer, which of the two is more accurate than the other.

During the reading, the procedures followed were to ensure that the study participants were relaxed at-least for 10–15 min before blood pressure reading taking, while seated the legs were uncrossed and back supported as well as arm at heart level. Before the measurements, appropriate sizes of the cuffs are worn, where each instrument was used to measure blood pressure twice for each participant, an average of the two readings recorded, and lastly, all the participants' blood pressure readings of the study participants repeated the exercise at 30-second intervals.

There have been strategies that have been laid to detect blood pressure fluctuation. Blood pressure measurement are read using any of the two different techniques, which include the Auscultatory technique and Oscillometric technique (Musyoka, Thiga, & Muketha, 2019b). The auscultatory procedure involves attending to korotkoff sound, which gets generated by the body during the blood pressure reading with a stethoscope,

while the correct analysis depends on the size of the cuff, wrapping technique, and release of the pressure. The oscillometric method depends on measuring oscillation signals in the cuff which is quite an easy and automated technique and more accurate than that of oscillometric technology (Holey & Bhosale, 2016). The finger cuff method of the Penaz technique depends on oscillometric techniques, while and Ultrasound techniques depend on auscultatory technology.

The auscultatory method uses mercury sphygmomanometer for office blood pressure measurement, though it is diminishing due to mercury use, with the widespread of hybrid sphygmomanometers (Ogedegbe & Pickering, 2010). The hybrid devices typically join the features of both the electronic and the auscultatory devices, such that there is a replacement of the mercury column by an electronic pressure gauge, which is similar to the oscillometric devices. However, the blood pressure device is treated as same as mercury or aneroid device by health practitioner using a stethoscope and producing for the Korotkoff sounds (Ogedegbe & Pickering, 2010).

Ogedegbe & Pickering (2010) stated Marey was the first to demonstrate an oscillometric technique in 1876, and afterward, showed that when the fluctuations of pressure in a sphygmomanometer, there is a documentation of the cuff during gradual deflation, the point of maximal oscillation agrees with the mean intra-arterial pressure. These fluctuations begin at almost systolic pressure and continue below diastolic so that systolic and diastolic pressure can only be estimated indirectly according to some empirically derived algorithm. This method is valuable in that, no need for a transducer over the brachial artery, it is less susceptible to external noise, and that the cuff can be removed and replaced by the subject while monitoring. The main disadvantage is that

such recorders do not work well during physical activity when there may be considerable movement artifact compared to the oscillometric technique.

Another technique that is in use is an ultrasound technique. The devices integrating this technique use an ultrasound transmitter and receiver positioned on the brachial artery under a sphygmomanometer cuff. As the cuff deflates, the movement of the arterial wall at a systolic pressure leads to a shift in the Doppler phase in the reflected ultrasound, and diastolic pressure measurement recorded at the level at which the decrease of arterial motion occurs (Ogedegbe & Pickering, 2010).

The finger cuff method of Penaz is a technique that works on the principle of the "unloaded arterial wall." A photo-plethysmograph detects arterial pulsation in a finger under a pressure cuff (Ogedegbe & Pickering, 2010). The output of the plethysmograph is used to drive a servo-loop, which rapidly changes the cuff pressure to keep the output constant so that the artery stays in a partially opened state. This method gives an accurate estimate of the changes of systolic and diastolic pressure when compared to brachial artery pressures; the devices developed using the techniques enable readings to be taken over 24 hours while the participants are ambulatory, though it's a bit cumbersome to undertake the process.

The free maternal care program has immensely contributed to the reduction of maternal mortality in Kenya since a huge number of mothers have been going to hospitals for delivery(Ministry of Health, 2017). Conventionally, monitoring of blood pressure is performed in a clinic with trained personnel by mounting inflatable pressure cuffs with stethoscopes to the patient's arm, known as the auscultator method. This method does not achieve continuous monitoring, and the patient is supposed to be in a definite

position, which is likely to read false blood pressure measurements due to clinical environment such as stress, among others (Yilmaz, Foster, & Hao, 2010).

While using these techniques, there are technical challenges that are faced when taking blood pressure readings and are the potential sources of error. They include Effects of posture; most guidelines recommend taking blood pressure reading while sitting, but there is no consensus as to whether blood pressure should be routinely measured while seated or supine since several studies have systolic pressures were the same in both positions (Ogedegbe & Pickering, 2010). The body position during blood pressure measurements also influences the accuracy of readings. The same study reported that the participant's needs support during the measurement since if the participant is sitting upright, the diastolic pressure may go up to 6.5 mm Hg higher than if sitting back. Cuff size relative to the diameter of the arm also matters.

With the rapid change of technology, there are newer techniques that are recently being used to avoid the challenges faced by traditional blood pressure measurement techniques. Sensor technology has made this possible whereby mobile devices and other embedded systems have a sensor integrated into them to read blood pressure when the device comes into contact with the device. According to Waltz (2018), researchers have developed prototypes for a blood pressure sensor that can be incorporated into a smartphone and smart wearable watches and requires only the press of a fingertip.

Mobile phones are normally fixed with a sensor consisting of two main components: photoplethysmography (PPG), an inexpensive optical tool that measures blood volume changes, and a thin-filmed force transducer that measures applied pressure.

The user presses his/her finger on the sensor in the sensor chip on the phone, and an algorithm computes his/her blood pressure that works by illuminating tissue and measuring the changes in light absorption due to changing blood volume. The pressing of the fingertip generates external pressure on the underlying artery, much like that generated by a blood pressure cuff. The other most popular approach is the use of pulse transit time, where two separate sensors are required, one placed near the heart and the other placed further away, such as on the wrist (Waltz, 2018). The device then measures the time it takes for a pressure wave to travel from the heart to the other location in the body. With this technique, it is so convenient that people are encouraged to take blood pressure readings often at any time without even going to the health care centre for a checkup.

Several types of blood pressure monitoring devices are placed either on the wrist or on more popularly placed on arms. The armband monitors are unusual because they typically are more extensive and they need extra equipment that is attached to the armband (Alisinanoglu, 2015). Alisinanoglu (2015) reported that the armband blood pressure monitoring devices are less convenient than the wrist blood pressure monitoring devices since the wrist devices are self-sufficient with no extra equipment mounted on them.

Wireless Blood Pressure Monitors devices they uninterruptedly and continuously take readings from patients to see the fluctuation at any given time. It has been evident that people's blood pressure varies a lot during the day but it's controversial what to do about it since someone's blood pressure might normally be read when taken at home in the morning but then again reads high when taken later in the evening during the same day in a doctor's office. Wireless Blood Pressure Monitoring device provides many

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readings throughout the day and would give an improved and factual representation of patients' blood pressure, and hence, the device could be a research tool to help better understand the effects of blood pressure on the patient's body.

2.2 Internet of Things

The IoT is a combination of pervasive communication, connectivity, and computing along with ambient intelligence, where all the real-world components can stay connected (Sundaravadivel, Kougianos, Mohanty, & Ganapathiraju, 2017). The technology helps users to plan every day, and it integrates real physical world elements such as electronic devices, smartphones, smart watches, and tablets that can communicate both physically and wirelessly. It extends the benefits of the internet such as easing remote access, data sharing, and connectivity, among others, to various other application domains such as healthcare, transportation, parking activities, agriculture, surveillance, among other (Kougianos, Mohanty, Coelho, Albalawi, & Sundaravadivel, 2016). With its vast benefits and characteristics such as documentation, location, sensing, and connectivity, attached to the IoT, it is the integral component of smart healthcare, with a wide range starting from regulating medical equipment to the personalized monitoring system (Kougianos et al., 2016).

The Internet of Things setting is characterized by a high degree of hardware and software heterogeneity, incorporating several devices with different capabilities and running different network protocols (Maia et al., 2014). For establishment of value-added IoT applications by accessible resources at the Internet, it is essential to provide advanced models that will offer generalizations over physical devices and services, as well as several levels of transparency and interoperability. Additionally, it is crucial to

develop a more standardized and scalable approach to integrate smart objects in the online that will permeate several levels.

The low level integrates numerous heterogeneous physical devices with each other. The intermediate level makes data provided by the tools get to be easily made available at the Internet providing value-added services on the top of the sensing functionalities. While, a higher level provides a standardized programming model that can provide the decisive integration in terms of transparently assembling and transforming information from sensing devices without requiring any specific knowledge regarding the specificities of these physical devices and the networking environment (Maia et al., 2014).

In the Internet of Things perception, middleware paradigms have ascended due to upcoming resolution for offering interoperability proficiencies and handling the increasing variety of smart devices associated with the applications and end-users that use data provided by them. An Internet of Things middleware is a software platform between applications and the fundamental infrastructures such as communication, processing, and sensing that offers standardized means to access services provided by the smart objects through a high-level interface (Maia et al., 2014). Internet of Things middleware platforms must support runtime adaptation under vibrant environmental circumstances where applications make use of the organized heterogeneous devices. They disclose gaps that involve supplementary research energies, such as the creation of robust, fault-tolerant infrastructures that can accomplish and process data collected from numerous integrated smart objects.

Also, other gaps include the organization of indecisions and engagement of resolution, satisfactory support for familiarizing applications under vibrant environmental settings,

and; the minimization of the overhead of security tasks into the middleware platforms themselves (Maia et al., 2014). Globally the Internet of Things has countless eminence in promoting and controlling the development of information technology and economic.

2.2.1 Internet of Things Technologies

In a study carried out by Mishra & Roy (2017) it discussed use of Active Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN) for Real-time low cost data monitoring, where each patient was assigned an Active RFID Tag that monitored Heart-Beat pulse rate and their Body temperature using KYOTO' s Heart Monitoring machine and Microcontroller TMP36 from Analog Devices respectively. Each RFID Tag along with data value was stored, measured values were collected on a centralized computer to plot real-time graphical data and emit an alarm in case of emergency. An active RFID transmitter could transmit 16 bit unique ID on 433 MHz frequency giving a range of around 25 meters. An RFID reader connected to Arduino Micro-Controller, data-id is then sending wirelessly using Xbee Communication at 2.4 GHz. Later, a mainframe computer possesses all the required data of the patients (Mishra & Roy, 2017).

Apart from RFID technologies, Bluetooth and Android are technologies used in IoT for health care. A study carried out on Personal Health Monitoring with Android Based Mobile Devices was based on Bluetooth and Android technologies. The study proposed a system to monitor medical parameters such as Heart Rate and Temperature, whereby sensors were designed and interfaced with the microcontroller ARM7, which had inbuilt ADC to convert the sensors input analog signals to digital signals. The heartbeat sensor is intended to give a digital output of a heartbeat when a finger is placed on it. It

consists of a super bright red LED and a light detector. It then proceeds to the monitoring system phase that communicates the received results to the patient and physician. The collected data is transmitted by simple means of Bluetooth via UART serial communication, where one Bluetooth acts as a transistor and the other as a receiver. The received information is transferred to the respective Smart Phones via UART. The Smart Phone is capable of displaying, monitoring, recording and sharing the collected data (Avinash & Venkateshwarlu, 2015).

Mishra & Roy (2017) proposed an IoT device that used sensors that are Motion-object sensors and Temperature sensors. The sensors interact through Wi-Fi. Raspberry Pi technology was to access the input received by the sensors and process the data accordingly. Since Raspberry Pi lacks in-built micro SD, the Mobile App and Server complemented the storage. The data processed by Raspberry Pi was then accessed by the user using the Mobile App to check the updates and previous data. The server then served as a component to help in notifying the user/doctors and emits alarms during an emergency, also storage of data.

In another study (Alisinanoglu, 2015) that discussed the aspects of blood pressure data collection showed that collected data could be wirelessly sent using any of the connection options such as; Bluetooth, 802.15.4, ZigBee, Wi-FI, 3G and GPRS depending on the used application. Data can be transferred to the Cloud to perform permanent storage or monitoring in real-time by sending the data directly to a laptop or Smartphone for another person to access the patient's information when both parties are not near each other. It was concluded that with the proposed prototype system, more features could be integrated such as functionalities to monitor Electrocardiogram (ECG) graphs of a person. Also with the further attachments of the different medical

sensors with remote monitoring system the prototype would have an enormous application in the human health care field where there are more convenient and accurate results to be analyzed by the doctor for diagnosing a medical problem of the patient which resulted as abnormal blood pressure readings.

In another study (Mohammed & Pawaskar, 2017), discussing smart healthcare based on the Internet of Things, it depicted that Internet Technology technologies consist of four technologies; first, an Internet technology that enables communication with any person and object at any time and place. Second, RFID Technology, which is a non-contact, programmed recognizable proof innovation for protests with the assistance of noncontact perusing and composing gadgets. Third, Sensor Network Technology, which is the centre of IoT and its RFID frameworks to track the status of objects, and it better, consists of several detecting hubs. Last is Wireless Communication Technology, which is a remote correspondence innovation that subsequently transmits the data put away in the RFID tag to the central data framework, and it incorporates Bluetooth, WIFI, UWB, Zigbee, among others.

These are mobile communications standards which allow the Internet of Things users to access the Internet wirelessly using different devices such as mobile phones, tablets and other portable electronic devices whereby some of Internet of Things models used 3G while others used 4G (Yuan, Hong, Li Da, Yan, & Fan, 2014).

In another study that described a universal conceptual approach of an Internet-of-Things (IoT) system development and implementation to enhance bathroom safety, it showed that the main aim of IoT is to collect data measured by sensors integrated with short-range wireless networks such as Bluetooth, ZigBee, or Wi-Fi, that then, transmits data again to more extensive systems. The sensors that are integrated into IoT are useful

since they offer low cost, scalable, efficient, low power, thought the networks (Koo, Lee, Sebastiani, & Kim, 2016). However, as the more sensors collect data then data collection in repository increases too causing what is defined as big data through Internet of Things offers a reliable means of data collection, detection of continuous monitoring of activities, efficient algorithms to act on the events, and big data storage for analysis.

Architectural styles are also considered when designing and implementing Internet of Things applications. According to Dias & Ferreira (2018), there are fundamental building blocks for Internet of Things systems which include; sensory devices, remote service invocation, communication networks and context-aware processing of events where IoT controls these building blocks as a unit where the smart objects and the human beings responsible for operating them are capable of universally and ubiquitously communicating with each other.

IoT system is said to be dependable, adaptable, handle dynamic interactions, highly scalable, and human-centric, which then has to follow an architectural style that is compatible with updated standards. Dias & Ferreira (2018) explained in their study that IoT systems are generally based on either a Representational State Transfer (REST4) architecture or a Simple Object Access Protocol (SOAP) architecture. On the one hand, SOAP is a traditional architectural style that consumes high bandwidth, more complex and uses Extensible Markup Language (XML) data-exchange format while, on the other hand, REST is more flexible, coupled with JavaScript Object Notation (JSON) data-exchange format, and is usually faster and consumes less bandwidth.

2.2.2 Mobile Health

Before the advancement of the Internet of Things, mobile technology was highly use to perform different services; thus, IoT has evolved from mobile technology. Mobile Health technology and mobile devices have, in recent years, swiftly lanced globally. Nearly all parts of the world. The technology of mobile devices have reached more people in many developing countries than other technologies such as power grids, road systems, waterworks, or fiber-optic networks, among others (Munyua, Rotich, & Kimwele, 2015).

The adoption of mobile technologies in every dimension of life has also been remarkable, and in twenty years, ever-more sophisticated mobile technologies have fundamentally altered how people communicate and conduct their lifestyle. The high scalability of mobile information and communications technologies within health service delivery and public health systems has generated an assortment of new prospects to deliver new practices of interactive health services to patients, clinicians, and also health care providers.

Several mobile technology platforms that have done this possible service include but not limited to cellular and wireless networks, tablets and cell phones, smartphones, wearable devices, mobile-enabled diagnostic and monitoring devices, or devices with mobile alert systems. mHealth has drastically changed the traditional way of delivery of healthcare services, thus sanctioning for continuous, pervasive healthcare anytime, anywhere to acquire real-time information. With mHealth, health care practitioners, home caregivers, and patients have the opportunity to monitor health conditions and access health information outside of the hospital.

Mobile Health technology has expanded entrance into health information and services that lead to healthy personal wellness, preventive care, and chronic disease management, promoting efficiencies in care-management practices and enlightening personnel and population health consequences. Whereby, its scope has ranged from modest direct-to-individual consumer and interactive patient-provider communications to more complex computer-based systems enabling coordinated patient care and management (Hanauer, Wentzell, & Laffel, 2009).

Mobile Health has been defined as a medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices (Colaci, Chaudhri, & Vasan, 2016). Solutions for the prevention and management of pregnancy hitches exist; however, implementation of these solutions is also controlled since the overall access to quality care is lacking, and thus, health systems strengthening is essential to address this critical context. mHealth has the potential to reduce disparities in care through a variety of mobile applications that has an intent of effective communication between clients and providers, promote pregnant mother's behavioral change, improve training, and assist in data collection; to improve access to and quality of maternal care.

Mobile Health is a crucial technology for patients, doctors, nurses, and health care providers to assist a healthy lifestyle. It is has been accepting awareness from patients together with their health care providers in giving the best practices about their health. Some of the mHealth application categories available for patients and healthcare professionals include telemedicine, diagnostics, support for research and data collection, health promotion and behavior, sensors and peripherals, E-learning medical, information sharing and drug reference, and many more.

The combination of sophisticated mobile technologies and data analytics are easier for healthcare professionals to provide the best care possible, away from high-cost services such as hospitals and doctors' offices, and closer to where patients live, work, and even during the travel (Mohammadzadeh & Safdari, 2014). It was discovered that mobile applications had been advanced in topical years with a high number of dispositions by patients and healthcare professionals. In the study, it was reviewed that regardless of the benefits of smartphones in healthcare application categories, the majority of researchers believe that there are some critical issues related to usability, security, and privacy of the application.

According to a study (Waegemann, 2010) reported the spread of mobile devices are considered as one of the fastest adopted technology in human history which offers cheap communication creating a tremendous impact on the society as a whole thus, spreading mobile technologies applications and bringing a considerable innovation perspective. According to the International Telecommunication Union (ITU), there are now approximately 5 billion mobile phone subscriptions in the world, with over 85% of the world's population now covered by a commercial wireless signal (WHO, 2011). These mobile phones and wireless signals are the ones used to address the main health concern, which has evolved as a new era known as e-health or mobile health.

Up to date, the world is experiencing some health diseases that are either communicable or non-communicable diseases, long term to short term, yet there is a shortage of health workers who are mobile due to low settlement areas identified in developing countries. This has been proven by statistics in (WHO, 2015) that showed 57 countries need at least 2.4 million health workers in different parts of the country resulting in millions of citizens worldwide being affected by this shortage of health care practitioners,

especially vulnerable groups like pregnant mothers and infants. Thus, mobile health technologies, based on wireless communication technologies and mobile phones, are primarily available to increase public health services.

2.2.3   Maternal Health with mHealth Technology

Mobile Health remains to be one of the most significant technological breakthroughs to address health, as was revealed during the 2011 annual mobile Health Summit in the Washington, DC area (Munyua et al., 2015). Globally, this technology has risen the healthcare agenda. Progressively pervasive and influential mobile technology embraces the potential to address long-standing disputes in healthcare delivery. However, there were found to have a few established business models of executing this technology whereby a global survey of 114 nations was undertaken by the World Health Organization and found that mobile Health initiatives have been established in many countries, but there is variation in adoption levels (Hall & Khan, 2002).

The most famous movement was the implementation of health call centres, which respond to patient inquiries. This was followed by the use of SMS for appointment reminders, accessing patient records, measuring treatment compliance, raising health awareness, monitoring patients, and physician decision support. A study on Economist Intelligence Unit (Boston Consulting Group, 2012) was conducted to examine the present state, the potential of mHealth in developed and emerging markets, the ongoing barriers to its adoption, and the implications for companies. In the study, two surveys were carried out, and it was found out that although the level of mHealth penetration of mHealth was low, 60% of doctors and payers believed that its adoption was inevitable in the near future and would eventually become an essential part of care provision.

However, it was recommended that approval of mHealth would require changes in actors' behavior who were in the view of protecting their preferences.

It was concluded that the adoption of mHealth would provide patients with better convenient health care with greater control, and health practitioners would provide better patient care and ease the administrative issues they currently face. It was established that in the US, out of 10000 consumers, about 31% of the U.S. population have used mobile phones for health information and applications (apps) in 2012. Also, consumers aged 35 – 44 are most likely to use mHealth apps, with 23% leveraging health apps three times more than consumers ages 55-64 (7%) (West, 2012).

Currently, there is evidence of marked enhancement in maternal and child healthcare service delivery strengthened by mHealth solutions (Akinseinde, Badejo, & Malgwi, 2016). An extensive literature survey conducted in (Watterson, Walsh, & Madeka, 2015) established the effectiveness of mHealth tools in improving the use of antenatal care, postnatal care, and childhood immunizations through behavior change in developing countries.

The mHealth solutions provide pervasive technology to work out challenges that are repeatedly encountered in these developing countries, such as; lack of health information, tracking patients' data, and limited training for health workers, among others (Akinseinde et al., 2016). The study led to the development of a personalized and localized content application development suitable for health care for pregnant mothers that would perform several functionalities. Among the features are due date calculation, calendar, and growth of fetus, complications, medication, drug and health alerts, as well as childcare information for women with young children who are less than five years old.

The developed mHealth solution presents the needed resources ranging from simple short messages to multimedia content to patients, relatives, and community health workers. It was tailored towards facilitating low-cost involvement for prenatal, neonatal and postnatal health information and services, thus strengthening the maternal health care system (Akinseinde et al., 2016).

Also, it was reported that early recognition of signs and symptoms of hypertensive disorders it's the only way to prevent preeclampsia condition (Romero et al., 2018). The study concluded that pregnant women with hypertensive disorders could benefit from mobile health (mHealth) solutions where Information and communication technology could be used to support diagnosis and monitoring, management and self-care, communication between patients and maternity care providers, and patient education and empowerment.

Several mHealth solutions have been reported to control factors that lead preeclampsia by creating awareness on genetic predisposition, having a previous history of preeclampsia, obesity, excessive weight gain, elevated Blood Pressure, multifetal gestation, maternal age, among others. This control of early symptoms is applied to LMIC settings, with delayed identification of women with hypertensive disorders because of their limited health care capability and facilities for testing and managing such patients.

With the use of Information Communication Technology, a considerable number of pregnant mothers could be treated at any time and reduced health care costs, while the quality and efficiency of care are maintained. They then concluded that; there is a need for simple mHealth solutions developed explicitly for resource-poor environments that meet the United Nations Sustainable Development Goals (SDGs) to achieve SDG 3 that

states "Ensure healthy lives and promoting well-being for all at all ages, which among its targets are to reduce the maternal and neonatal mortality ratios."

In a study on the use of mobile health applications in obstetric care, it was reported that organizations like WHO and UN have reported that preventable pregnancy-related complications have accounted for many deaths for women and children, and the improvement in obstetric care will help achieve SDG 3. In the study, it was found out that mhealth aids many applications in obstetric care such as health promotion, health information access, emergency obstetric care access, EMR, mhealth apps for pregnancy, and apps connected to biomedical devices.

In the review it was executed that in 12 studies carried out in in US and African region is South Africa, Zambia, Zanzibar, and Nigeria, the issues faced in pregnancy were health promotion, disease prevention, prevention of HIV transmission from mother to infant, obesity, and overweight, smoking problem, antenatal knowledge and attendance that required mhealth applications to cease. However, in the study, the only mhealth application found to be used text messaging whereby seven studies developed an application to send text messages to pregnant women, while five studies used a simple mobile phone to perform the same task. These apps were Text4baby app, Preg CHAT text, MoMTECH, Quit4baby, and Wired Mothers app.

2.2.4 Internet of Things Application Areas

At Present, the application of the Internet of Things requires special requirements that are a challenge in meeting them due to use of features such as; high bandwidth and rate, non-line-transmission ability, large-scale data collection and high cost-effective, and it has the capability of video monitoring, among others (Colaci et al., 2016). Since

the technology is rising rapidly, the study carried out focused on WiFi-based WSN in the development of Internet of Things applications, which includes; Smart Grid, Smart Agriculture and Intelligent environment protection. The development work of a Wi-Fi-based Smart Wireless Sensor Network for monitoring an Agricultural Environment was analyzed where the system consisted of three stations: Sensor Node, Router, and Server. The system is intended for monitoring of agricultural climate such as field or greenhouse. The sensor station is equipped with several sensor elements such as Temperature, humidity, light, air pressure, soil moisture, and water level.

An investigation was performed to integrate a novel planar electromagnetic sensor for nitrate detection. The communication between the sensor node and the server is achieved via 802.11g wireless modules. This showed that monitoring systems and sensors systems have increased in recent years though this expansion increases in installation and maintenance cost attribute too. Sensor technology is applied in applications of the Internet of Things to measure and acquire data, but they require a valid data transfer mechanism to enable complete applications that utilize the data they collect embedded systems.

In recent years, information, communication, and technology, the rapid evolution of electronic devices, smartphones and tablets, which can be communicated wholly wirelessly, have become the ultimate tool of daily life. According to (Ulla, Ali, & Zhang, 2016), they depicted the Internet of Things (IoT), which connects devices, sensors, appliances, vehicles, and other "things," which is becoming the next generation in connecting the whole world. These things or objects may include the radio-frequency identification (RFID) tag, mobile phones, sensors, actuators, among other related appliances.

While using the IoT, objects are connected accessed from anywhere and anytime, and even efficiently, access is experienced. The critical purpose of IoT is to outspread the benefits of the Internet with remote control ability, data sharing, constant connectivity, among others. The Internet of Things technology is currently used in different fields of life, including the digital oil field, home and building automation, intelligent Grid, digital medical treatment, smart transportation, among others (Ulla et al., 2016).

Internet of Things (IoT) devices that apply pervasive and ubiquitous computing indicate the imminent of the world and reveal exciting visions of many smart things such as smart cities, smart homes, smart cars, and other intelligent spaces such as malls, workplaces, hotels, and schools.

Internet of Things has been given the name SmartHome where it is implemented in homes. In a comprehensive review conducted by (Singh & Bhattacharya, 2017) use of Internet of Things technology in homes was discussed. The study showed that there is a vast number of aged people in the USA, Brazil and Japan countries with prominent nuclear families. Thus, older people tend to live alone in their houses despite being prone to diseases and health complications, and so they require quick attention in case of an emergency leading to continuous monitoring. This issue of smart home systems caters to such situations in giving solutions to aged people and even patients who are left at home without any health care provider.

The study by (Mano et al., 2016) proposed the use of camera and wireless-based network architecture that would help in resolving the issues that aged people and patients face when left at home alone, such as falling, among others. This system uses sensors and decision-makers who would capture an image and infer the data from feelings and emotions in a patient that is not felt when one is communicating with these

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patients over the phone. The captured data is then sent to a health care practitioner or a health care provider who helps in decision-making and perform relevant action at the moment. Mostly, these IoT systems would operate with the help of reliable power supply and could have a battery backup in case of outages.

Similar to the concept of the Internet of Things in developing a smart home environment, the smart city is also an emerging IoT application. A smart city refers to new industries that make use of information and communication technologies (ICT) besides the functions and environments of metropolitan areas (Sterbenz, 2017). The importance of IoT in cities is highly encouraged since smart cities will contribute to the efficient and effective utilization of energy and electricity thus, providing a convenient and economically sound infrastructure for the well-being of society (Park, Pobil, & Kwon, 2018). In the city, various services are required for operation and utilize different types of data collected in daily life can be provided. This means that multiple services using IoT technologies in a smart city can bring about a sustainable and pleasant living environment for its citizens.

Physical injuries that are experienced in bathroom activities cannot be ignored either since statistics have shown that a bathroom is one of the most dangerous places, especially for aged people. Older people usually have difficulties with mobility and stability, making them more vulnerable to fall and slide in a bathroom floor (Koo et al., 2016). Moreover, women and children can also experience unacceptable activities in the washroom where they can be attacked for sexual violence, and thus, with the help of Internet of Things application in bathroom places, it can save them from the agony.

Internet-of-Things (IoT) is a new paradigm applicable to almost everywhere and human-made objects whereby wireless sensors detect anomalies and send data through

the available network, a large amount of data is collected from the integrated IoT devices and after that analysis is done for any abnormality experienced.

In decades ago, innovations have been made in the agricultural sector to help in food security improvement by increasing the yield and even reducing human power, which is quite tedious work to do. However, the demand for extra foods from the increasing population will never get satisfied since statistics have shown that a prediction that the world's population will reach 9.7 billion by 2050, which is about 33% more than today (United Nations Organization, 2015). Therefore, to attain the required amount of food for such population growth, then the global production of food has to rise to at least 70% to feed the whole world.

With the help of advanced technology, is an Internet of Things paradigm that is portrayed as the next big thing that can have a significant influence on the future of the world, then a lot of improvement in agriculture can be made. According to the study (Zhang, Dabipi, & Brown, 2018), it was concluded that application of latest IoT technologies in agriculture practice, the traditional ways of farming could be fundamentally changed on every aspect, to pave the way to a new agriculture pattern that consists of three stages. Namely, the real-time data acquisition, data analysis, and decision-making, and corresponding precise treatments where these stages can be greatly facilitated with the advancing of the IoT technologies in recent years.

In the book chapter authored by (Zhang et al., 2018), the following application areas in agriculture were reported to have utilized the Internet of Things paradigm to improve agricultural efficiency and productivity. Application in agriculture irrigation where Crop Water Stress Index based irrigation management uses IoT by acquiring crops' water demand of a site in farmland, in which modern remote sensing technologies can

contribute a lot. Secondly is, agriculture fertilization where the IoT paradigm has remote sensors that collect data from plants by estimating spatial patterns of fertilizing requirements with acceptable accuracy and minimum labor work required.

With the use of Autonomous Driving System, which are vehicles that design paths, auto steer, make turns, and follow edges and rows to cover the entire field while applying fertilizers and other matters. The other application is in Crop Disease and Pest Management that allows for disease forecasting, modeling, or real-time monitoring. Moreover, Precision Livestock Farming is also an application that enables optimal animal feeding and nutrient utilization by the use of innovative applications such as smart chicken farm, smart cow farm, among others. Lastly, Aquaculture application that enables water quality monitoring and maintenance, remote fish status monitoring, and precise feeding, Information management, Logistics, and fishery products quality traceability, among others.

Manufacturing industries are moving to influence Internet of Things technologies and data analytics to survive and stay competitive with each other. Smart manufacturing is an application that employs Internet of Things paradigm in creating an environment where all relevant and related information is available from inside the industry and also along the supply chain, whereby the data is captured in real-time, made visible and turned into actionable insights (Anita & Abhinav, 2017).

In enabling IoT operation in smart manufacturing, then the aspects such as business, blurring the boundaries among plant operations, supply chain, product design, and demand management will be integrated and be monitored remotely. This application integrates several technologies, such as network connectivity technologies that include wifi and M2M, the cloud storage environment, Big Data analytics for the intelligence

to analyze data and provide insights on the flutter, and end-user applications such as ERP and mobile devices for more active and precise business decision-making.

2.2.5 Application of Internet of Things in Health Care

The IoT plays a substantial role in healthcare applications, from managing chronic diseases at one end of the spectrum to monitoring day-to-day physical activities that could help in maintaining one's fitness goals. Globally, there is a considerable number of people whose health may suffer because they do not have appropriate access to hospitals and health monitoring but due to the up-to-date technology, small wireless solutions which are connected to IoT can make it possible to monitor patients remotely instead of visiting the physical hospital (Ulla et al., 2016).

According to Ulla, the study reported that sensors that are attached to a patient's human body could be used to get health data securely. The data can then get analyzed and sent to the server using different transmission media, which include: 3G/4G with base stations or Wi-Fi, which is connected to the Internet where medical practitioners can access and view the data, make decisions accordingly to provide services remotely.

According to a study carried out by Neelam (2017), it was stipulated that the Internet of Things is used in health care in different areas. These areas include: Blood Pressure Monitoring that is known as the most important physiological parameters of the human body, and IoT is implemented and integrated with health care systems and sensors to make secure communication between the patients and doctors and health care providers. This helps in collecting the real-time data of the patient BP levels ready for doctor's analysis. The other area that was reported is Rehabilitation System. This enhances functional abilities and improves the quality of life for the individuals who

are living with disabilities. This is done by mitigating the problems that they face as well as older people who are highly ignored due to a shortage of health experts, and this is done by use of an ontology-based automating designing method connected with IoT-based smart rehabilitation system (Islam, Kwak, & Hossain, 2015).

Oxygen Saturation Monitoring is another health application area for the Internet of Things, which continuously monitors the blood oxygen saturation of the persistent in a noninvasive way that helps health care practitioners to know the oxygen levels in the blood and also the heart rate (HR). This operates where the Internet of Things sensor is connected to the human body where it monitors and senses the patient's heart rate and oxygen levels. The other type of application reported in the study was wheelchair management that is utilized by people who are living with physical illness and disabilities, and they can't walk.

The operation of this application is as follows: Wireless body area networks (WBANs) connects to smart objects using the Internet, to be used as a people-centric sensor and accelerator sensor devices for wheelchair users. Then a pressure cushion detects when the human body is falling from the wheelchair. The health care practitioner hence, remotely monitors the patient's data from the hospital. Finally, there are healthcare solutions using smartphones mobile devices and healthcare apps that help health care practitioners access health records, other communications, appointments, and making a reliable decision based on the output after analysis. This study has shown that with the rapid growth of the Internet of Things technology, then the health care sector can highly benefit in improving patients' health.

Moreover, Singh & Bhattacharya (2017) did an extensive review on application areas of IoT in health care and found out the following areas: IoT for Rural Healthcare

Monitoring and Control that is used to monitor patients progress in rural areas where RFID sensors record patients data and sent to health care provider though SMS or alert messages. Secondly, Personalized Service Model for sharing medical devices among patients, an example being sharing of an IoT based glucose meter. Thirdly, the ingestible sensor that was developed by Proteus Digital Health is implemented using high volume semiconductor and pharmaceutical components to help in monitoring whether the patient has taken drugs as prescribed by the doctor. Fourth is, IoT based Hearing Aids that was invented by Doppler Lab using EQ and audio effects to create a feeling for the listener, which is a wearable earing device used for communication, fitness management and provides biometric data.

The fifth application that was discussed in the paper was IoT based Mood Enhancing Device that is developed using neuro signaling technology, which ascertains moods and uplifts moods of a human. These signals are useful in balancing nerves and lead the participant to a calm situation. Sixth is IoT based Healthcare Charting which helps in reducing the time consumed during interrogation between patient-doctor relationships.

This system uses smart glass technology like Google glass integrating them with voice command systems to allow health care practitioners to record patient's data. The system then transmits and stores data in secure storage. The other application that was reviewed was an Adverse Drug Reaction System that captures data related to a patient's medical history and allergy profile from electronic health records available.

Children Health Information System is another application area reviewed by Singh & Bhattacharya (2017) that emphasizes on child-related issues such as nutrition, emotional, psychological and behavioral developmental challenges. Rehabilitation Management is another application that was discussed in the paper that helps to provide

reliable services to patients with functional and mental disabilities since the experts in the field are few. Other applications that were also mentioned in a study by (Neelam, 2017) are Oxygen Saturation Monitoring and Body Temperature Management Internet of Things based systems.

Mobile technology as a tool has been leveraged to provide healthcare services globally and especially in developed countries. It has focused on several areas such as; emergency response systems for road traffic accidents, emergency obstetric care, disease surveillance and control, and human resources coordination. Also, it focuses on synchronous and asynchronous mobile telemedicine diagnostic and decision support for clinicians at point-of-care, remote patient monitoring and clinical care, health extension services, health promotion, and community mobilization, health services monitoring and reporting, health-related m-learning and training for health care workers, among others (Maitra & Kuntagod, 2013).

Many of these healthcare services aim at direct interpolation at the point of care from a remote location, thus leading to the need for a robust communication network. According to the study Maitra & Kuntagod (2013), it has shown that the health care practitioners are barely willing to go into rural settlements in India, and asking an expert to attend a large number of m-health calls could be unsustainable. Also, women in rural India would find it tremendously costly and socially intolerable to deliberate any pregnancy-related matter with a remote advisor through a mobile phone. Most of the healthcare solutions available today hardly use the substantial memory storage and processing capability that a modern mobile device possesses, and thus the cost of hosting the application on the server-side along with the demand of the high-speed, reliable network makes them unusable for rural low-income consumers.

Wearable devices are everywhere and are as commonly used as mobile phones. Since the first-ever wearable device, the Bluetooth headset, which debuted in 2000, wearable devices seem to have finally arrived in the mainstream market. In the e-health context, wireless body sensors are small biomedical devices that are placed on the human body or are hidden under clothing and have wireless capabilities in order to allow increasing patient comfort and mobility, thus not impairing his/her normal activities while monitoring his/her health status regardless his/her location (Maia et al., 2014). Wearable devices collect a variety of information about human emotion conditions such as physical, social, and locomotives obtained through big data analysis then later diversify the results.

Technology plays a significant role in every aspect of human life. With the emerging domain, technology has drastically changed the roles of medical services with the advent of upcoming medical technology used in surgery, scanning, among others. Current technology such as cloud computing and the Internet of Things has enabled patients to spend minimum time in hospitals and satisfactory (Mishra & Roy, 2017).

According to Adapa (2016), wearable technology has experienced a lot of challenges such as battery life, display, privacy, among others, before getting an opportunity into the mainstream market and being accepted by people. Some of these challenges are eliminated with time, and as technology continues to evolve, other problems do arise. Joseph Dvorak, who has over ten years of experience in wearable technology and design, identifies five broad elements that affect the acceptance of wearable technology in the mainstream as wearability, ease of use, compelling design, functionality, and price (Adapa, 2016).

Many of healthcare services aim at direct intervention at the point of care from a remote location; hence, a robust communication network is necessary (Maitra & Kuntagod, 2013). Another major challenge in wearable body sensors arises mainly in terms of interoperability among several heterogeneous devices from a variety of manufacturers (Maia et al., 2014).

Wearable existing tools may be inadequate to: facilitate behavior change among target populations and improve data collection for research in low-resource settings (Bill & Melinda Gates Foundation, 2017). The behavior change barriers include span motivation, skills and knowledge, environment, and lack of social support. Besides, research data is often limited by the burden of collection, resulting in incomplete or inaccurate data whereby mothers and new-borns that don't reach facilities are left out, and data may not reflect population realities. This shows that there is a need to focus on the role of wearable devices in enhancing behavior change and research data for pregnant mothers in an informal settlement to avoid pregnancy complications such as preeclampsia.

Another study carried out on arm-band wearable devices for blood pressure in pregnant mothers (Suhasini & Sudarshini, 2015) recommended that ongoing researches on patient monitoring systems should focus on ensuring systems are more compact and readily available at affordable price. New technologies could also enhance the performance of the new systems. This indicates that less has been done on wearable device acceptability due to compatibility and affordability issues.

In recent times, there have been technological enhancements that make IoT a certainty, such as wireless communications, low power processors, and electronic devices. With visualization of IoT, all entities on Earth can be recognized, addressable, measured, and

monitored via the Internet (Musyoka et al., 2019a). The wide distribution of IoT model has revealed its prospective to produce a substantial impact on the daily lives of human beings which has been progressively employed in applications from numerous real-world domains, such as domotics, ambient assisted living (AAL), energy, transportation, and environmental and urban monitoring (Maia et al., 2014).

Interoperability is a significant challenge in having a wearable body sensor that communicates over the web due to heterogeneous devices from a variety of manufacturers. A study introduced EcoHealth (Ecosystem of Health Care Devices), which is a Web middleware platform for connecting doctors and patients using attached body sensors to provide improved health monitoring and diagnosis for patients (Maia et al., 2014).

Maia et al. (2014) acknowledged that one of the application domains that can benefit from IoT solutions is e-health, which can be defined as the health care practice supported by electronic devices and information and communications technologies that are composed of electronic medical records, electronic prescriptions, remote monitoring, and health knowledge management.

Wearable devices are of four categories, which include: healthcare & fitness trackers, wearable cameras, smart glasses, and smart watches. Others include smart rings, smart helmet, and smart headgear, among others (Tran Vu, 2015). Healthcare & fitness trackers are of different kinds of wearable devices existing on the market currently, such as fitness trackers, wristbands, and smart watches which have special functions for health tracking.

The devices can measure the victim's heartbeat, energy consumed, steps taken, distance traveled, and more so some of them can be used for treatment. Wearable cameras as a category are different from other cameras in that they are mobile and flexible thus create more interesting ways for users to use the wearable camera to interact with the world. These cameras are attachable to users' bodies or clothes or can be worn on ears. Others are mountable on helmets to perform the task intended to perform. Smart glasses are also a category in wearable devices which are different from the traditional lenses that are used for eye diseases or luxury fashion accessories but also can be turned into smart devices which can provide information, notifications, entertainment and a distinctive point of view such as virtual reality space in three-dimension (3D) mode (Tran Vu, 2015).

Smart watches are the other category of wearable devices that are day by day released through annual international electronics events such as Consumer Electronics Show (CES) or IFA - Berlin Shows or manufacturers' shows. Reported that about 40 companies had launched smart watches in 2013, and the latest company was Apple Inc. by releasing Apple Watch on March 2015. Most top markets of the smart watch industry are China and the United States that take over half of the distribution of smart watch globally.

2.3 Smart Armband Watches

In decades ago, computing devices could only send and receive data through physical copper or glass fibre wires, but in recent times, with the advent of wireless communication technologies, it has become possible to connect devices to networks by use of electromagnetic radiation. With this advent, there have come smart objects that facilitate communication between different devices with the use of protocols and

standards. In this era, smart watches, although still in their infancy, are to contribute to this Internet of Things that utilizes the new age of wireless communication with smart objects (Stork, Bont, & Szabo, 2017).

Smart armband watches are prospective in supporting health in everyday living by assisting in self-monitoring of personal human activity, obtaining response based on activity measurements, allowing for surveys to identify patterns of behavior for decision making, and supporting multi-directional communication with health care providers and family members. However, smart watches are an emerging technology and research with these devices is at an emerging stage (Reeder & David, 2016).

The first innovation of a smart watch was well-thought-out to by IBM Linux which was launched in 2000 (Narayanaswami & Raghunath, 2000). During the past 18 years, smart armbands have developed and now offer greater functionality compared to the first innovation. In 2012, the Pebble Smart watch was launched on a crowdfunding website, and up to date, smart arm watches have received increasing attention from people.

According to Cecchinato et al. (2015) he defined a smart watch as "a wrist-worn device with computational power, that can connect to other devices via short-range wireless connectivity; provides alert notifications; collects personal data through a range of sensors and stores them, and has an integrated clock." This definition gives a practical description of the kind of smart armband that was utilized in the study that was carried out.

A smart watch is not only a device to display date and time but also a wrist wearable device that consists of sensors, and that is networked to help interact with other networked devices for productive interaction. Smart watches have the potential to

transform health care by supporting health in everyday life. They are familiar to most people hence becoming an available consumer device, enable near-real-time data monitoring of physical activities, support messaging and giving of alerts, ensure there is timely interaction between parties either doctor and patient or family member and patient, and assist in making decisions after reliable information is collected.

Smart armband watches have been used in healthcare to assist doctors and other health care providers in monitoring different types of sickness in a human being. A study carried out by Dolgin (2014) explained two areas where smart watches have been of great importance as; epilepsy and cardiology treatments. Smart watches do record information that can integrate with promising Internet of Things platforms, such as Lab of Things (Brush & Mahajan, 2014) and electronic health record (EHR) data to provide all-inclusive views of personal health trails across settings.

Studies have shown that there is a considerable demand for smart watches. A study by Rawassizadeh, Price, & Petre (2015) reported that the predicted growth of smart watch demand was 214 million units in the year 2018 and reported also that from a financial feasibility standpoint, current prices for smart watches start at less than USD 100 for the Pebble Classic. The availability of smart watches has gained the attention of amusing users, but their use for health care decisions will require the evaluation of these devices for that purpose by an expert.

This smart watch technology has benefits and comes with challenges as well such as Power consumption. Several studies have reported the need for higher battery power with current devices, which will increase with the need for more on-board processing of data before transmission to other devices (Reeder & David, 2016). Rapid changes in technology are also a concern where when one purchases a device, in two months

period, the device is out of stock, and other devices have replaced it. Reeder & David (2016) found out that out of the nine different smart watch models employed in a review, two were no longer available and one was a last generation watch model.

Another challenge that was reported is data hostage with the fear of who will manage it and who will pay for it. It was concluded that proprietary data management models from single vendors could solve the problem of data collection, analysis and hosting with subscription models, though, the approach is not transparent from the standpoint of algorithms used to analyze data and can present problems of data ownership and access, primarily if vendors are sold or go out of business. Some respondents also claimed that the small screen size of smart watches impaired the usability of the device.

According to a study carried out by (Wang, 2017), one of the most significant issues with smart watches was found out to be that batteries within them don't last long before they get recharged. The average battery life is about 1 to 2 days at most whereby; Apple Watch Series 2 and Huawei Watch battery life lasts for one and half days, for Samsung Gear S3 lasts for 3 days, Pebble 2 lasts for 10 days but has the disadvantage of having a small RAM and storage space with minimal number of functionalities.

Other issues that would require solutions related to privacy, confidentiality and security of smart watch data as well as the ethics of data ownership and use (Vesnic, Breitegger, & Guimaraes, 2016).

2.3.1   Usability of smart watch

Physical inactivity and sedentary behavior increase the risk of chronic illness and death, where smart watches offer potential as a multifaceted intervention to help people become more active. There are several devices developed by different vendors with different features that could lead to usability and acceptability issues.

To assess the acceptability of commercially available wearable activity trackers, (Kathryn, Lora, Eric, & Parmit, 2016) carried out a study where they were identifying all devices available to Canadian consumers as of November 1, 2013. They reviewed four devices by Fitbit, two devices by Jawbone, and one device each from Withings, Misfit, and Nike. The study found out that all four devices used an accelerometer to assess steps (pedometer). The researchers opted to use Fitbit Zip because it was inexpensive, could be clipped to clothing, and allowed users to track the activity on a simple interactive screen. They also opted for Jawbone Up 24 as it could be worn on the wrist and could collect data on sleep quality. Misfit Shine was also selected as it could be worn on the wrist or clothing, was waterproof, and could double as a watch. Finally, the Withings Pulse was chosen because it could capture heart rate data.

For practical use, Tsung-Chien, Chia-Ming, Matthew, Cheng-Chung, and Anne (2016) noted several key factors that should be developed to implement wearable devices, which included; miniaturization, integration, networking, digitalization, and standardization. They also argue that unlike smartphones, smart watches can be truly wearable without interrupting our daily lives, and can also serve as a readily accessible extension of the smartphone. In the review of literature, they found out that since late 2013, there were 24 studies involving smart watches in healthcare applications where the majority were published in 2015.

The platform that they found mostly used in health care research was that of the Android Wear, and none applied the Apple Watch. The reviewed literature showed that smart watches are being used as a platform for a variety of healthcare applications such as health monitoring, smart home environment for the aged group of people, and monitoring of chronically ill patients.

Using wireless communications links (Wi-Fi or Bluetooth), smart watches connect to a smartphone, host system, or the Internet. Wi-Fi is a short-range of a hundred feet system that typically covers the network operators' property. Bluetooth connectivity is used for a very short distance of about 33 feet connection. Bluetooth connects special-purpose devices over a very short distance, such as between a cellphone and its wireless headphones or a paired smart watch while Wi-Fi provides faster data transfer rates used for more general-purpose connections between computers and networks (Wang, 2017).

The material being used is also vital to consider due to reactions to the human body. The Huawei Watch has IP67 water and dust resistance rating, where a consumer can use it when washing hands, cooking, or in a rainy season (Huawei, 2016).

Smart watches are rapidly penetrating the health informatics research space (Reeder & David, 2016). In their study, they recommended that smart watch measurements must be validated against ground truth measures in more extensive studies to understand the reliability of data that is collected. They also found out that power requirements are one of the significant limitations experienced in the usability of smart watches and besides, in the research, there is a matter of considering the one to host and manage collected data.

In addition, in generating the source code, the IoT based model evaded unnecessary time consumption by the developer in the realization of tasks and activities, with prospective gains in productivity, hence a good performance system. Mobile application is everyday more present in our daily routines, which is explained by the great evolution that occurred in recent years causing the emergence of a variety of new mobile devices and operating systems, increasingly more sophisticated and powerful. The effort made by the mobile industry companies such as Google, Apple, and Microsoft among others has contributed to the ubiquity of mobile devices in our lives and to the variety of mobile platforms and devices available.

These industries have enhanced the popular use of mobile applications whereby their stores are providing free apps for different categories such as education, entertainment, health, among others. However, the mobile apps on health are focusing on fitness tracking and mostly for self- management. With the advancement in Internet of Things technology, there is great need to implement smart watches for maternal health.

According to a study from 2015 developed by Allied Market Research (Nunes de Melo, 2017), segmented the uses of smart watches in four categories. About the Fitness category, the device entails typically not only a watch but rather a smart wristband known as a fitness tracker or activity tracker, which has features for fitness monitoring having several indicators. The following Table 1 shows the categories of smart watches.

Table 1: Summarized features for smart watches categories.

Segment	Personal Assistance	Fitness/Wellness	Sports/Adventure	Medical/Health
General characteristic	- clock/time - make/receive calls - Calendar - E-mail - Mobile apps	- Steps, calories, distance - Heart rate - Sleep track - Optional: clock, message notification, music control	- Fitness monitoring - Outdoor activities feature such as swimming, golf & cycling	- The nervous system, heart rate, sleep tracking - Emergency, inactivity alerts - Medication and task reminders
Brand Example	Apple iWatch, Samsung Gear	Fitbit, Xiaomi	Garmin, TomTom	Empatica Embrace, CleverCare
Average Price	400€-1000€	20€-250€	150€-500€	250€-400€
Image				

Source: (Nunes de Melo, 2017)

In the study, Nunes de Melo (2017) found out that about half of the participants (53%) who do not own a smart watch would like to have one. It was also found out that the price for smart watches was stated as the most significant issue, with 1% reporting them of being too expensive while for 49% stating them as very expensive when compared to regular wristwatches. Concerning its category, Fitness/Wellness and Sport/Adventure were said to be more consonant with actual market price than Personal Assistance and Medical/Health categories.

Moreover, concerning the design, 12,9% of participants mentioned there is a lack of similarity to regular wristwatches and its bulkiness and would prefer the use of a smart watch designed by a wristwatch brand design. Moreover, half of the respondents stated the low battery life as a problem and referring to a reasonable average of about nine days of battery life. It was concluded that smart watches could be considered as a disruptive innovation, which implies a radical change in consumer behavior to adopt it, thus giving reasons to why its adoption rate is quite at deficient levels.

2.3.2 Smart watch platform

The Operating System (OS) is the controller of any electronic computing device. A program allows communication between hardware and software, where the device is impractical without the operating system. There are several operating systems used in smart watches among them being; Android, Android Wear, Tizen and Linux (Tran Vu, 2015). Each OS has different environments that mean a different way: to program, to create applications and communication between software and hardware. This has challenges with it for programmers who want their applications to be known as much

as possible, so they have to re-create the same idea in different languages; thus, it does take much time and effort to get the work accomplished.

Android wear is the underlying platform of the smart watch design because it is open source. It allows the possibility for anyone to be a smart watch vendor who can build the hardware around the platform. Google also announced Google fit, which is a set of APIs that made use of data from all the sensors in their phones and watch to generate real value. The condition of it being open source opens up millions of possibilities not just on the hardware side but also software. As seen with the Internet of Things, the same opportunity is given to the smart watch platform (Akash, 2015).

Timex introduced a Linux based watch that enabled users to add schedules and contacts to their watch. Smart watches had never been introduced to the consumer market, and the times they were, they were always a standalone product rather than a platform.

In a study by Stork et al. (2017), they stated that a User Interface of the Android Wear Operating System (OS) usually works with messages that show information that is retrieved from any handheld device such as mobile phone, smart watch, among others. This information appears on the screen of the handheld device inform of text messages, emails or personalized information that becomes useful to a user. The same information can be sent to other devices when simple controls are performed and protocols adhered to. In the same study, it was reported that Google launched the Android Wear Operating System in March 2015 when later, other devices have been developed over the years when pebble's fruitful smart watch kick-starter campaign opened the eyes of other lucrative companies.

In a study (Wang, 2017), the study compared four popular smart watches that used dissimilar operating systems: Apple Watch Series 2, Samsung Gear S3, Huawei Watch, and Pebble 2. Also, the processor, RAM, storage, battery life, and some other hardware features based on published data were compared too. In this study, it was found out that Android Wear, which operates the Huawei Watch, is the most common operating system among smart watches and it is compatible with both iPhone and Android smartphones.

Apple Watch uses Apple Watch OS and is only compatible with iPhone devices. Samsung and Pebble have their own operating systems for their smart watches: Samsung Gear S3 uses Tizen, and Pebble 2 uses Pebble Firmware. This indicates that android wear is an open-source platform to use in smart watched due to the benefits of open source standards.

In a study carried out on the comparison of wearable fitness devices by Kaewkannate and Kim (2018) on the evaluation of wearable device from the four devices selected, the study focused on objective and subjective methods to get the physical comparison results where the results were independent of manufacturers' claims. To evaluate on satisfaction level, they used eight categories namely: synchronization, hardware design, UI app, sleep tracking, step count, nutrition analysis, calories, battery, and user-friendliness which showed that the most satisfying device based on the participants' rankings was the Withings, followed the Misfit, Jawbone, and Fitbit.

During an evaluation, online reviewers showed that Jawbone UP24 is well designed and fits comfortably for the subjects. Its UI app is colorful and easy to understand; the sleep tracker is brilliant and also has useful alarm functions. However, it has demerits showing that the design does not have a screen, it is not waterproof, and the battery

charger is very complicated. The other device to be evaluated was Withings Pulse that showed it has useful features such as the heart rate function, the display is large enough to show the results tracking, and the data log can be updated automatically via Bluetooth syncing or wireless.

The demerits were that the design proved to be not attractive since it is hard to read the display under exposure to sunlight, and the sleep-tracking feature does not work automatically. The third device to be evaluated was Fitbit Flex that showed; it has a slender and attractive design, is waterproof, and offers several social features. Its demerits were; it has no screen, the food log and calories tracking are not easy to use, the food log is hard to learn for beginners, and the tap screen is sometimes confusing. Lastly is the Misfit Shine device that proved to be attractive, elegant, and fashionable design, thoroughly waterproof and especially suitable for water sports. Its demerit was that it could only be used with the iOS operating system. In the study, it was concluded that the Withings device provided the highest satisfaction and was the most user-friendly from the perspective of the users. It was also the highest-ranked for accuracy and repeatability in step count and distance tracking. Tracking accuracy is vital in fitness tracking. The study thus focused on wearable devices with the aim of performing fitness activity and not on health care to manage diseases such as preeclampsia.

During the connection, a smart watch connects with other devices through tethering. According to (Lamkin, 2014), android wear can connect to a two handheld device over a 6-digit encrypted Bluetooth 4.0 connection. The device is also connected via Wi-Fi to the cloud node, the Google Servers so that that data can be synced between devices from a more excellent range. Figure 1 shows that an android wear device cannot communicate to the internet directly which raises issues of power and size constraints.

This implies that for android wear to connect to a web browser, it has to first connect to its host which will establish the connection. In this case, the handheld device serves as a proxy server to which the wearable client can connect to enter the internet by handling Hypertext Transfer Protocol (HTTP) requests to the webserver and receives its responses.
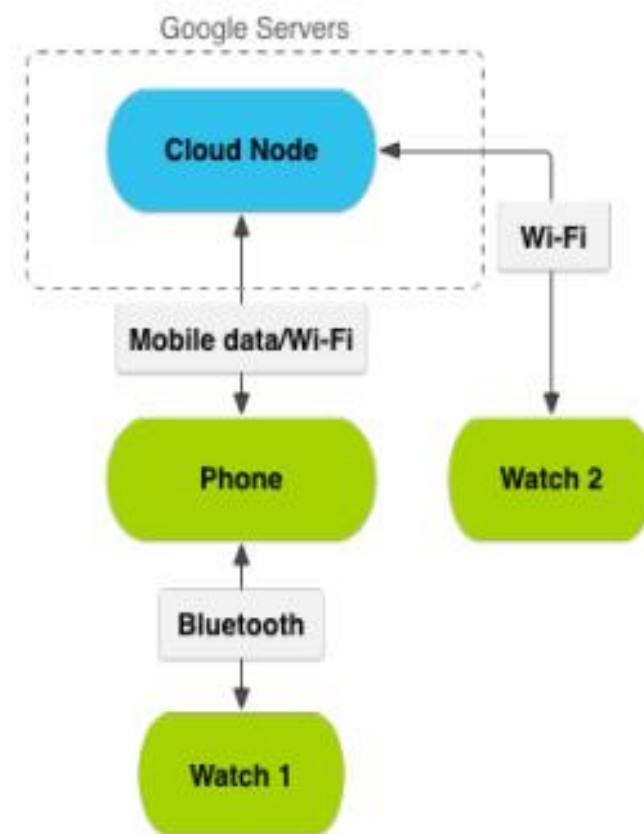
Figure 1: Android Wear Data Communication

Source: (Stork et al., 2017)

When a programmer is developing android wear, he/she requires to develop two Android Package-files (APK). One for the wearable and the other for the handheld device watch where the APK has to be packaged inside the handheld APK, but since a wearable cannot yet browse on the internet to download and install an APK

autonomously, the package is downloaded on the handheld device which pushes the Wear APK to wearable via the Bluetooth connection (Android, 2019). Moreover, API developers use the Java programming language to develop applications, and Google Play services application runs in the background of the Android operating system and creates a channel for communication between two devices which is established by implementation of Wearable Data Layer API in their code (Stork et al., 2017).

2.3.3 Blood Pressure Monitoring Mobile Application

Mobile application (mobile app) is a type of software that is installed on mobile devices, such as smartphones and tablets. It has the same functionality as the applications running on the desktop platform. However, because it runs on mobile platforms, a mobile application is small and has a limited function (Sandi, Nugraha, & Supangkat, 2017). The mobile app typically offers general productivity and information retrievals, such as email, chat, contacts, and traffic information. However, due to public demand and availability of advanced developer tools drove rapid expansion into other categories, such as learning, health, games, entertainment, news updates, geo-location-based applications, banking applications, among others.

In the health sector, remote monitoring to patients incorporates digital mobile applications that encompass the establishment of care to patients in terms of medical conditions that can be supervised, frequency to be monitored and whether they should be managed real-time or periodically (Musyoka et al., 2019a). Remote supervision is the supervision of a medical assignment from a remote setting, providing a diagnosis to the patient without the patient being extant physically. When medical monitoring is comprehensive, then a guidance on whether the patient requires immediate attention by the doctor is released through a monitoring device. According to Hemavathy, Sinthuja,

& Manoharan (2014), remote patient monitoring technologies are safer, more effective monitoring of health and safety among older adults, control visits to hospitals to address cost, decongestion issues, geographic challenges, geriatric conditions and lack of mobility.

As smartphones and tablets are trading at a low price and hence becoming common globally, mobile data collection and analysis applications are increasingly used for health sector services as well as health monitoring. In Prasad et al., (2013) research has shown that health workers are more prone to error in blood pressure measurement than certified nurses who are themselves more prone to failure than physicians, hence there is need to assimilate an amending device with mHealth recording systems to guide non-clinical workers in the field while they measure a patient's blood pressure and to record appropriate data about the blood-pressure reading.

The smartphones consist of hardware and software essential to record vital signals, compute and display the outcomes and save them to a database automatically. Moreover, assistance on decision-making is provided to the health worker after the smartphone has recorded the vital signals. By divesting software application analysis that is being administered on the phone, firmware updates to the system are also retrieved in case of a breakdown without any shipping of a device or calling of a hardware specialist intervention (Arteta et al., 2016). This would allow for continual improvement of hardware without having to purchase a new one. Also, synchronization is applicable in mobile platform whereby Blood Pressure readings with other data in the database server either locally or remotely are shared with authorized specialists, providing a permanent monitoring service for decision-making purposes.

Moreover, the blood pressure monitoring apps are widely deployed in tablet devices with android operating systems due to their efficiency and conducive to data collection, and also their sales have already surpassed other mobile devices in developing countries (IDC, 2013). Moreover, (Gartner, 2017) reported that globally, the market share for Android was 86.2%, iOS 12.9%, Windows 0.6%, Blackberry 0,1%, and Others 0.2%. The report showed that worldwide app downloads by April 2017 were: 16 Billion for Google Play Store and 7 Billion for the iOS App Store. This indicates that android smartphone devices are widely used in developing countries, and hence, Google play store has apps that are compatible with these devices enabling them to be in large-scale and cost-effective in the mobile Health sector.

Mobile applications are being developed by the use of software development software called programming languages. To date, several programming languages include Java 2 Micro Edition (J2ME), Python, C/C++, Easy Mobile Programming (EMP), among others. According to a study by (Mattila, 2010) complemented that of all these languages, J2ME stands out as the programming language that outweighs others due to its features being platform-independent and being composed of a rich set of APIs appropriate for mobile devices.

According to a study (Maia et al., 2014), due to the recent habits and increase in diseases such as cardiovascular diseases, heartbeat rate, and blood pressure, there have been critical vital signs used to identify a variety of health problems that may affect a patient. The most popularly used sensors are ECG sensors. They are used for measuring heartbeats in medical tests due to their utility in the diagnosis of several cardiac pathologies. On the other hand, monitoring blood pressure is essential especially for hypertensive people, as high blood pressure can lead to severe hitches, such as heart

attack. Therefore, continuous monitoring of such variables is quite essential as a heart problem might not always show up on the ECG, and high blood pressure usually does not have any symptoms. Moreover, such monitoring can enable prevention procedures by improving medical diagnosis, bring proactive responses to possible emergency conditions, and even help to reduce the number of deaths due to cardiovascular diseases.

In the study, the EcoHealth scenario was used to assimilate cardiovascular-targeted devices and to screen variables at runtime, as well as to prompt alert messages in case of abnormal conditions (Maia et al., 2014). To collect such data, an ECG sensor with electrodes fixed on the patient's chest and a blood pressure oscillometric sensor was used in the study where the sensors were connected with the Arduino Uno open platform that was made possible by the integration of a variety of biometric sensors then the data was sends to EcoHealth. The EcoHealth web application could process data obtained from the sensors and present them in an efficient, useful way to health care practitioners. However, mobile health application still comes with their challenges due to the use of a mobile phone as a vital tool in perspective.

During the implementation of mobile applications, the following software packages are needed for a workable app: Java Development Kit (JDK), Android Studio (AS), Android Software Development Kit (SDK) manager, and Android Virtual Device (AVD). According to guidelines set by Oracle for Java download, Java Development Kit 7 is needed to compile and run the Android applications with a version of JDK 7 being the minimum requirement (Oracle, 2019). Then, Eclipse was the de facto standard for Android application development with the Eclipse ADT (Android Developer Tools) plugin. Android SDK manager is also an essential tool to download and install all the

libraries, drivers, tools, and other packages developed by Google that are desirable for Android development (Android, 2019).

2.4 Internet of Things based Healthcare Models

The following five IoT Health models were reviewed.

2.4.1   MAMICare Model

MAMICare is an Information Technology model solution that is based on mobile devices. It is a model that was developed due to an alarming number of maternity and infant deaths in rural areas of Mexico due mainly to inadequate monitoring of pregnancy progress and lack of an appropriate alerting mechanism in case of abnormal gestation progress (Lavariega et al., 2013). MamiCare architectures are based on mobile devices, and health sensors such as ECG (electrocardiogram), stethoscope, pulse oximeter, and blood-glucose meter to automatically collect relevant health data for better monitoring of pregnant women.

This functionality of the architecture involves the following. First, a tool for allowing a health professional to check on the patient and a remote physician to give complete feedback on time. Secondly, data is locally stored and used to follow up on the patient's record correctly and at the same time data being shared to a centralized database in the community center for analysis. Lastly, is a risk-condition assessment tool to identify situations and alert the social worker for critical conditions. The study on the MAMICare model is based on the observation of a real case. Therefore the challenges that were identified include communication issues and availability of communication technologies. In the MAMICare model study, it was concluded that the MAMICare

model adoption or its rejection depends on the approval of the state and federal health

agency. Figure 2, shown below, depicts the MamiCare architecture.
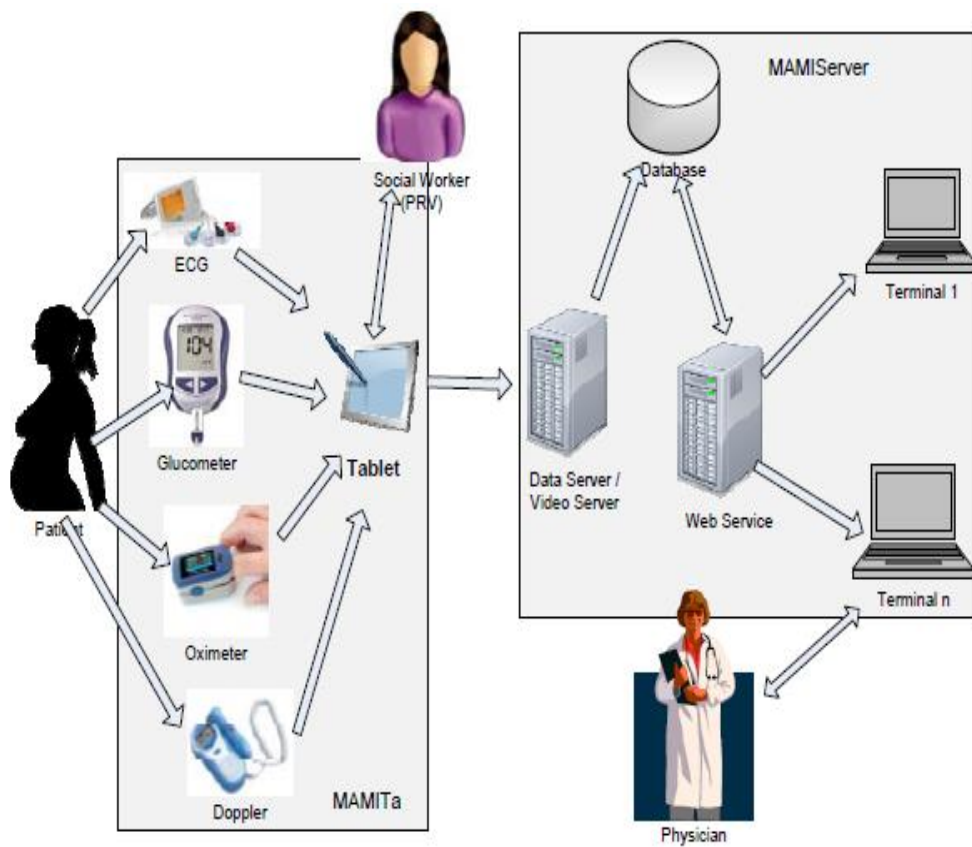
Figure 2: MAMICare Overall Architecture

Source: (Lavariega et al., 2013)

Based on the architecture, details such as heart rate, blood sugar, oxygen level, and

movement of fluids are collected from pregnant mothers then locally stored in a tablet,

which is owned by a social worker. The social worker can share the data in a centralized

place whereby other physicians can have access. This implies the collected data by the

social worker is not reliable since it has to be locally available then later centralized.

2.4.2 IoT-based health care security model

A different study was carried out on IoT-based health care technologies that reviewed the state of the art network architectures, applications, and industrial trends in delivering IoT-based health care solutions (Islam et al., 2015). This study proposed an intelligent collaborative security model that is used to minimize security risk and to discuss how different innovations can be leveraged in a health care context. The model is shown in Figure 3 shown below.

This figure visualizes a scenario in which a patient's health profile and his/her information are captured using portable medical devices and sensors attached to his or her body. The captured data is then analyzed and stored. Based on analyses, a health care provider can monitor the patient from any location and respond accordingly. The study gave a general picture of the elements in healthcare and not specifically on blood pressure detection. Also, the model focused on security and privacy features, threat models, and attack classifications from the health care perspective without paying much attention to the application of IoT in ensuring sustainability in health care. The model was just a proposal that was not implemented to prove its applicability in the Internet of Things technologies.
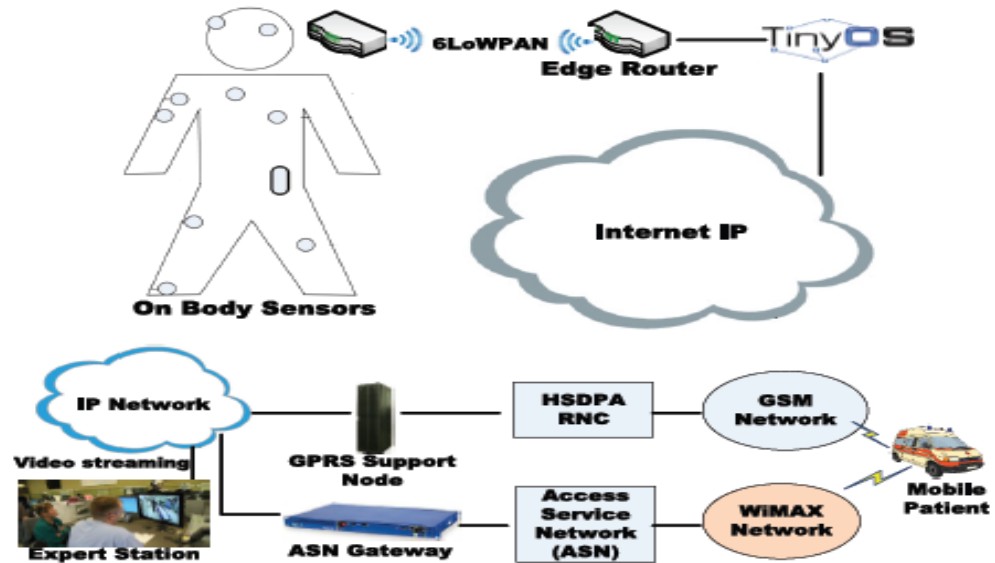
Figure 3: Remote monitoring in wearable and personalized health care

Source: (Islam et al., 2015)

2.4.3   Smart Health Care Model

Smart Health Care model is another model that studied Internet of Things applications that have proven to be beneficial in the health and wellness domains and are widely being developed to monitor patient's health in the form of a wearable device (Sethi & Sarangi, 2017).
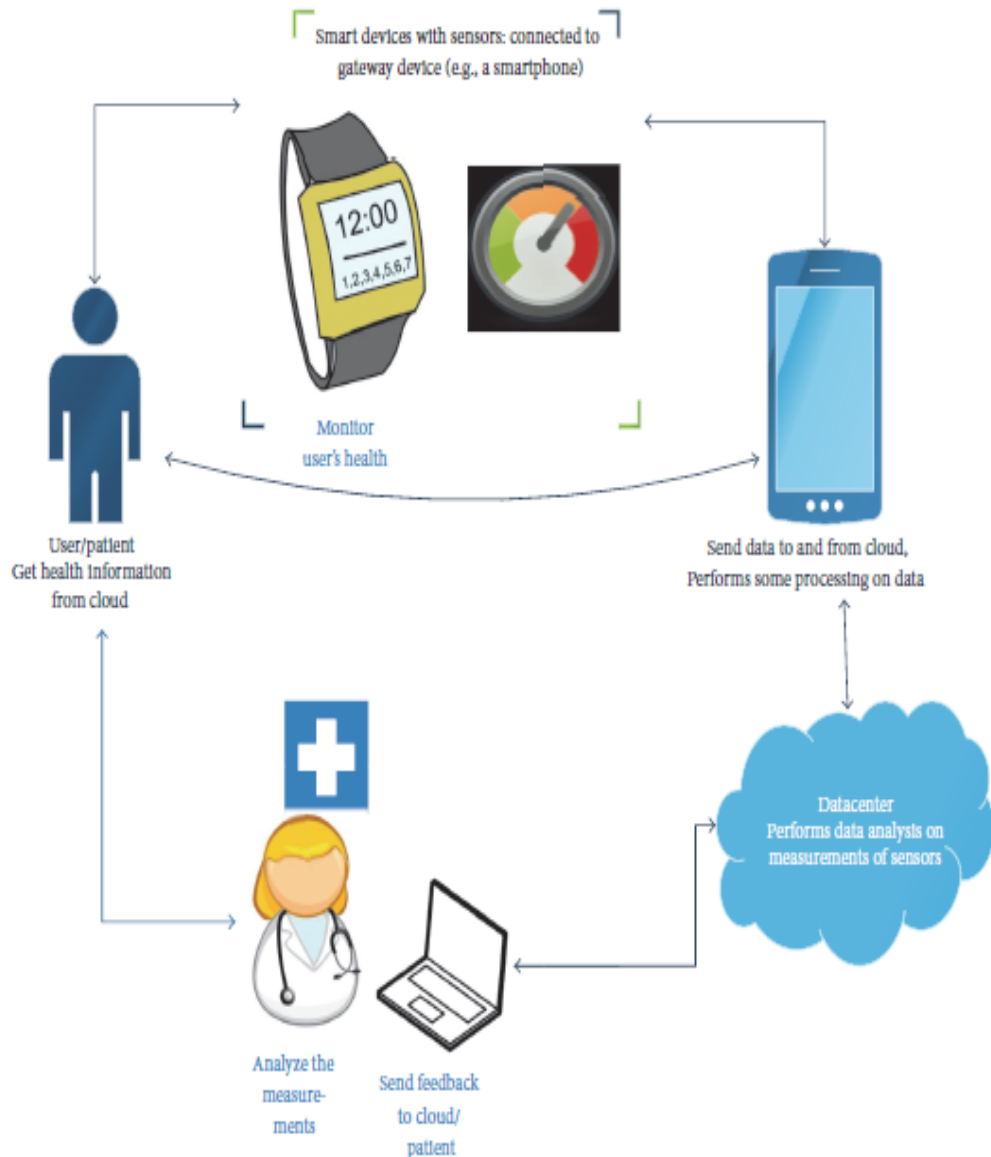
Figure 4: Block diagram of a smart healthcare system

Source: (Sethi & Sarangi, 2017)

Figure 4 shown above depicts the monitoring and analysis of data from the initial stage of a patient through the cloud to a caregiver. When Sethi & Sarangi (2017) were developing the model, four things that were put into consideration are: First, is the design of the sensors where they chose small sub mW boards meant for a sensor that has Arduino or Atom boards that consume 300–500mW of power. Second is an issue

of logistics where they require experts who might not be readily available. Thus, it is better to bundle a sensor with commercially available embedded processor kits. Thirdly, it is communication for IoT nodes.

For these nodes to communicate, power is the most leading issue, and in addition to effective communication between the sender and the receiver objects, then communication technologies should be reliable such as ZigBee for small building and Sigfox or LoraWAN for a smart city. This study focused on the concept of IoT in several IoT applications, yet none of the claims had implemented the model to show how it works.

2.4.4 K-Healthcare Model

The K-Healthcare model is an additional model that was reviewed in the study. According to Ulla et al. (2016), the K-Healthcare model was developed to capture the process of production, anti-counterfeit, and tracing of medical equipment delivery, manage medical information such as sample identification and medical record identification. The model aimed to construct systems that can continuously monitor the patients, remote consultation, critically ill patients, and health care management platform using different techniques and equipment which can sense, capture, measure and transmit the information of body or things. With the combination of sensors and the microcontroller to get accurate measurements of blood pressure, heart rate, oxygen levels, and glucose in the patient's body, and monitoring and analyzing the health status leads to increase the power of IoT in healthcare. The model is depicted in Figure 5 shown below.
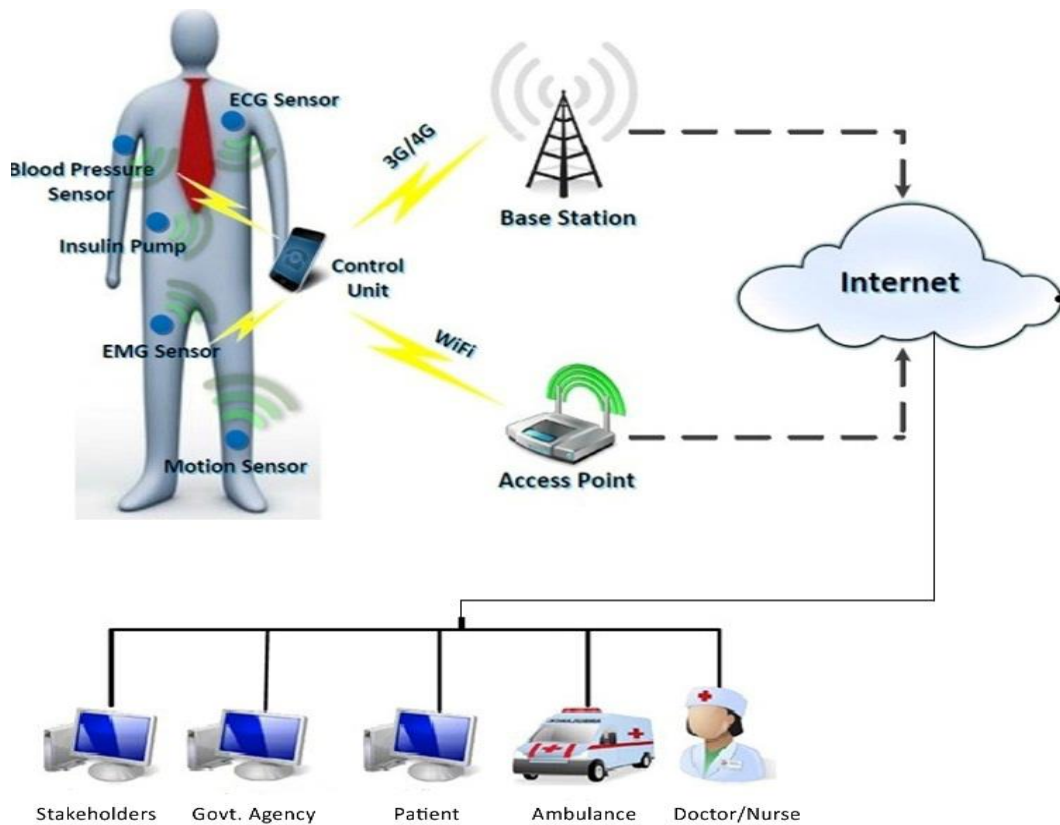
Figure 5: An application Scenario of k-Healthcare model

Source: (Ulla et al., 2016)

This K-Healthcare model provides a platform for physical sensors, which are connected directly with the patient's smartphone to obtain data at run time where the data is processed and stored in the cloud storage to be accessed by health practitioners later to observe and monitor patients' health. The model deployed in the field of medical and healthcare consists of four layers namely: sensor layer, which is the bottom layer of the that have different components are lying on it as RTX-4100, wireless two-lead EKG, Arduino & Raspberry Pi, blood oxygen sensor, pulse oximetry, and Smart Phone sensors. The second layer was a network layer that pays the role in communication to connect the devices with WAN using different protocols, which are; 3G, 4G, ADSL, DSLAM, and Routers. The layer also supports other communication protocols like

IEEE 802.16 for 3G, IEEE 802.16m for 4G, IEEE 802.20, and ITU G.992.1 - ITU G.992.5.

Thirdly is the internet layer that provides the functionality of data storage and information management, which is cloud storage for this case that offers different services and algorithms on-demand like cloud storage, cloud data store, cloud SQL, BigQuery, RESTful services for iOS, Android, JavaScript, and machine learning algorithms. Lastly, is the services layer that provides direct access of data to health practitioners who can easily manage the patients, view the medication history, provide remote support in case of emergency, and perform other related services. The services layer supports protocols and techniques like HTTP, HTTPS, JavaScript, RESTful web services, etc. these layers are presented in figure 6 shown below.
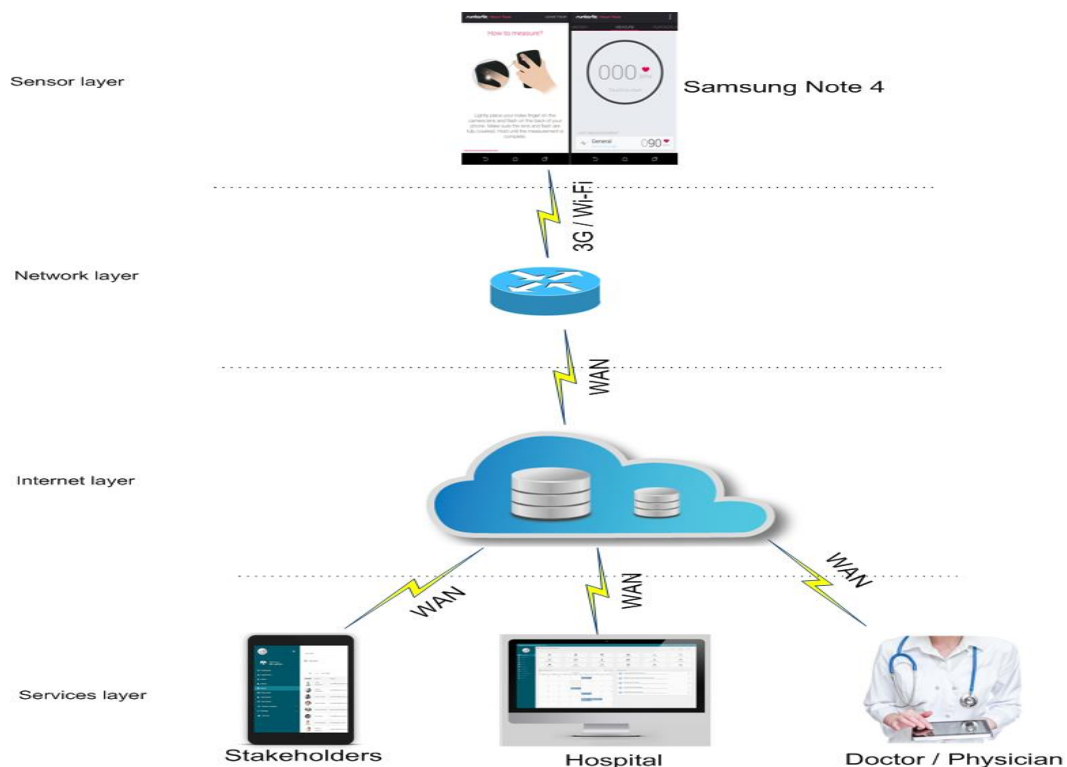
Figure 6: An application domain of k-Healthcare model using Samsung Note4
Source: (Ulla et al., 2016)

K-Healthcare model has presented the IoT application in the health care sector. However, the model is not tested where an application is implemented using the model to prove its applicability.

2.4.5   M-Mamee M-Health IoT Model

A different model referred to as M-Mamee M-Health IoT Model was developed (Karagiannaki, Patelarou, Panousopoulou, & Papadopouli, 2015). During the development of the mMamee model, it was reported that many efforts had been made to prevent and minimize exposure of pregnant mothers and neonatal to widespread environmental risks such as air pollution, nutrition, among others; which with adverse exposure to them could lead to deaths. With this problem, the mMamee mHealth model was developed to provide the means for remotely capturing the environmental factors that affect maternal health and replace it with the traditional way of obtaining information such as the use of face-to-face interviews. It focused on monitoring and assessing maternal environmental exposure and was developed using a client-server architecture to discourse the integration of sensing data and descriptive input on maternal daily practices. The model consist s of smart-phones, sensors, and cloud database components to perform its role as presented in Figure 7 below.
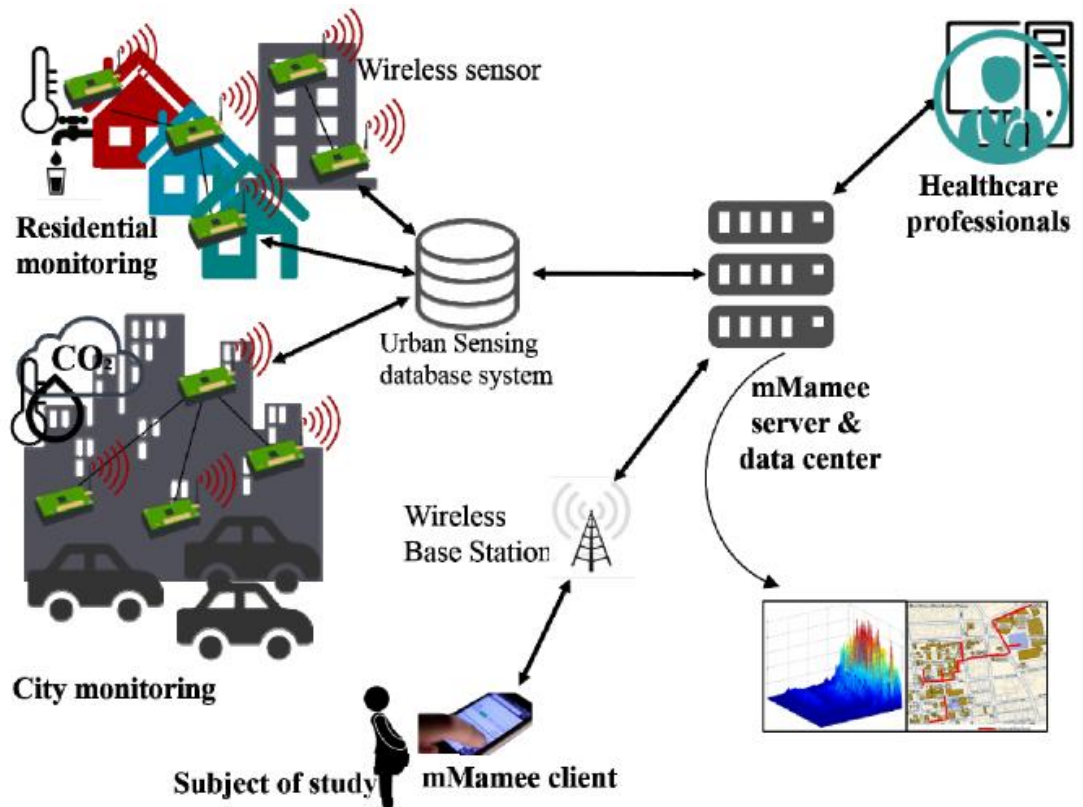
Figure 7: mMamee MHealth Model

Source: (Karagiannaki et al., 2015)

The mMamee mHealth model involves a sensing infrastructure that is installed in the urban environment for recording ambient conditions, such as temperature, humidity, CO2 in the atmosphere, and level of city noise. The information is then stored in a database that is applying client-server architecture. Then data is sent to a smartphone owned by the pregnant mother asking questions concerning the health issue that could be affected by the ambient conditions. mMamee MHealth model was also implemented using a prototype, but the user engagement from the target population is a pivotal aspect to its adoption was not performed.

2.5 Evaluation of Internet of Things based Prototypes

Healthcare providers use much time while travelling between their patients and hospitals when the equipment they are using is stationary (Musyoka et al., 2019a). Due to the resolving of time consumption, a mobile application has originated rapidly thus reducing these challenges faced by health care providers.

According to (Hussain, 2013) reported that due to the rapid use of the mobile application in health care, there is an eminent need to investigate the current position of the acceptance of those mobile health applications that are tailored towards the tracking patient's condition, share patients information and performing other related health care services. In the study, Hussain applied Technology Acceptance Model has to investigate the user acceptance of mobile technology applications within the healthcare industry. In the study, a quantitative approach based on a Technology Acceptance Model (TAM) was utilized to evaluate the system mobile tracking Model.

The related constructs that were found for evaluation were Perceived Usefulness, Perceived Ease of Use, User Satisfaction, and Attribute of Usability which was then modified to suit the context of the study. It was recommended that practical evaluation of healthcare systems is an essential task that should be taken after the implementation of mobile applications to make sure that these systems meet the requirements with user satisfaction and information processing needs of the users and health care organizations.

Evaluation is an activity related to data collection related usability of a product, involving a group of users in a specific environment and context (Yvonne et al., 1994). Although the usability evaluation consists of sequences of procedures performed to

collect data related to the interaction between users with software products, to find out how significant the contribution of software is in helping users get the right product as desired. In the end, usability evaluation is used to predict the success of a system product after its deployment.

According to (Nielsen, 1993), while conducting usability evaluation in a system product, twelve steps should be done. Sequentially they include: define the usability evaluation's goal; specify the user interface features to be evaluated; identify the target consumers; determine the usability metric that will be used; and decide the evaluation method. They also include: select the tasks that will be executed, plan the experiment, gather the usability evaluation data, give improvement recommendations by commenting on the user interface; reiterate the step if need be; and summarize the result.

In addition, usability is a qualitative valuation of the system's user interface, such as mobile applications, in addition to its purpose that allows users to achieve specific goals. Besides, usability can also be described as "the extent to which a product can be used by a particular user to achieve its goals with effectiveness, efficiency and satisfaction in a particular usage context" (Nielsen, 1993). Therefore users need mobile applications that are easy to learn, take less time when completing a task, and are easier to use, and evaluation of these mobile applications in terms of its usability needs to be done to know the quality of the application from the user side.

In a study on Innovation Acceptance of Wearable Mobile Computing on Pervasive Computing Perspective by (Taib, De Coster, & Nyamu, 2016) studied that the occurrence of mobile phones and its applications has reached the mass adoption with

daily activities services such as mobile internet, mobile banking, online shopping, media socializing and internet surfing.

They have found out that studies on acceptance of mobile computing have been developing; however, the review of users' acceptance of the emergence of wearable mobile computing is still at its early stages. In the study, they found out that the perceived value of the wearable devices could not be fully realized until it is accepted and adopted by potential users and that the occurrence of wearable mobile computing will accelerate the development of pervasive computing technologies and become a challenge in information technology research studies.

2.6 Performance evaluation of Information technologies

The need to evaluate the information systems performances has grown rapidly because of a higher requirement of establishing the effectiveness and efficiency of work processes in an organization. According to Gordana (2009), evaluation of Information System performances means an assessment of achievements in hardware, software, computer networks, data, and human resources to upgrade and improve in quality of maintenance.

The procedure of assessing the system performance fulfills it how the information systems meet their objectives. The process of evaluation includes synthesizing and determining gathered scores to form a common opinion about the functionality of the evaluated Information System. There are several important factors that may be regarded as the most vital factors that influence the success of an information system: functionality of Information System; data quality; expected usefulness of Information System; expected usage simplicity of Information System; self-efficiency of

Information System user; usage of Information System; influence of information system on individuals; Information System user's satisfaction and organizational factors (Gordana, 2009).

Information Technology performances that influence the success or failure of an information system (Balaban, Ristic, Durkovic, Trninic, & Tumbas, 2006). The study classified performance evaluation into two dimensions, which were the system aspect as well as the human aspect of information system successfulness.

Current performance evaluation in mobile systems can be classified into two groups: analysis of the resource consumption and its influence on the performance of applications and the mobile operating system (Kim, Agrawal, & Ungureanu, 2011). According to Thiago, Erika, & Moreira (2018) metrics are criteria used to compare the performance and they used three parameters to compare performance: Response time; the time in seconds (s) that the browser takes from the beginning of its execution to the end of loading the entire web page content, the second was CPU time; the time in seconds that the process of viewing the webpage occupied the CPU resource and thirdly memory usage; the volume in megabytes (MB) that the process of displaying the page used in the RAM of the execution environment.

2.7 Theoretical Framework

In recent moments, the world is rapidly changing and highly competitive, whereby innovation is a crucial source of competitive advantage and survival needs. Every new product, a process, or service originates from a new idea and addresses client need. Currently, the design and development of projects are facing a complex landscape of interrelated challenges, such as technological feasibility, customer desirability,

business viability, and environmental sustainability, among others (Eppinger, 2017). Due to such challenges, the program ensures a structured approach to design and customer analysis processes that draw on essential trends that have become essential to successful innovation in today's products.

The main contribution of the study was the development of the Internet of Things based prototype that helped a pregnant mother read the blood pressure, sends the details to a cloud database, and connects to several healthcare providers and a family member. The connected users receive blood pressure readings from the pregnant mother, and in case the blood pressure is becoming abnormal, and then a notification is sent to both of them as well as the mother showing the readings.

This being a novelty study, innovation technology strategies are applied in this study. According to Li, Zhu, Yang, Wang, & Sun (2016), technological innovation is divided into two: Sustaining Innovation (SI) and Disruptive Innovation (DI) in product innovation technology. Sustaining innovation is further divided into incremental innovation, which is defined as the innovation which relies on existing technology that can configure and product or production process continuously and bit by bit in order to achieve product performance improvement stably, and radical innovation which occurs when the product evolves to the exit stage, the improvement of the existing technologies has reached its limit, and, the product is unable to meet the market requirements, then, the innovation is realized by new alternative technologies.

Disruptive Innovation refers to technology, process, or business model that brings to a market, a much more affordable, simple, portable, and easy to use products. The proposed framework was based on disruptive innovation to enhance the performance of existing resources making it adhere to customers' preferences.

In technology innovation, resources are considered critical issues due to availability. In this study, TRIZ tools and non TRIZ tools will be considered as resources tools. TRIZ is a complete system of invention problem solution theory proposed by Russian scholar Altshuller and others since 1946 (Li et al., 2016). The authors classified resources to function resources, Information resources, Space resources, Time resources.

According to Hansen & Birkinshaw (2007), innovation as a value chain comprising is viewed as three phases, namely, Idea Generation, Idea Conversion and Idea Diffusion. In the first phase, the generation of ideas can happen inside a unit, across units in a company, or outside the firm. The second phase is to convert ideas that deal with a selection of plans for funding and developing them into products, while the third phase is to diffuse those products and practices. In this proposed model, there are no actionable techniques provided to simplify the innovation processes.

Sheu & Lee (2011) modeled the innovation process into five phases: Opportunity Definition, Problem Definition, Solution Definition, Project Execution, and Application Exploration. In every stage, the researchers identified tools to apply for practical completion of each phase. Opportunity Definition consists of project identification and project selection. The selected best project is then fed into the Problem Identification and Selection stage to identify all possible problems that many conflicts in the project to attack. The mini-problem is then fed into the Solution Generation stage of the Solution for the generation of all possible solutions.

Innovative solutions are generated in this stage by the use of practical tools while the best innovative solution is selected. The selected best innovative solution is then executed at the Project Execution stage to solve the target problem and to review the results. Upon completion of the project execution, a new product may likely be created

which is then further exploited in the Application Exploration stage to extend its applications across different industries for innovations.

Systematic Innovation Process is a cyclic life cycle that is supported by the integration of heterogeneous resources such as TRIZ tools and non-TRIZ tools.
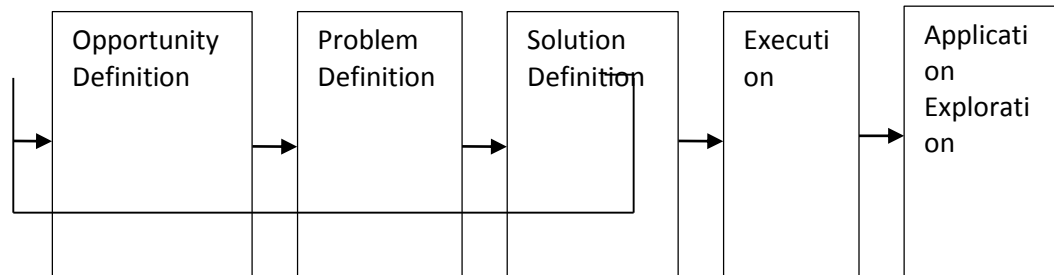
Figure 8: Systematic Innovation Process Phases

Source: (Sheu & Lee, 2011).

Due to big data that is frequently experienced in IoT, there is a need for efficiently searching and retrieving big data that satisfy users' intentions (Widya, Yustiawan, & Kwon, 2018). To retrieve real-time blood pressure readings from data sources, then a query language using JavaScript Object Notation (JSON) was developed. Vital query processing functionalities for IoT applications was provided on top of the IoT based architecture.

Query Language Algorithm was used in the study since it optimizes system resources that are essential in justifying a query and also providing the user with the quick retrieval of accurate results.

According to (Widya et al., 2018), the query language definition is set as follows:

A-One Machine Query (OMQ) technique receives a query q $=\{n, D, \square\}$, which consists of n data sources, data sources definition D=$\{d^{(1)}, d^{(2)}, ..., d^{(n)}\}$, and a set of query

operators $\boxed{?}$. A data source definition $d^{(x)}$ It is a set of data source properties a user wishes to query in the form of a key-value pair. A query consists of several connecting operators $\boxed{?} = \{\theta_{prejoin}, o_{join}, \boxed{?}_{postjoin}\}$ which are divided into three parts:

- Pre-join operators $\theta_{prejoin} = \{\theta^{(1)}_{prejoin}, \theta^{(2)}_{prejoin}, ..., \theta^{(n)}_{prejoin}\}$ $where \theta^{(x)}_{prejoin} = \{o^1, o^2, ...\}$ defines a set of chaining query processing operators that will be applied for each corresponding data source as pre-processing steps before joining the data into a single tuple.

- A join operator o_{join} defines a join function that joins the inputs from several data sources into one tuple.

- Post-join operators $\boxed{?}_{postjoin} = \{o^1, o^2, ...\}$ defines a set of chaining operators applied to the data after being joined into a single tuple.

A query engine architecture was also designed which performs query panning tasks and a stream processing. This algorithm was used in the study to analyze the blood pressure readings fluctuation and send a notification when the real-time reading of a specific mother reaches a wanting level.

2.8 Conceptual Framework

The conceptual framework for the proposed wearable device for measuring blood pressure in pregnant mothers is presented in Figure 9 and comprises of the following major components.

   i. **Pregnant Mother:** This is the expectant mother who is the subject of the study.

ii. **Blood pressure monitoring sensor device:** this device consists of an integrated chip for sensing, recording, storing, and analysing the level of blood pressure of the pregnant mother. It will then share the data to the big data centre

iii. **Cloud with data centre:** The interpreted data is received by the cloud with data centre for proper follow up the patient's record. Information is shared with a centralized database in which it was properly analysed for statistics and in-depth knowledge of the level of blood pressure of the patient. Once there is an alarming condition, an alert message was sent to a health care professional smartphone.

iv. **Cloud Transceiver and simulator:** For blood pressure monitoring device and cloud data centre to communicate, there is a need for receiver and sender of transmitting signals. The simulator was required for each pregnant mother. This is the terminal device that is connected to the server and data centre. To health care professionals, it receives an alert message in case of an emergency.

v. **Healthcare Provider:** this client is the owner of the smartphone terminal who receives the alert message sent to a smartphone terminal by server and data centre. The health care professional then responds accordingly to the patient.
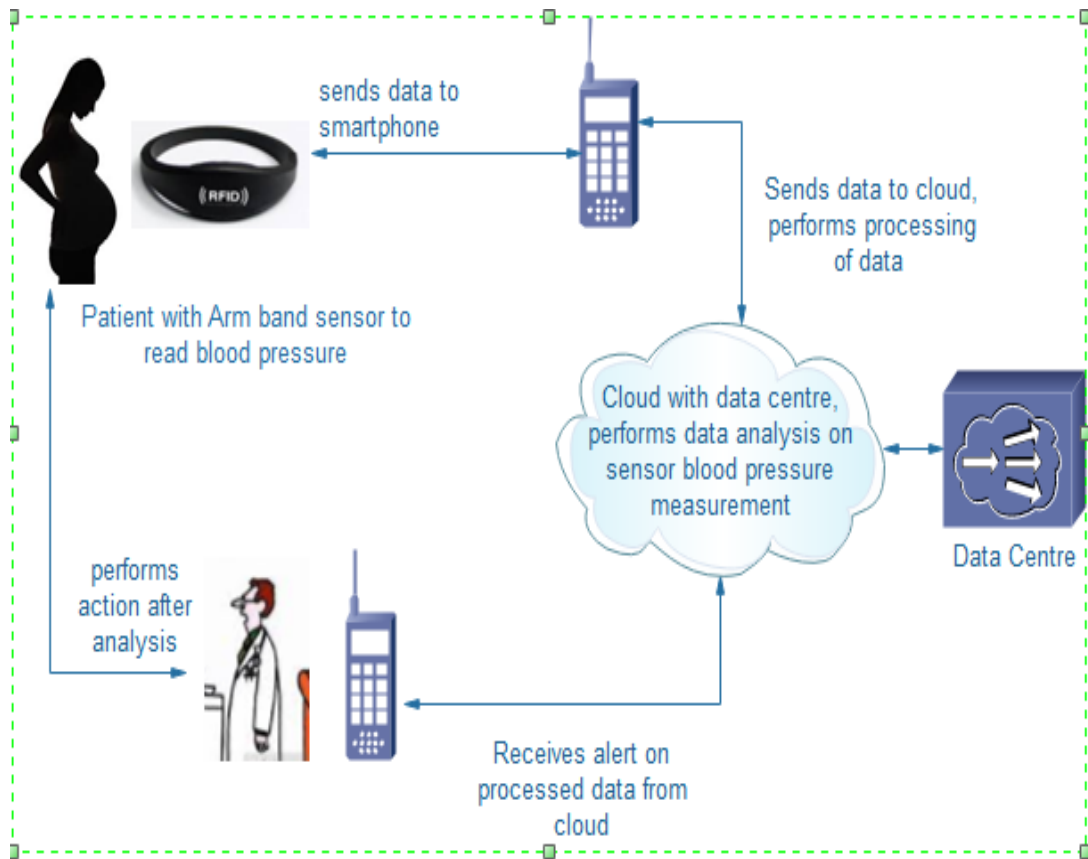
Figure 9: Conceptual IoT based Framework for Preeclampsia monitoring during antenatal care

2.9   Conclusion

This chapter presented a discussion on maternal health care, Internet of Things technology and its applications, existing IoT based models in health care and their gaps, and evaluation of IoT based models. The theoretical and conceptual frameworks for the study were also presented and discussed.

The next chapter will outline in detail the methodology to be used in the development, prototyping, and evaluation of the IoT based model for preeclampsia monitoring in antenatal care.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter provides information and details about the methodology that was utilized in addressing the research questions. It describes the research process during conception, design, implementation, and performance evaluation of the proposed IoT prototype for preeclampsia monitoring in antenatal care. It also discusses logistical and ethical considerations.

3.1 Research Design

This study used a mixed research design that involved, exploratory, rapid prototyping approach, and quasi-experimental design that was applied in different objectives.

The search and analysis for suitable smart armband devices involved an exploratory research design. The Internet of Things based model development process was exploratory given that there was no existing approach that was evaluated based on its performance (Musyoka et al., 2019a). Exploratory research design seeks to look for patterns, ideas, or hypothesis rather than to confirm any predetermined hypothesis (Sage Research Methods 2019). The exploratory approach aims at identifying the boundaries of the environment in which the problems are likely to reside and to determine the outstanding factors that might be found there and be of relevance to the research (Creswell, Plano, Gutmann, & Hanson, 2003).

Rapid prototyping approach was involved in the development of IoT based prototype, which was carried out in six steps (Pfleeger, 1995).

1. Conception Phase: in this stage, the researcher identified and stated the problem. The goals of solving the problem were also defined in this stage.

2. Design step: this stage involved translating of identified objectives into formal questions.

3. Preparation step: which included readying the subjects for the application of the treatment

4. Execution phase: in this stage, the experiment was executed.

5. Analysis stage: which involved the review of measurements to ensure they are valid and useful and also analysis of data to tell if research questions were answered.

6. Dissemination and decision-making stage: This stage involved the documentation of conclusion and any other critical aspects of the study.

The quasi-experimental research design was used to evaluate the performance of IoT based model for pregnant mothers and its prototype. It was used to explore the causal effects of an intervention, treatment, or stimulus on a unit of study. In the approach, (Hoy, 2010), the researcher applies a treatment, introduces changes, notes the effects, and has partial control over the design of the study. The approach does not offer random assignment of treatments across a population. The benefit of using the approach helps establish the effect of the intervention on the target population or the absence of an expected outcome. Besides, it helps in building on narrative-based approaches that construct a story around the impact of an intervention (Barrett & Anderson, 2017). Pre data and post data before and after the treatment is applied, recorded, and analyzed.

To reduce the magnitude of error, controls were applied in the experiment where pregnant mothers of 20 weeks pregnancy period and above were selected since preeclampsia occurs at that stage. Blocking and balancing of units as part of control was applied were selected two counties in Kenya acted as experimental units.

3.1.1   Research Philosophy

In order to determine the most appropriate research philosophy for the study, the researcher sought to position the study within the broader context of information technology research. A research philosophy is a belief about the way in which data about a phenomenon should be gathered, analyzed and used. This study adopted logical positivism philosophical paradigm.

The study was framed upon the philosophical and methodological foundations of logical positivism that reality is observable (Mack, 2010; Nwokah, Kiabel, & Briggs, 2009). Logical positivism research deduces and formulates variables, hypotheses and meanings based on existing theory (Durgee, 1987) and therefore this study formulated its variables and hypotheses, and operationalized definitions based on existing theories and then statistically verified the hypothesis using a scientific method of analysis.

3.2 Identification of suitable of Smart Armband for Blood Pressure Measurement

The objective of an analysis of a suitable smart armband device was achieved by the use of an exploratory research design. The analysis was conducted to establish the suitability of viable smart armband for taking blood pressure measurement. The smart armband could also work well with Android Operating System platform handheld devices. The reason for choosing the Android platform was that the handheld phones build on this platform are becoming readily available and accept open-source apps.

Besides, a suitable smart armband was also vital in ensuring that there was effective communication between the smartphone and the device via Bluetooth Technology. The smartphones with less than Bluetooth Version 4.0 could not recognize the smart armband devices.

The review of documentation from vendors of the devices was used to give guidance on the selection of the device indicators/specifications for the smart armband. Secondary data was collected by retrieving previous documents from the manufacturers of the smart armbands which include: Digicare Technology Ltd, Desay Information Technology, and Huawei Technologies Co. Ltd. A rigorous, systematic, and transparent approach was followed, which consisted of writing the specifications for the document reviewed. The specifications were many, but the ones that involved the study were selected. The suitability factors were identified, consisting of a document analysis guide that was used to determine the relevant factors for the study.

Document analysis incorporated coding content into themes (Bowen, 2009). Thematic analysis was applied in the analysis of suitable smart armband. The four categories were identified, which include functionality, hardware, software, and affordability. These categories were used as crucial headings in the data analysis tables to select specifications with a high accuracy level from the manufacturer.

3.3 Development of Internet of Things based model

A model is a representation of one or more concepts that may be realized in the physical world (Friedenthal, Moore, Steiner, & Kaufman, 2012). Besides, it is a concept of a system, aimed at understanding, communicating, explaining, or designing aspects of interest of that system (Dori, 2002). The study aimed at developing an Internet of

Things based model, which consisted of several smart objects with the aim of effective communication for preeclampsia monitoring in antenatal care.

The functional decomposition approach for system analysis and design was used to help in the development of the Internet of Things based application. Dietz (2006) defines Functional decomposition as a "technique for mastering the complexity of the function of a system," where the technique is applied to a functional model of sub-systems. The functional model is a black-box model of a concrete system, and the function is the set of services the concrete system can provide.

Functional decomposition focuses on the functions and sub-functions that a system needs to perform and the interfaces between them. It is a top-down system development methodology that begins with the abstract and broad description of the system requirements (NASA, 2011). IoT consists of a huge number of complicated sub-components such as blood pressure monitoring app, blood pressure sensors, network communication technologies, databases, and interfaces. Therefore, the functional decomposition approach would be the best tool to help in the identification of the components and their functionalities.

The functional decomposition process shown in Figure 10 was used in the implementation of IoT based model for preeclampsia monitoring in antenatal care, focusing on prototype development.

The following Figure 11 is an implemented functional decomposition for IoT model. The model consisted of three sub systems which included: Mobile application, network communication, and cloud data server.
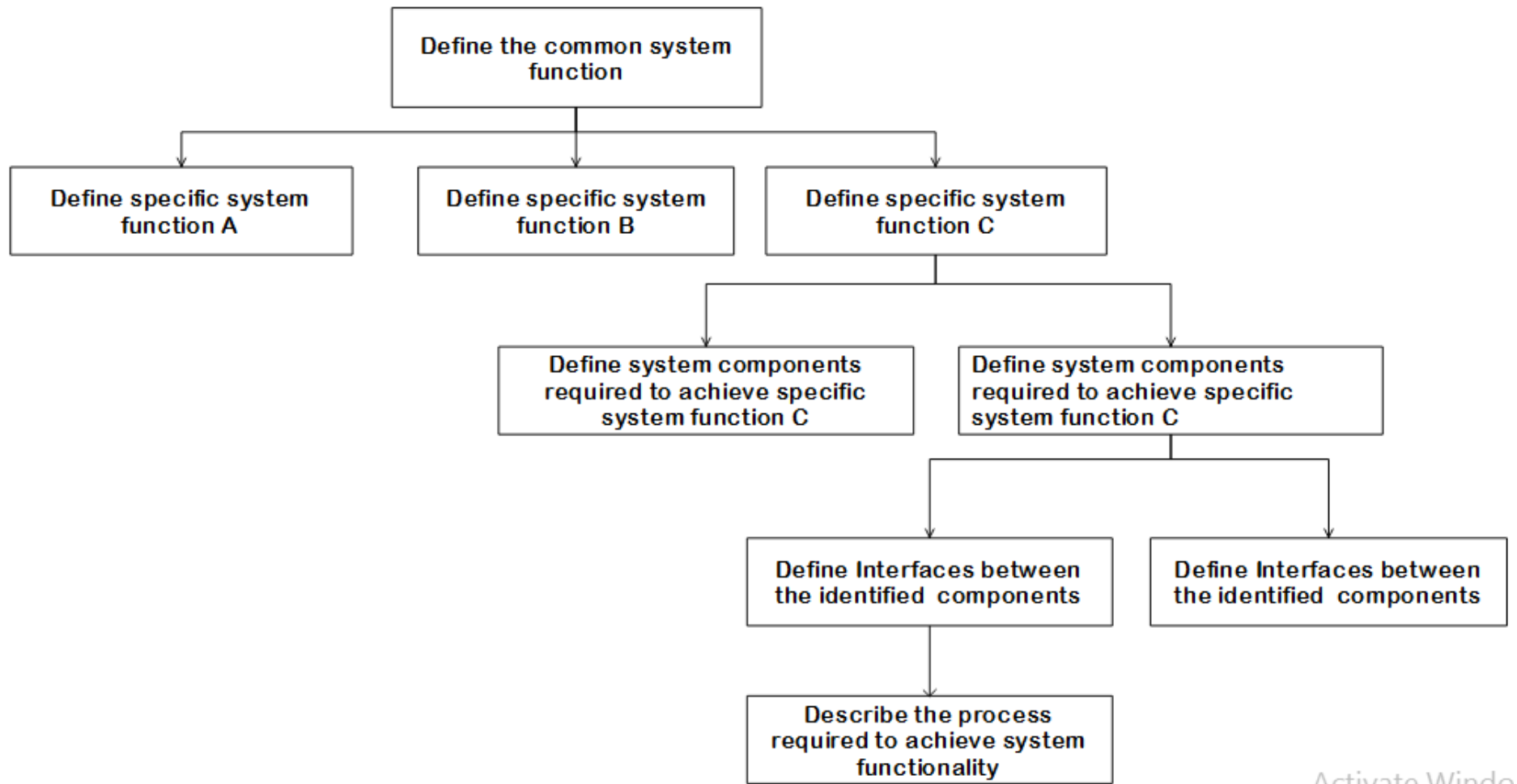
Figure 10: Functional Decomposition

94
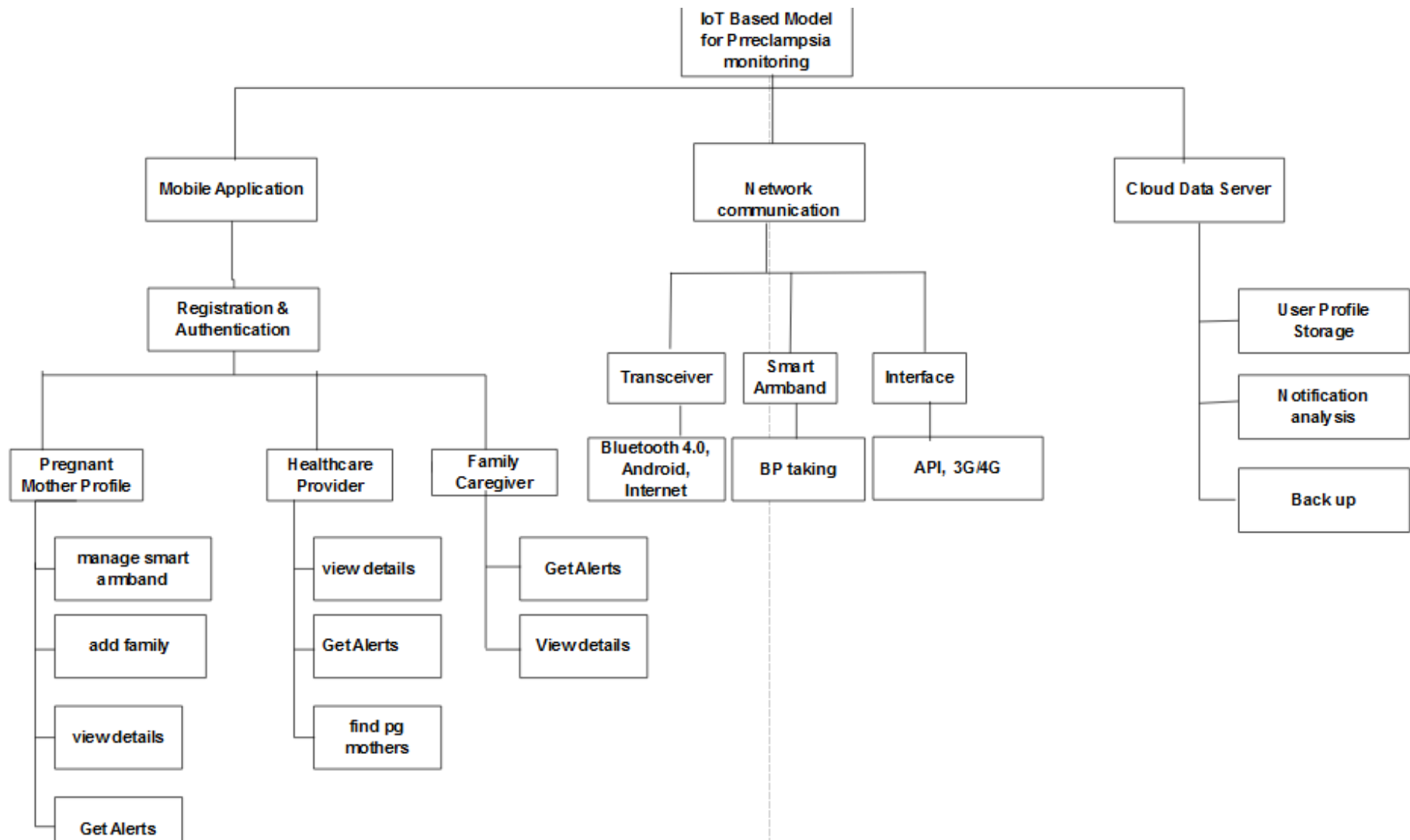
Figure 11: Functional Decomposition of Internet of Things prototype

3.3.1 Network communication

The developed blood pressure monitoring device was configured to read blood pressure fluctuation from pregnant mothers and using a cloud simulator. The data collected from the armband device with BP sensor bundled in chipboard is then transmitted to a smartphone. The smartphone acts as a transceiver with Bluetooth 4.0, Android 4.3+ operating system, and with 3G network features as the minimum features for IoT technology. Since the smartphone has Bluetooth feature, it acts as both a transmitter and receiver and connects the sensor device to cloud IoT. Once the blood pressure data reaches the cloud, it is stored in the data center, analyzed, and shared with the authorized health care providers and family caregivers. The smartphone apps will connect to the cloud server using API protocols.

3.3.2 Mobile applications

The proposed prototype supported three types of mobile applications, the Pregnant Mother Client App and the Healthcare Provider Client App, and Family caregiver Client App. Pregnant Mother Client App consisted of three application modules: manage smart armband, add family caregiver, view details, and get alert when blood pressure is above normal.

The health care provider module consisted of view of details, receiving push alerts in real-time whenever there is an emergency to the pregnant mother client, and also finding pregnant mothers whenever there is a newly pregnant mother data uploaded into a cloud server.

3.3.3   Implementation of Cloud Decision Support application

Firebase Database server was used to organize, store and manage the collected data from pregnant mother which should be available when requested, updated, and be easily retrievable. It had function rule for producing a real time alert after blood pressure readings are produced.

3.4 Implementation of Internet of Things based prototype

A prototype is a blueprint of a system in part or whole. It is used to demonstrate various aspects of the product, such as interfaces or functionality. It is used as a 'proof of concept' to aid in the development of a product or system where no transparent approach is evident. It is used to see if a proposed strategy will work and to demonstrate to a user what the intended system will look like, what it will do and how it will work (NASA, 2011).

Software development models are methodologies that are used for software project implementation. There are different software development models that are used to achieve diverse objectives, each having various phases of the process. Among the models include the Spiral model, Evolutionary Prototyping Model, Incremental model, Prototype model, Extreme programming model, Waterfall model, Rapid application development model (RAD), among others (Whitten & Bentley, 2007).

In the development of The IoT based Preeclampsia Monitor app, the Rapid Prototyping Model was used. The reason for using this model is that users are actively involved in the development process, and the user gets a better understanding of the prototype being developed. The other advantage is that errors are detected much earlier. Besides, quick user feedback is available, leading to the right product. Missing system functionalities

are also noted, and the ambiguous ones are also identified (N. Mohammed & Govardhan, 2010). Figure 12 below shows a rapid prototyping model.
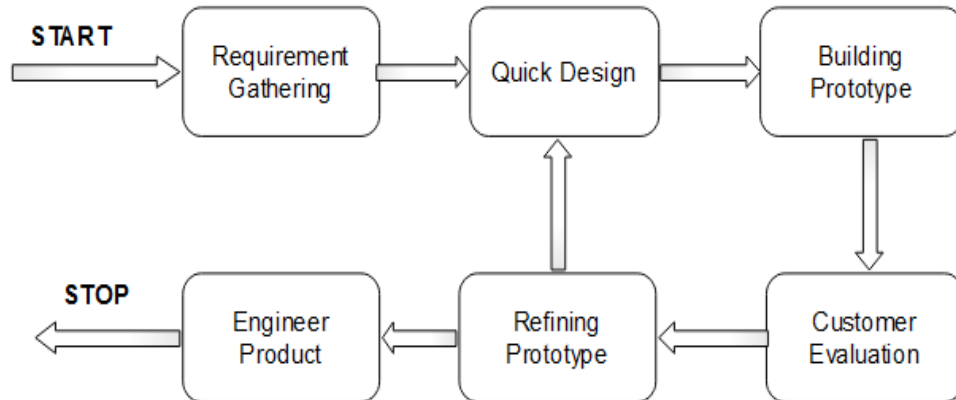
Figure 12: Rapid Prototyping Model

The following Figure 13 shows rapid prototyping approach that was used in the translation of the IoT based model into a functional prototype.
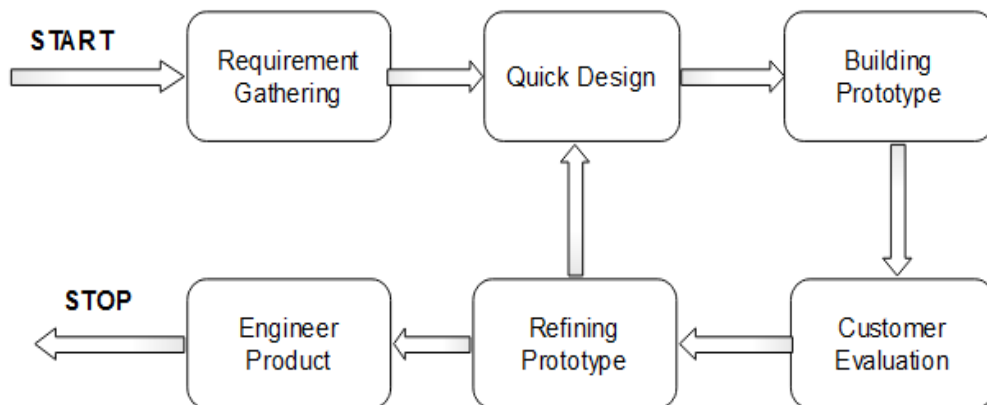
Figure 13: IoT based Rapid Prototyping Model

The study followed the prototyping phases to develop a practical IoT based prototype that was later evaluated for its performance.

3.5 Performance Evaluation of IoT based prototype

Performance evaluation of information technologies is an important task for it leverages the benefits of the technologies (Vijaya & Sarojadevi, 2018). Thus, for sustainable quality of mobile applications, mobile app developers need to know about the performance of the application. After implementation of the actual IoT based prototype for preeclampsia monitoring, an evaluation was conducted to confirm that the prototype performed as expected with the aim of satisfying the user need which is preeclampsia monitoring.

The performance metrics used for the study are depicted in the Table 2 below:

Table 2: Performance Metrics for IoT model

S/N	Indicator	Description
P1	Consistency:	Taking two BP readings from the same pregnant mother within the same sitting to see the level of variation between the readings
P2	Response Rate:	Computation of time difference between when the BP reading was taken and the time the message got to the health care provider/family caregiver.
P3	Accuracy:	a comparison between the BP readings from the same pregnant mother using the proposed IoT system and those obtained from the electronic hospital device (Omron System)
P4	Reliability:	Computation of the percentage error rate produced during BP readings
P5	Output:	The system produces a notification to family member, doctor, and Pregnant mother when BP is above normal

An end to end performance mobile application analysis was conducted. All users; pregnant mothers, health care providers, and family caregivers registered and logged into the mobile app. The performance of the application was monitored in real time using the performance metrics. The results were then collected from the mobile application, cloud database, and electronic BP system used in the hospitals with the aim of measuring the performance of the IoT model.

3.6 Location of the Study

The study was carried out in selected Kiambu and Embu Counties in Kenya. Kiambu County was selected since it has a population of 1,782,083 million as per the 2009 Census and moreover, the rate of delivery at health institutions stands at 80.4 per cent which reveals that it's easy to access the pregnant mothers (Kiambu Government, 2015). Embu County currently has a population of 603, 094 and moreover, the rate of delivery at health institutions stands at 81.5 percent which also shows that is quite easy to access pregnant mothers in public hospital (Ministry of Health, 2015).

3.7 Population of the Study

The study was carried out in two selected counties: Kiambu County and Embu County in Kenya. These counties have a large population and the rate of delivery at health institutions is high which shows there is likelihood of accessing pregnant mothers during evaluation of developed IoT blood pressure monitoring prototype. In addition, the counties were selected out of eight regions in Kenya to avoid bias of carrying out the study.

The target population for the study was pregnant mothers who were 20 weeks pregnancy period and above and who are attending antenatal care clinic in level 5

hospitals for the two counties: Thika level 5 hospital and Embu level 5 hospital. Level 5 hospitals were selected because, most mothers go for ANC visits in these hospitals. The choice for the pregnancy stage is because hypertension disorders are diagnosed from the second semester of pregnancy period.

The number of respondents for the study was computed as follows:

$$n = \frac{z^2 pq}{d^2}$$

This is a Cochran formula (Cochran, 1963) where; n is the desired sample size of the study population. Z is the standard normal deviate, p is the proportion of pregnant mothers in target population estimated to be 20 weeks and above of gestation period and, d is the degree of accuracy allowed. Cochrans' formula is appropriate when the target population is unknown as the exact number of pregnant mothers who attend antenatal clinic is not known which was discussed with the chief nurse in charge of Reproductive Health Unit, Thika Level 5 hospital (J. Mwangi, personal communication, July 2019).

This study used 90% (0.90) confidence level for pregnant mothers with 20 weeks, and above gestation period who attends antenatal care visits which correspond to standard normal deviate (z) of 1.28, p is unknown and hence set at worst-case value of 50% (0.5), and d is 10% (0.10) as proposed by (Fisher, Lant, Stogeckel, & Townsend, 1998). Using this formula for the pregnant mothers with a gestation period of 20 weeks and above sample, the sample population was found to be 41 pregnant mothers which was the minimum number as shown;

$$n = \frac{z^2 pq}{d^2}$$

$$n = \frac{1.28^2 * 0.5 * 0.5}{0.1^2}$$

$$n = 41$$

During the assessment of developed IoT blood pressure monitoring prototype, the sample size of pregnant mothers was purposively and randomly selected in Embu and Thika level 5 hospitals. The selected pregnant mothers were the ones in their second and third trimester since preeclampsia is detected in those stages of pregnancy.

3.8 Sampling Technique

Sampling techniques is a process of selecting several respondents from a population such that the chosen group comprises of elements representative of the characteristics found the entire target population (Kombo & Orodho, 2003). Mugenda & Mugenda, (1999) assert that a sample is a small group collected from the accessible population as a representative of the whole population. A sample design is a plan for getting a sample from a given population. It refers to the technique the researcher would use in selecting items for the sample (Kothari, 2004).

The study sample was derived using both purposive sampling and simple random sampling techniques. Each respondent had an equal probability of being chosen from their respective category. Purposive sampling is a non-probability sampling procedure where sampling procedure does not afford any basis for estimating the probability that each pregnant mother in the population can be included in the sample (Maxwell, 2012). Purposive sampling is a sampling technique that helps a researcher to select and use cases that have the required information concerning the objective of the study

(Mugenda & Mugenda, 1999). The aim of the study targeted pregnant mothers who were 20 weeks of pregnancy and above since are the ones who are vulnerable to preeclampsia conditions; hence, purposive sampling was applied. Purposive sampling is useful, where only limited numbers of people can serve as primary data sources (Black, 2010). As in the case of this study, only pregnant mothers with 20 weeks pregnancy period were considered.

Simple random sampling is a probabilistic sampling procedure where every entry in the population has an equivalent opportunity of being included in the sample. Also, each one of the possible samples, in the case of a finite universe, has the same probability of being chosen (Kothari, 2004). Every pregnant mother within the gestation period of 20 weeks and above had a chance of being selected to removes bias from the selection procedure.

These techniques were used to select the sample population of pregnant mothers used in the study, who were the primary respondents in this study.

3.9 Data Collection Procedure

Before any data was accessed, the researcher got research approval from Kabarak University through the School of Post Graduate Studies. After that, the researcher acquired a research permit and a letter of authorization from the National Commission for Science, Technology, and Innovation (NACOSTI) to carry out the study. The copies were submitted to County Commissioners, County Director (Education), and County Director (Health) for Embu County and Kiambu County who wrote an authorization letter to Medical Superintendent of the two level-5 hospitals. Lastly, the researcher got

a letter of authorization from the Medical Superintendent to collect data from the hospitals.

A document analysis guide was used to review the suitability of smart armband devices. Also, in measuring the performance for IoT based model, it was used to create performance metrics. A document analysis guide is a qualitative research tool in which documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen, 2009).

During the collection of data from pregnant mothers, the respondent was assured that the information collected and stored in the mobile application was treated strictly confidential and purely for academic work.

3.10   Pilot Study

A pilot study was conducted in order to collect data for use in reliability analysis as well as to test the validity of document analysis guide tool developed for use in the study. Three respondents were used to pilot the study. Every pregnant mother stayed with the F1 smart armband for 24 hours and took BP readings at several intervals. The data collected was used to determine the reliability of the tool. The tool was found to be suitable for collecting the data required for the study.

3.11   Validity and Reliability

Validity refers to the extent to which a test measures what we actually wish to measure (Kothari, 2004). To ensure validity, the pilot study conducted confirmed that the IoT based prototype could read the blood pressure, analyze the information, and send alerts to recipients when the BP was considered to be above normal.

Reliability is a measure of the internal consistency of a research instrument as well as a measure of the degree of homogeneity among the research items in a construct. The aim of reliability is to assess whether the instrument would give consistent results in repeated tests held at different subjects and times (Wamuyu & Maharaj, 2011). To ensure reliability, the blood pressure readings were both taken from the proposed F1 smart armband and the electronic BP tool used in the hospital referred to as Omron System. From the repeated data from different subjects within different intervals, the collected data was found to be slightly similar with minimal variation. Thus, the instrument was found to produce consistent results.

3.12 Ethical Considerations

To the pregnant mothers anonymity and confidentiality are vital issues. To address the issues, the researcher used unique identification numbers for both health care provider, family caregiver, and pregnant mother where their identities were not included in the analysis and subsequent reports. Besides, voluntary participation was encouraged and informed consent was conducted before field test to prepare them for participation since the test required four BP readings of one hour interval. Non-discrimination was ensured where each respondent within the selected gestation period had an equal chance to participate in the study. Ethical approval was sought from the two level 5 hospitals that involved an interview with the ethical review board committee and submission of documents: copy of national identification number, research proposal, research profile, documents from NACOSTI and university letter, with payment for the service.

3.13   Conclusion

This chapter described the approach and methods that guided the conduct of the study. The overall methodology was based on mixed research design. It entailed exploratory design, functional decomposition approach for model development, the rapid prototyping approach for prototype development, and the quasi-experimental design for performance evaluation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

In this chapter configuration of smart arm band with blood pressure monitoring mobile application, model development, model implementation, and evaluation of the developed model was discussed.

4.1   Identification of suitable smart arm band for blood pressure measuring

This section sought to identify the suitable smart armband for preeclampsia monitoring in antenatal care.

4.1.1   Introduction

Suitability is the ability of a device having properties that are right for a specific purpose (Farlex, 2019). The specific purpose of this study was to identify a suitable smart armband that consists of an acceptable score of properties. These properties include functionality, hardware, software, and affordability to collect blood pressure readings from pregnant mothers and transmit the blood pressure measurements to the smartphone. On functionality property, the smart armband is considered to be suitable if it measures the blood pressure of a person showing both systolic and diastolic readings. In a hardware property, the smart armband is deemed to be ideal by having provisions that cannot lead to damage. The hardware provision include waterproof material, sweat protection material, long standby after full charge, and mode of operation properties. Besides, hardware sought to get technologies required to enhance

the function of the device, which includes Bluetooth technology. Software property sought to have a tool that has instructions coded and presented in English language, coded instructions that are open source, and with alert notifications instructions. The device is also considered to be suitable by the affordability attribute, where the cost is less than other methods.

4.1.2 Study Findings

Three different smart armband devices were examined in order to identify a suitable device that can be used in preeclampsia monitoring. The devices had specifications for measuring blood pressure besides fitness trackers. They included the following product names: F1, Huawei Band 2 Pro, and DigiCare smart bracelets, as shown in Table 3 below.

Table 3: Analysis for suitable Smart Armband for Preeclampsia monitoring

Category	Property	F1	Huawei	DigiCare
Functionality	Blood Pressure measurement function	Systolic/diastolic	Systolic only	Systolic only
Hardware	Waterproof	IPV67	5 ATM	IPV67
	Bluetooth technology	4.0	4.0	4.0
	StandBy after full charge	7 days	21 days	7 days
	Operation	Single touch	Single touch	Single touch
	Sweat protection Material	Silicon +Pc	TPU	TPE
Software	Language	English/Chines	English	English
	Standards	Open source	Proprietary	Proprietary
	Alerting messaging App	No	No	No
Affordability	Price in Market (Kshs.)	6,999	14,260	8,999

The following are discussion on the properties identified during the analysis of smart armband suitability:

i.   Functionality

The study sought to identify the smart armband that displayed blood pressure for both systolic and diastolic readings in the interface. Out of the three models, the F1 smart armband was found to display both readings on the device's interface. Functionality was a crucial parameter since the electronic devices used in hospitals have these readings; hence, F1 was found to have a high score on this parameter.

ii.   Hardware

. In the hardware category, five properties were found to be parameters required in selection for a suitable device for preeclampsia monitoring. Waterproof standard parameter means the smart armband is invulnerable to water regardless of how long it is submerged (Parker, 2019). IP67 standard parameter means the smart armband is immune to water when immersed in a size depth of up to one meter for up to thirty minutes. 5ATM means that the device is invulnerable to water up to fifty meters in depth for ten minutes. The IPV67 was found to be more suitable than 5ATM to pregnant mothers who may use water for a more extended period.

Bluetooth technology version 4 is an optimized version of the proprietary wireless Bluetooth technology standard for data exchange over short distances that enhances compatibility with classic Bluetooth-capable devices (Bluetooth, 2019). All examined devices were found out to have this latest version thus could connect with smartphones that also have the latest version.

Standby after full Charge is also a property in hardware, which is the time the user is not actively using the smart armband though it is on. Huawei Band was found to have the most prolonged period of 21 days for standby after full Charge, while F1 and Digicare had seven days of standby. Therefore on the parameter, Huawei band was more suitable compared to the other two devices.

All three devices have a single touch operation that has a small touchscreen and side buttons for user interaction while requires bimanual interaction (Al-Megren, 2018). The single-touch operation is a challenge to both devices since the screen is small and cannot operate as a full touch operation like in the case of mobile phones.

Sweat protection material is also a parameter to be considered when identifying a suitable smart armband. Due to a prolonged wearing period, there is the need for a device with a material that is exceptionally flexible, durable, and smooth to the touch. TPU is considered to be the most flexible, oil-resistant, and even be sterilized compared to other materials (Zmore, 2012). Besides, Silicon +Pc material was found to cause the skin not to sweat in case of hot weather conditions.

iii. Software

Language is a crucial parameter to ensure a practical understanding of the operation and data collection by the user. All three devices used the English language, which is the national language used in the country where the proposed suitable device was used. F1 smart armband had a new language, Chinese, which is an added advantage in case of modification, the manufacturer can understand the functionalities with ease.

Licensing standards was also a key parameter to be considered since it ensures appropriate usage of software and compliance with existing software agreements by

users. The aim of choosing the suitable smart armband was to help implement Internet of Things based prototype, thus, it was essential to select a smart armband that could not violate licensing standards. The F1 smart armband was found to be the device with the open-source standards, which allows the software to used freely, modified, and shared by the user. The other two devices had a proprietary standard that is licensed by the copyright holder under particular conditions.

For the three devices, none had an alert messaging app in them. The alert messaging app was to be used to send alerts to users when the blood pressure was identified to be above normal. F1 bracelet was configured with wearfit app, Huawei Band 2 Pro bracelet was configured using Huawei's Health app or MyFitnessPal, while, DigiCare bracelet was configured using Digicare App. Since these apps did not possess the attribute, therefore the study sought to implement a prototype that was used to operate preeclampsia monitoring.

iv.   Affordability

In the identification of the suitable smart armband, the cost of the device was also a key parameter to be considered. Digicare and F1 smart armbands' purchase value was found to be less than Kshs. 10,000, which was economical in developing countries with F1 smart armband being the cheapest.

4.1.3   Discussion

The study analyzed the suitable smart armband from the three devices. This study focused on an exploratory approach where data was retrieved from the specifications in device user guides.

Four properties were identified as functionality, hardware, software, and affordability. Ten sub-properties were classified in the form for analysis levels: Bluetooth technology, waterproof, Blood Pressure measurement function, stand by after full charge of the battery, user operation, language, and material for the case, standards, alert messaging, and price in the market.

F1 smart armband had eight properties rating excellent with a score of 8 out of 10. Both Huawei Band and Digicare smart armbands rated six properties unique with scores of 6 out of 10. Therefore, a suitable device based on the categories was found to be F1 smart armband device.

F1 smart armband has the capability to display blood pressure for both systolic and diastolic readings on the interface. This capability is similar to the electronic blood pressure devices used in the hospitals, unlike the other two that displayed systolic readings only. The F1 smart armband consists of IPV67 waterproof material, which is more suitable compared to the 5ATM material since it can allow the pregnant mother to insert the device in water for 30 minutes without it failing. Bluetooth Technology was also a key aspect, and F1 smart armband has the latest Bluetooth 4.0, which connects smart devices in the fast transmission of data.

The device is made using Silicon +Pc material for protection from sweat, other greasy liquids, and also it is easy to sterilize the material. The device uses a single touch operation that makes it small in size hence portable. F1 smart armband has both English and Chinese Language. English is the national language, while Chinese is an added advantage where, in case of modification, the manufacturer can understand the functionalities with ease. F1 smart armband has open-source standards that allow the software to be used freely, modified, and shared by the user. The purchase cost for F1

smart armband was Kshs. 6,999, which is economical. The challenge with F1 smart armband was on standby after full charge, which is indicated in documentation as the device can stay for seven days. While on a practical basis, its battery charge stays for 25 days, which is very beneficial. The other challenge was that wearfit app that was originally developed for F1 smart armband, does not have an alert messaging parameter, which would allow the BP readings to be sent to both health care providers and family caregivers.

The selection of F1 smart armband was found to be suitable and it aligned with the study (Modesti, Perruolo, & Parati, 2015) that concluded a reliable estimation of Blood pressure levels is crucial at both the patient and population levels and thus there is need to use automated devices that are of low-cost and reliable. Also, the study concluded that an assessment of hypertension on a single visit may lead to overestimation of prevalence and healthcare requirements.

4.2   Development of Internet of Things based model for preeclampsia monitoring in antenatal care

This section discusses the process that was followed in the development of the final Internet of Things based model for preeclampsia monitoring in Antenatal Care. The functional decomposition approach discussed in section 3.4 and depicted in Figure 10 was followed in developing a functional system of the model.

Internet of Things based model is a blueprint that was used to bring together subcomponents being smart objects, networks links, and interfaces together with the aim of developing an IoT prototype for preeclampsia monitoring in antenatal care.

These components included: users, network communication, interfaces, smart armband, transceivers (smartphones), and cloud database.

4.2.1 Functional Decomposition Process

Requirement gathering is the first step in creating any system model. First was to determine the aim of the system model, what the application should be able to do, what its primary request would be, which actual problem it was going to address, lastly, what part of life is aimed to improve. Detail design documents were created which outlined the planning design, development, and evaluation of the system project. The requirements for the proposed system were also inferred from Literature.

The aim of the study was triggered by the scenario where pregnant mothers normally attend a minimum of four recommended number of ANC visits in Health clinics, which may not be the case for pregnant mothers within low settlement areas. This might be a challenge to pregnant mothers prone to preeclampsia condition caused by high blood pressure, which does not display any symptoms. The proposed solution thus provides an option for health care providers and family caregivers to receive timely and effective data about the pregnant mother blood pressure readings instead of waiting a whole month for a mother to attend a clinic visit for her blood pressure be taken. Besides, the solution sends an alert notification to both users in case the blood pressure exceeds the normal range. This is achieved by implementing an Internet of Things based model for preeclampsia monitoring in antenatal care.

Quick Design is the second phase where the user interface was established. This step visually conceptualized the main features and a rough layout and structure of the mobile application. A wireframe for the proposed layout and its structure was drawn which

assisted in understanding the journey better. Figure 14 shown below is an example of such a sketch.
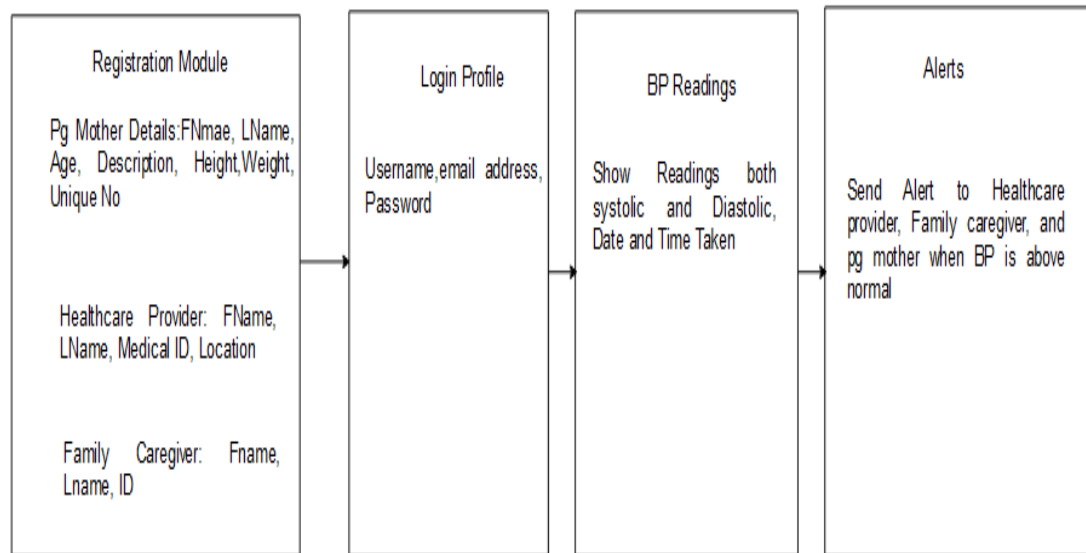
Figure 14: A wireframe sketch for BP Monitor App

The system processes are translated into flow charts. A database was then designed based on the proposed processes and flowcharts.

For the development of the model, six components were involved:

1. The first system component was users. There were three main types of users: First, a pregnant mother who was the subject of the study seeking to get her blood pressure taken by use of a smart armband that was found to be suitable in objective one. Secondly, a Health care provider user who was capable of receiving blood pressure information from the pregnant mother's mobile application after it has been read from the smart armband. The health care provider could also view the history of the Blood pressure and take any action if need be. Thirdly, the family caregiver who is added to the system by pregnant

mothers to view pregnant mother's blood pressure fluctuation and receive an alert notification when the readings rise above normal range.

2. The second system component is F1 smart armband. It is an electronic device that consists of an integrated chip for sensing, recording, and displaying real-time data on the screen. This band was selected because it was found to be suitable following the parameters identified and discussed in objective one being Bluetooth technology, waterproof, Blood Pressure measurement function, stand by after full charge of the battery, user operation, language, and material for the case, standards, alert messaging, and price in the market. In addition, it had a sensor made from piezo-resistive fibres in the armband that would measure the touching base pressure of the device on the skin. The fibre is electrically conductive; thus, it will detect any change in blood pressure, converts this into an electrical signal, and transfers this to the measuring device.

3. Thirdly was a pregnant mother's smartphone component. The data collected from smart armband device with BP sensor is then transmitted to a smartphone using Bluetooth technology, Android 4.3+ operating system, and with 3G network features as the minimum features for IoT technology. Since the smartphone has Bluetooth technology feature, it acts as both a transmitter and receiver and connects the sensor device to the cloud Internet of Things.

4. The fourth system component was the cloud database system. Once the data was transmitted from smart armband device, it reached the cloud, where it was stored in the data centre, analyzed, and shared to the authorized health care providers as well as family caregivers a functioning system was created to perform analysis and send a notification when the BP measurements exceed normal. When the blood pressure measurement reaches 140/90 mmHg and

above, an alert notification is then sent to the health care provider and family caregiver showing the BP readings, date and time. Another alert notification is sent to a pregnant mother, informing her that the blood pressure reading is above normal.

5. The fifth system component included health care provider's and family caregiver's smart phone. This smartphone consisted of a mobile application interface that connects with the cloud decision support system to receive an alert message hence taking action to the pregnant mother if need be. The mobile application allows the health care provider to view any new pregnant mother in a cloud database who is not allocated health care providers.

6. The sixth system component includes the interface between system components. For components to interact with one another, some interfaces have been used to ensure effective interaction. Bluetooth technology will provide two-way communication between the pregnant mother's smart armband and the smartphone. Besides, Application Programming Interface (API) is used for retrieval of information from the data center server to the mobile applications for both users' smartphones. The API specifies how software components would interact with one another and helping in developing Graphical User Interfaces. The interfaces and how they relate to the system components are presented in Figure 15.
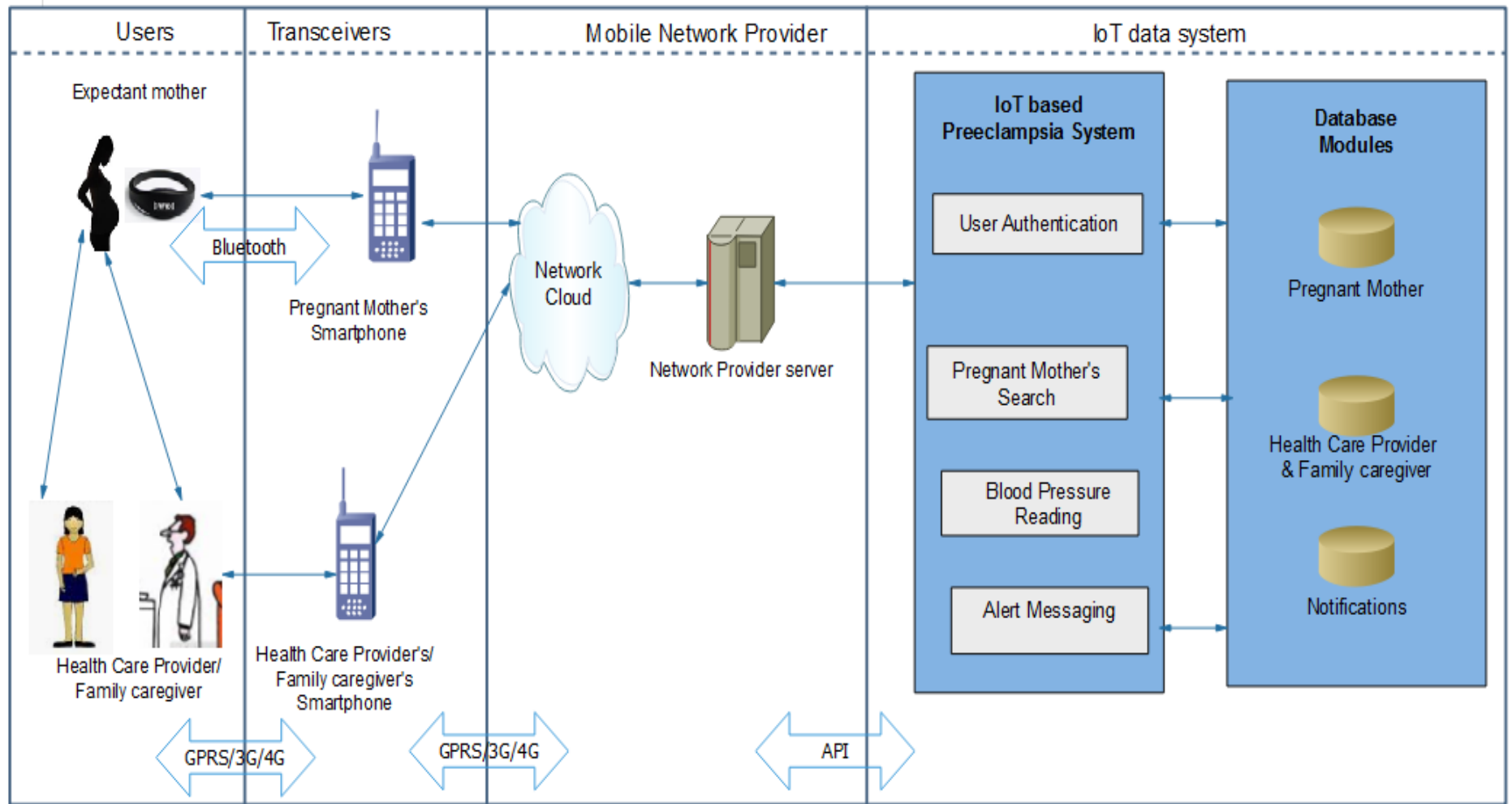
Figure 15: Internet of Things Based Model for Preeclampsia monitoring in Antenatal Care

4.2.2 Processes followed for achieving system objective

The functional decomposition was used in developing the Internet of Things based model that was structured in a step by step way as follows.

i. **Users:** These are users who get service from BP monitor system for preeclampsia monitoring. The Pregnant mother wears a smart armband to help in reading blood pressure. The health care provider and Family caregiver receive BP measurements and alerts if the BP exceeds normal to take appropriate action to the pregnant mother.

ii. **Smart armband:** This is a device that a pregnant mother wears to help in reading the blood pressure

iii. **Pregnant mother's smartphone:** This phone connects with the smart armband and displays BP readings at the same time, it sends the BP measurements to the cloud data system.

iv. **Cloud database System:** After BP reading completion, the data is sent to the cloud database which has a function to perform analysis of data. The data is also sent to the healthcare provider and family caregiver smartphones immediately as long as the phones are connected to the Internet. When the blood pressure readings exceed normal, the system sends an alert notification to all the three users showing the blood pressure has exceeded normal and the action should be taken.

v. **Health care provider's and family caregiver's smartphone:** This device receives BP readings of the pregnant mother and also receives an alert notification when the BP exceeds normal.

vi. **The interface between system components:** Bluetooth technology offers two-way communication between the smart armband and the pregnant mother's smartphone, while API offers retrieval of information from the IoT data system to the mobile applications for both users' smartphones. GPRS/3G/4G allows cellular networks to transmit data to external networks, which is the Internet where the data is received from the cloud servers to smartphones.

4.2.3 Discussion

The functional decomposition process was followed in the development of the model for the Internet of Things based model for Preeclampsia monitoring. The process involved the definition of system functionality, the description of the specific components, a discussion on the interfaces between the various components, and an outline of the process that was followed in transforming the model to a working application. The model incorporates six main system components, which include: users, F1 smart armband, pregnant mother's smartphone, health care providers and family caregiver's smartphone, cloud database systems, and the interface between components. The functional decompistion approach enhaneced effective communication of functional requirements that led to the development of IoT based prototype as it is the key functionality in any distributed computer system is ensuring communication between the different components (Bauer et al., 2013).

4.3   Implementation of the proposed Internet of Things based model for preeclampsia monitoring in antenatal care

This study aimed to develop an Internet of Things based model for preeclampsia monitoring, which was then used to design and implement an IoT prototype. This section is presenting the testing results from the developed IoT prototype.

4.3.1   Prototype Building

After the functional decomposition where identification and description of system components of the model were done, then a prototype was built. At this stage, all the ideas and features were concluded, as a clear picture of the structure for the system was created. A mobile application prototype was then built using Android platform with Java programming language, the database used was Firebase and hosted online by firebase which can power an app's backend, thus including data storage, user authentication, and static hosting. Firebase was also connected to existing backend using our server-side libraries to help in adding functionalities. Firebase database supports JSON data; thus, all users that are connected to it will receive live updates after every change made in the database. It also allows anonymous and password authentications.

The following subsections will describe the design modules that were adopted during the implementation.

i.   User authentication

The user authentication process is the starting point of the system. First, the user logs in to the system before accessing any of the system functionality. The login details include; username/email and password. When a user enters valid information, she is

allowed to view system activities; otherwise, the user is taken to the Registration step.

Figure 16 outlines the user authentication process of the system.
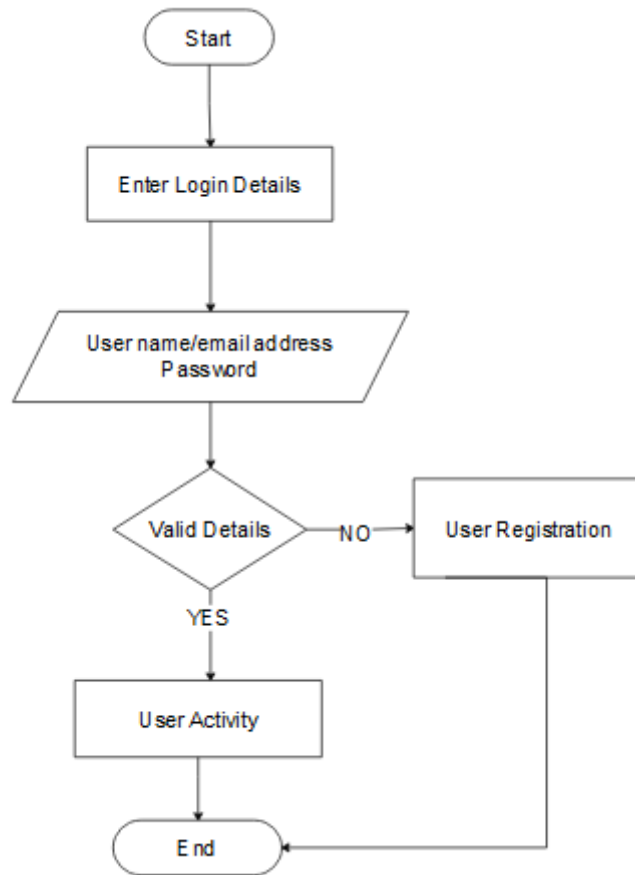
Figure 16: User Authentication Flow chart

i.   User registration

For registration, the user is expected to enter the user type. The user then enters registration details. If the details are valid, the user can save the details; otherwise, the system takes the user back to the registration process to enter the details again in case there are unfilled details. The flow of the registration proves as shown in Figure 17 below.
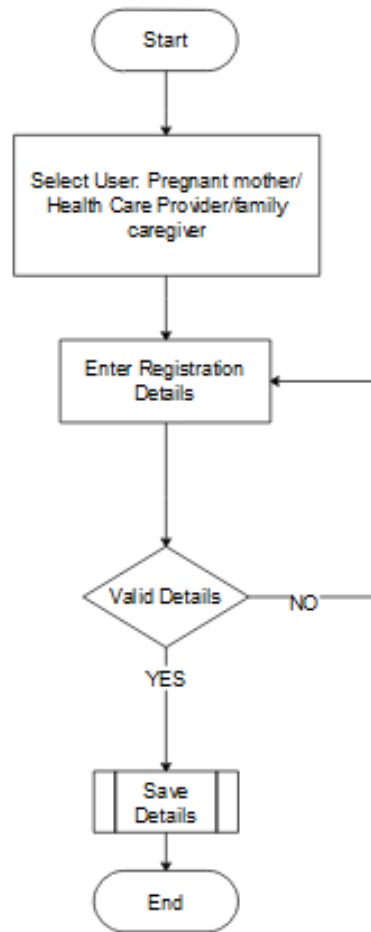
Figure 17: User Registration Process

ii.   Health Care Provider activities

Once the healthcare provider has registered to the application, there are several functions that he/she can perform. The healthcare provider can go ahead and find a pregnant mother. If the mother is linked to the healthcare provider, then the provider can view the mother's details; if the mother is not linked to any health care provider, then the provider can connect the mother to his/her circle of pregnant mothers. The process showing these activities is presented in a flowchart shown in Figure 18 below.

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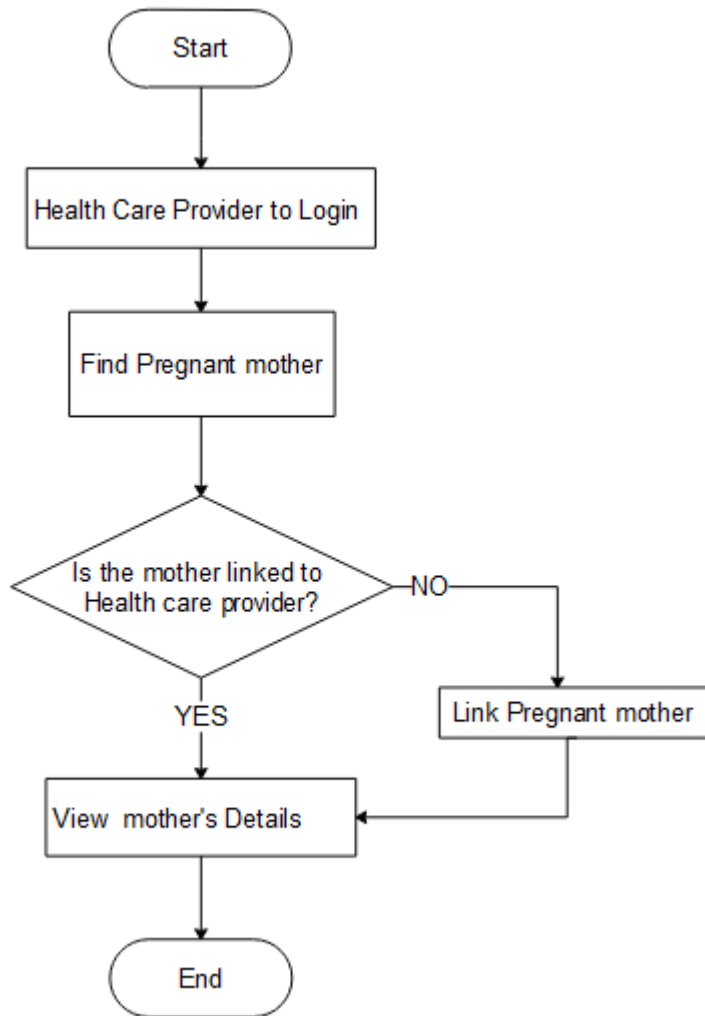
Figure 18: pregnant mother search Flowchart

iii.   Blood Pressure Measurement

When the pregnant mother wants to take a blood pressure reading, she has to login first

to the BP monitor mobile system. For the mother to take a reading, her device has to be

connected with Bluetooth. If the device she is wearing is not connected with Bluetooth,

then the app first scans the available devices for selection of the right device, then the

process of taking readings start. This flow of data is depicted in Figure 19, shown

below.
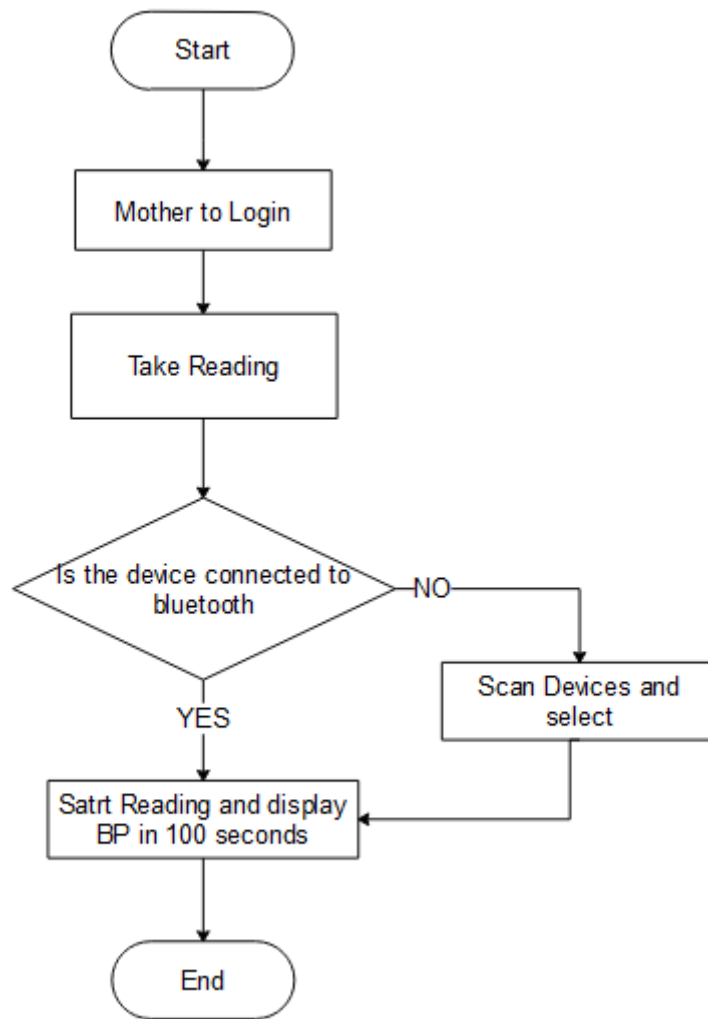
Figure 19: Blood pressure reading process

iv. Alert Notification

Alerts are sent to the pregnant mother's linked health care provider. Once the mother takes the blood pressure readings, as long as the care provider is connected to the Internet, he/she is notified within the shortest period, and if not connected to the Internet, the notification will pop up later when the health care provider's phone is connected. This automatic functionality will be prompted by the connection of the smartphone to the internet. The healthcare provider/family caregiver logs into the system checks any pop-up alert that comes after logging in. If the provider has not yet

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checked, the alert message remains highlighted and keeps popping up else, the alert message changes color to fade after it has been viewed. The following Figure 20 shows the alert notification data flow process.
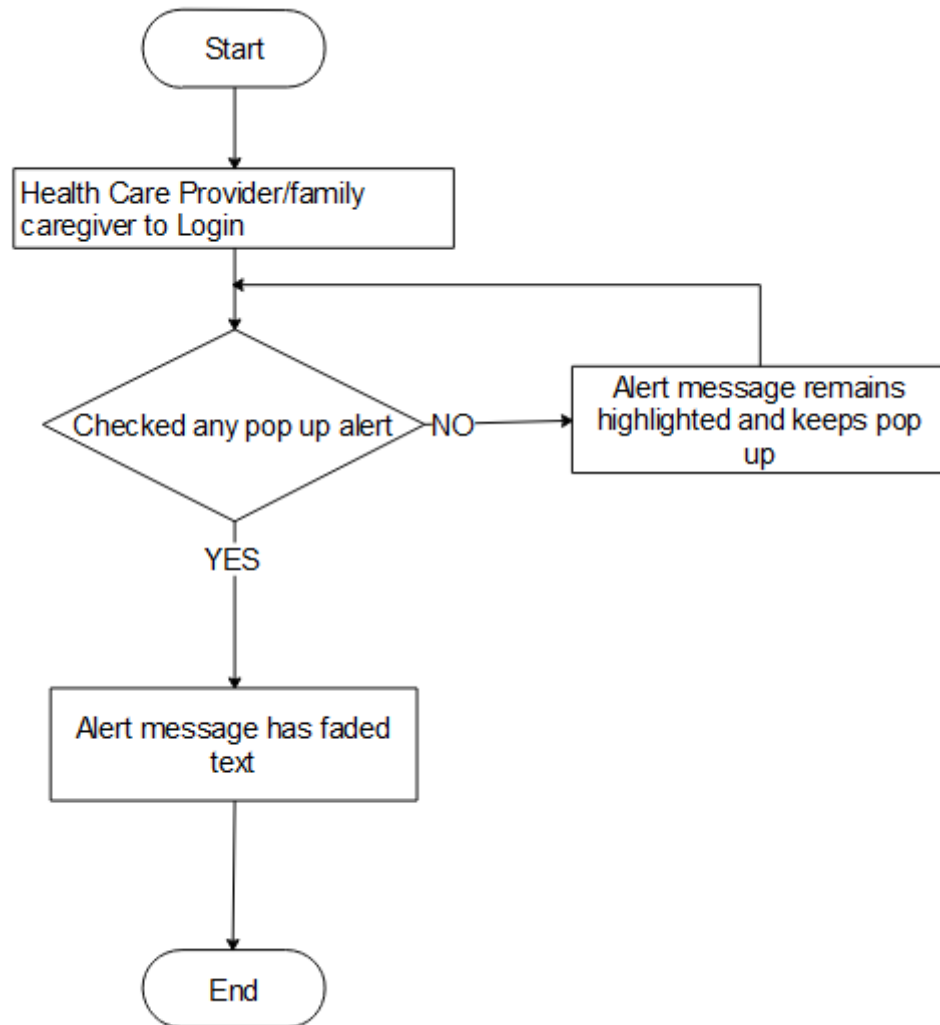
Figure 20: Alert Notification flow chart

4.3.2 Screenshots from BP Monitor Mobile application

The following sections describe the screenshots that were captured to show that the prototype was used to produce desired results in reading blood pressure, storing values, analyzing, and sending alert notification.

i.   User authentication

Before the user, either pregnant mother or health care provider or family caregiver, accesses the system, he/she has to login with login details being username/email and password, as shown in Figure 21 shown.
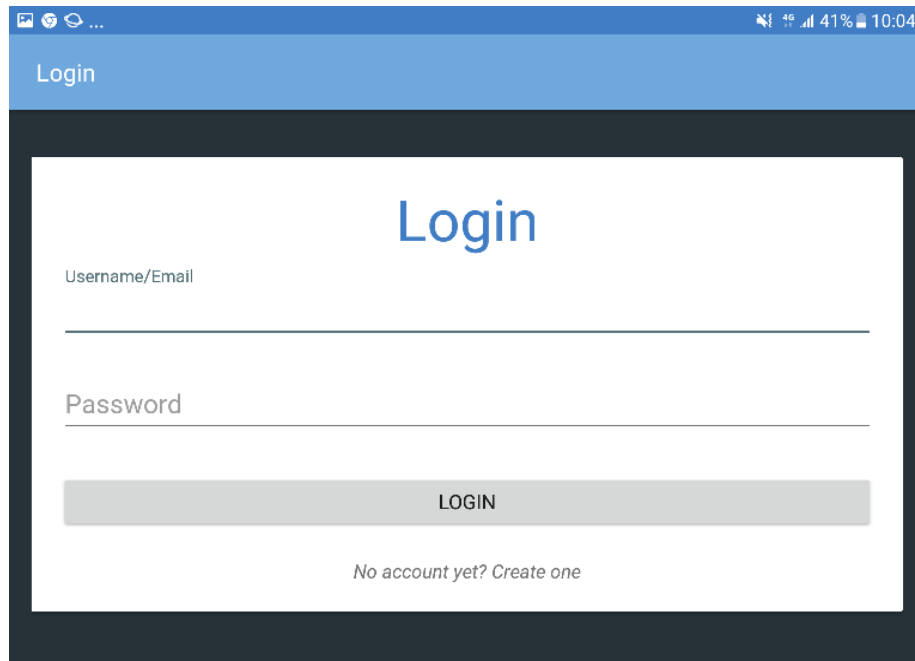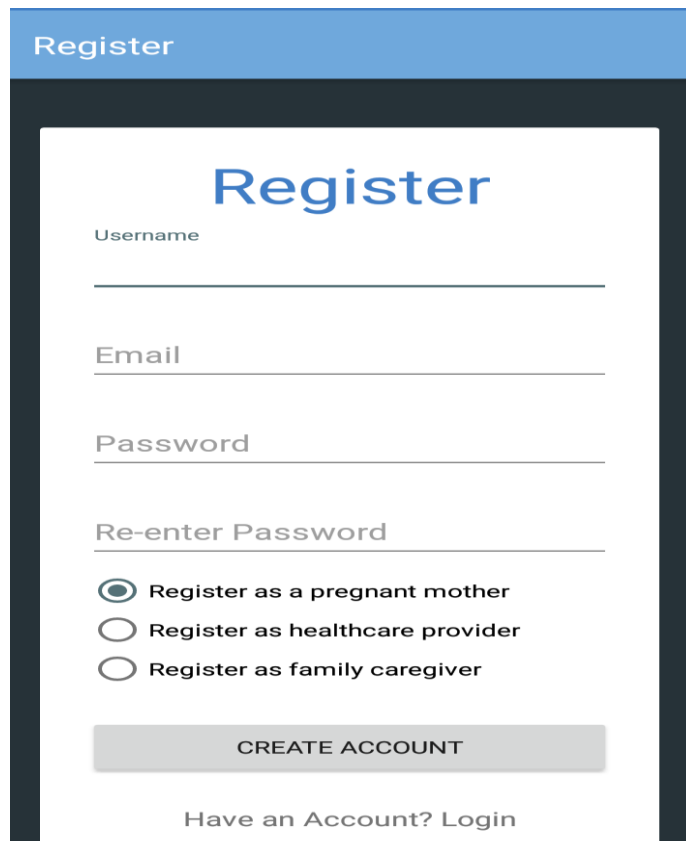
Figure 21: A login Interface to the BP Monitor App

In Username/Email text, the user should enter the user name or an email address that she /he used to register as well as the password, then click the login icon. If the user has a directly accessed login interface without registering first, then there is still an option to create an account by clicking the "Create one" icon. Also, if the details entered are not correct, the user is taken back to more information that is incorrect for reentering the details or register.

v.   User registration

A user accessing the BP monitor app for the first time is required to register before accessing the use of any of the system functionality, as shown in Figure 22 below. For

pregnant mothers, the details include name, Medical ID, Date of Birth, Height in centimeters, weight in kilograms, pregnancy start date, and expected delivery date. The system automatically updates the gestation weeks of the pregnant mother until the 42nd week is reached. The health care provider details include name, Medical ID, and Gender. The family caregiver details include name and gender.

Figure 22: User Registration Interface in the BP monitor App

vi.   Blood Pressure Measurement

Once the pregnant mother has registered and entered all the required details, with a smart armband placed on the wrist, she can switch on Bluetooth on the smartphone with BP monitor app to communicate with the smart armband. When connected to Bluetooth, then the pregnant mother will go to BP monitor app to click "Take a reading," icon, which will trigger the sensor on the smart armband to start taking the

BP reading. This activity takes 100 seconds to display BP measurements on the interface and automatically will be sent to the health care provider's smart phone's app. On the blood pressure monitoring application, Figure 23 shown below depicts the icon named "Take Reading", whereby a pregnant mother puts on the smart armband and clicks the icon to start reading blood pressure.
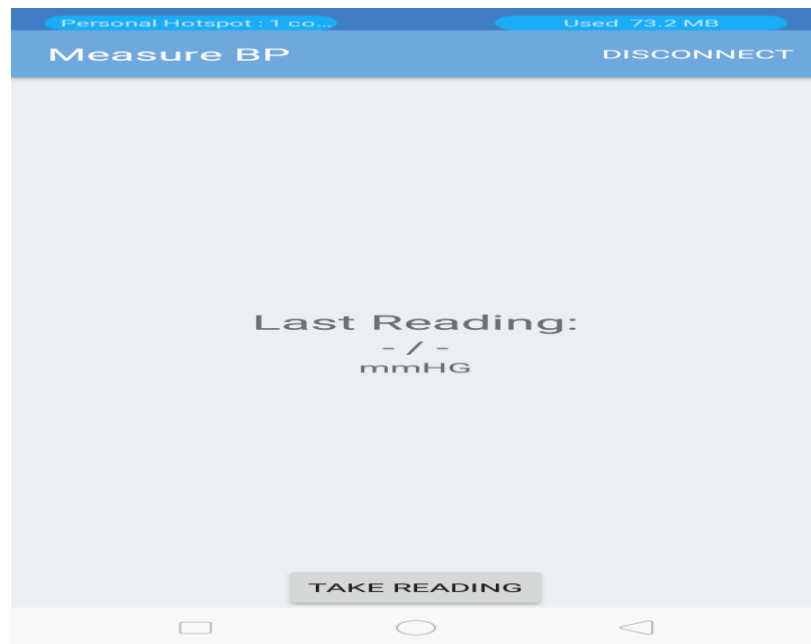
Figure 23: BP Monitor interface to Take Blood Pressure Readings

The following Figure 24 shows the already taken blood pressure from a pregnant mother and is displayed on the interface.
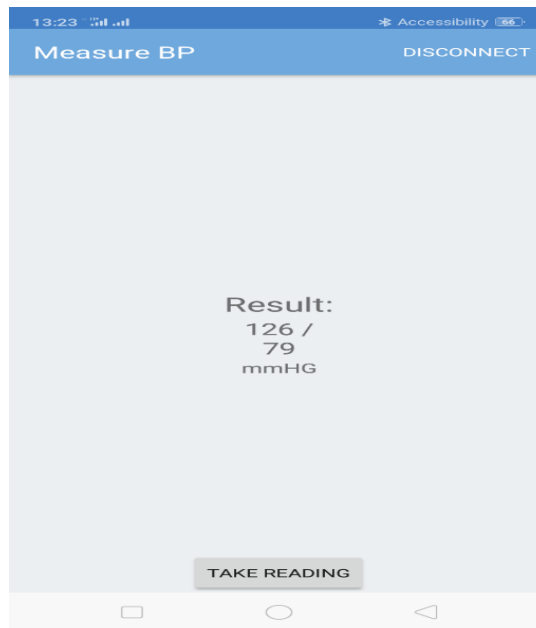
Figure 24: A Screenshot of displayed blood pressure reading

vii.   Alert Notification

An alert is sent to the healthcare provider when blood pressure is taken from the pregnant mother, as shown in Figure 25, shown below. Once the blood pressure reading is taken from the pregnant mother's side, as long as the health care provider is online, he/she can get an alert notification indicating the name and the reading of the mother. The message will keep on popping up until the health care provider accesses the notification.

Figure 25: A pop-up Alert notification received by the health care provider

In addition to alert notification pop up, when a health care provider reads some pregnant mothers' blood pressure readings and fails to read others, the pregnant mother's blood pressure interface shows the unread notification by having the readings text with the highlighted text while leaving the viewed with faded text as shown in Figure 26 below. This implies that the prototype is performing as expected, for it keeps popping up the alerts that were not yet read and even differentiating the unread with unread alerts. The use of alerts will improve the management of preeclampsia in antenatal care for the health care providers will get real-time BP readings from pregnant mothers and will be reminded by alerts if they have not accessed the BP readings.

Figure 26: List of viewed and not viewed blood pressures readings

4.3.3 Pilot Testing of the Prototype

The system requirements were refined on an ongoing basis using feedback from the system development, deployment, and testing process. This step involved the pilot testing of the prototype. The prototype was then modified to specify the application concept. A pilot study was conducted to test the system functionality and to explore any issues surrounding preeclampsia monitoring. A target of three pregnant mothers was selected. The following is a process on how the pilot study was carried out:

i. **Pilot Procedure**

a) Engaged pregnant mothers on the willingness to participate in the pilot.

b) Perform a system demonstration to the mothers

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c) Register willing pregnant mothers to use the Preeclampsia monitoring service and guide them on how to use the system

d) Allowed them to have the smart armbands to collect BP data from their houses for at least 6 times within 24 hour period

e) Collected the data with their smartphones after the 24 hours

ii. Pilot Study Report

The pilot was carried out between 24th July 2019 and 25th July 2019. Three pregnant mothers who had a gestation period of above 20 weeks were used in the study. The following were screenshots for the collected data.
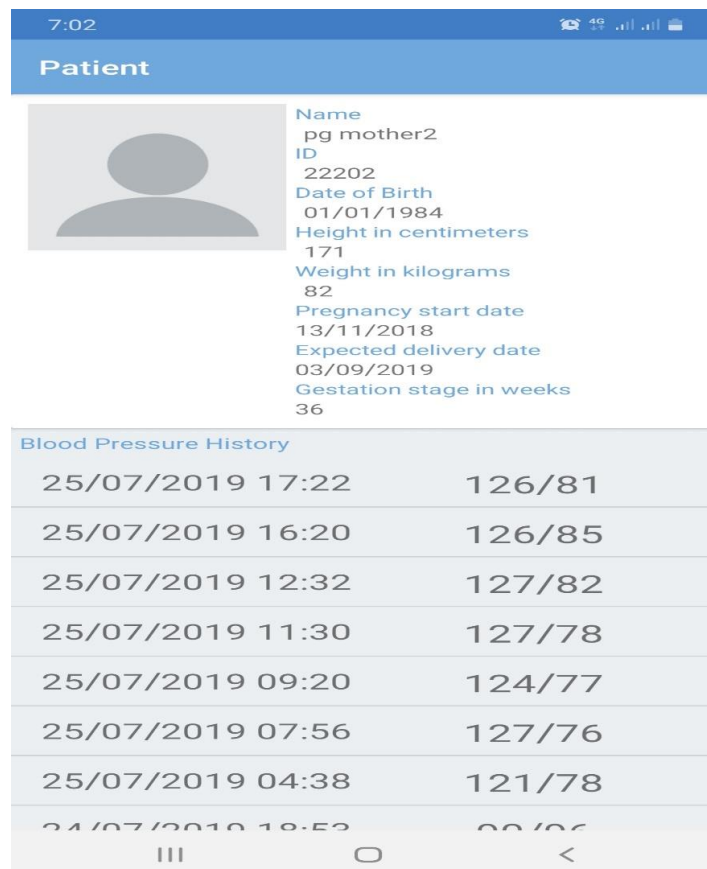
Figure 27: Pregnant mother View History

Figure 27 above shows the history of one of the mothers involved in the pilot study. Her details, date, time, and BP readings are shown on the interface.

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The health care provider can view the details of the pregnant mother assigned and also remove the mother from the list as depicted in Figure 28 shown below
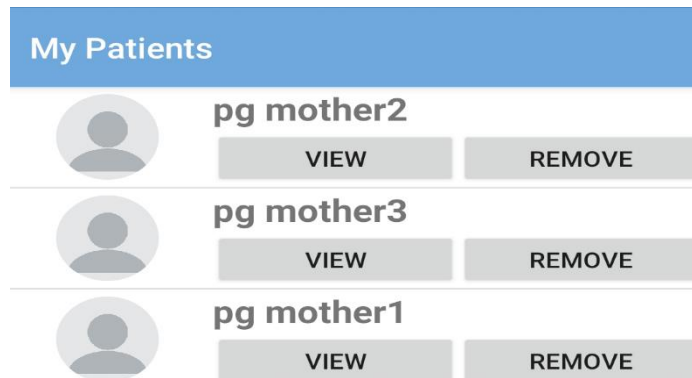
Figure 28: View Pregnant mother details

The other specific details that were collected during the pilot study are in Table 4 shown below.

Table 4: Pilot study BP Monitor details

S/N	Username	Date & Time	Systole	Diastole
1	pg mother1	24/07/2019 19:04:39	104	97
2	pg mother1	24/07/2019 20:17:13	127	83
3	pg mother1	25/07/2019 08:13:23	111	93
4	pg mother1	25/07/2019 09:23:18	79	93
5	pg mother1	25/07/2019 11:27:23	121	85
6	pg mother1	25/07/2019 16:28:25	0	0
7	pg mother1	25/07/2019 16:30:38	128	79
8	pg mother1	25/07/2019 17:16:20	127	77
9	pg mother2	24/07/2019 18:53:14	90	96
10	pg mother2	25/07/2019 04:38:11	121	78
11	pg mother2	25/07/2019 07:56:03	127	76
12	pg mother2	25/07/2019 09:20:07	124	77

13	pg mother2	25/07/2019 11:30:53	127	78
14	pg mother2	25/07/2019 12:32:19	127	82
15	pg mother2	25/07/2019 16:20:23	126	85
16	pg mother2	25/07/2019 17:22:27	126	81
17	pg mother3	24/07/2019 18:50:02	99	98
18	pg mother3	25/07/2019 08:17:50	99	97
19	pg mother3	25/07/2019 09:27:20	0	0
20	pg mother3	25/07/2019 09:29:04	0	0
21	pg mother3	25/07/2019 09:31:18	89	98
22	pg mother3	25/07/2019 11:01:46	124	81
23	pg mother3	25/07/2019 12:35:53	123	75
24	pg mother3	25/07/2019 15:26:01	121	83
25	pg mother3	25/07/2019 16:34:00	118	82
26	pg mother3	25/07/2019 17:12:26	124	84

Twenty-six (26) BP readings were taken from three pregnant mothers in 24 hours. This was a voluntary exercise where the pregnant mothers had more than a 20 week gestation period.

4.3.4   Refining Prototype

The refinement of the prototype is the fifth step that involved redesigning the blueprint, which aimed at creating a high-end prototype. After it was found out that the prototype worked as expected in some adjustments were made. The interface boundaries between the BP readings were adjusted which only affected the interface design on readability. The system functionality worked as expected. With the screen designs completed and implemented, the actual application idea was complete, the alert notification was also implemented, and the IoT prototype was implemented.

4.3.5 Repeat Step 2 to 5

This step involved testing the full design once more and collecting as much feedback as possible from a variety of users. The new ideas from users and comments were used to refine the application. A consistent look and feel of the layout were assured. Human interaction design was considered in this section to help in making the customer understand the terms used in the interface. The layout was made to fit the smart phone's screen. A quick design, building prototype, customer evaluation, and refining prototype steps were repeated to make the actual system function as expected.

4.3.6 Engineer Product

Once the application was found to be satisfactory, a final version of the prototype was completed, installed in smartphones, and tested for functionality in a live environment where 50 pregnant mothers of 20 weeks gestation period and above were selected in Embu level 5 hospital and Thika level 5 hospital.

The following subsections describes the screenshots that were captured to show that the prototype was used to produce desired results in reading blood pressure, storing values, analyzing, and sending alert notification.

i. Pregnant mother as a user

With the help of Bluetooth connection, once the F1 smart armband is connected to a mobile application then, a pregnant mother can take a BP reading. This is made possible when the smart armband is fixed at hand by clicking "take a reading" icon from the BP monitor app. The data is then displayed on the mobile application interface. The mother can also access the history of readings of blood pressure measurements taken, indicating the date taken, time taken, and the reading both systolic and diastolic.

Besides, she can click on manage the device icon to view the name of the device as well as connect the device to Bluetooth. The pregnant mother can also view the health care provider details, add family caregiver, and view the details. These functionalities are demonstrated in figure 29 shown below, which was captured during prototype testing. The details of the pregnant mother are also displayed.
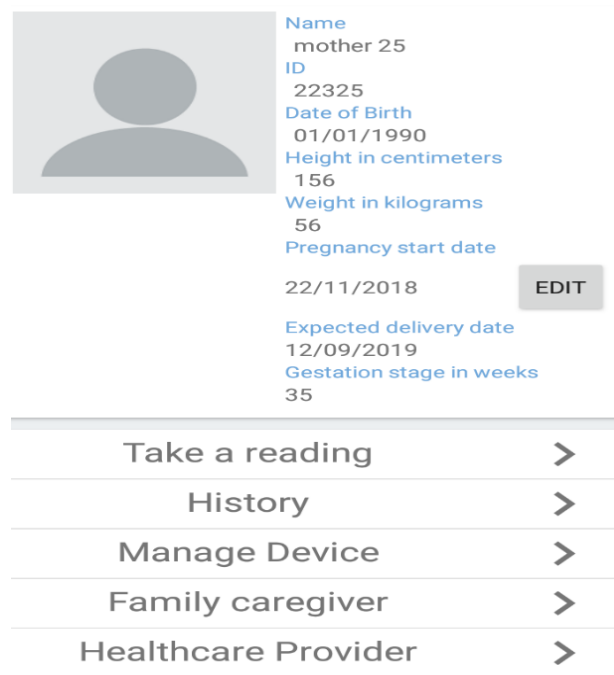
Figure 29: Pregnant mother BP Monitor App Interface

The pregnant mother can also view her history by clicking History Icon as well as viewing Caregivers by clicking the icon. For the pregnant mother, named mother 25, Figure 30 is what she could view for health care provider by clicking healthcare Provider and Figure 31 shows what she could view as history.
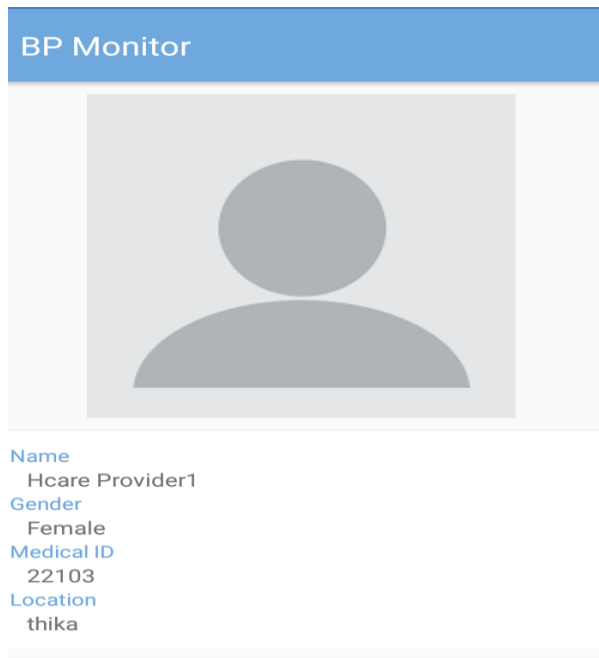
Figure 30: View health care provider screenshot

Figure 31: View history screenshot

The pregnant mother is the one who adds family caregivers to the circle. When she clicks an icon "Family Caregiver" she view the list of family caregivers who she can connect to as depicted in Figure 32 shown below.

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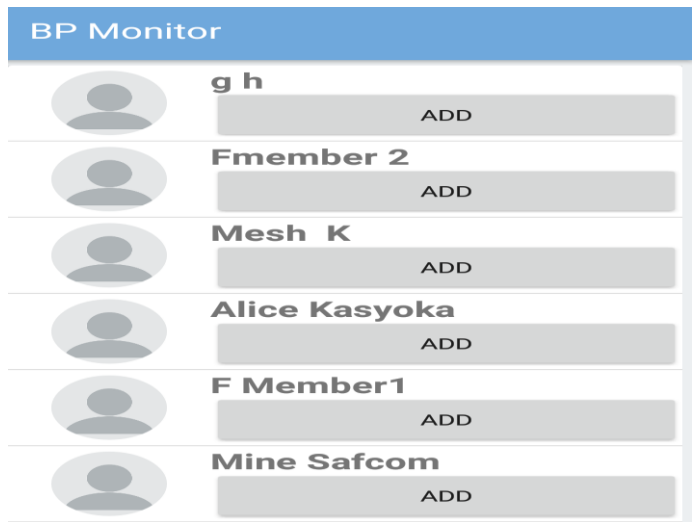
Figure 32: List of registered family caregivers

viii.   Family caregiver as a user

Once the family caregiver has been added to the application by the pregnant mother, there are several functions that he/she can perform which include: Pregnant mothers; where the family caregiver can view all pregnant mothers he/she is connected to. Alerts; which allow family caregiver to view any sent alert when the patient's blood pressure is taken. Figure 33 is a screen shot for family caregiver interface showing the name, gender, icon to click in order to view connected pregnant mothers, and icon to click in order to view alerts.

Figure 33: Family caregiver interface profile

The figure 34 shown below shows a screenshot of a family caregiver named Fmember 2 with the list of some pregnant mothers who added her to be their family caregiver.
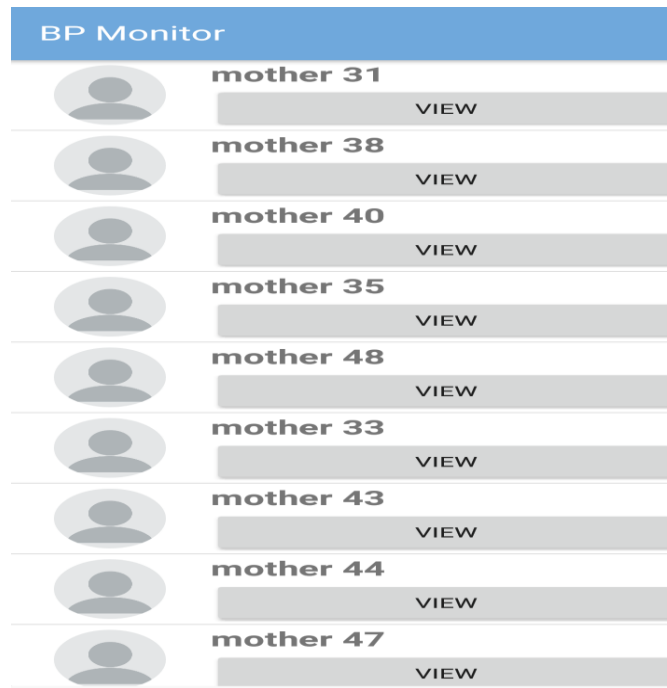
Figure 34: View Mother Details interface

The family caregiver can also receive an alert when the blood pressure is taken from the pregnant mother as shown in the Figure 35 shown below. Once the blood pressure reading is taken from the pregnant mother's side, as long as the family caregiver is online, he/she can get an alert notification indicating the name and the reading of the mother. The message will keep on popping up until the family caregiver accesses the notification.
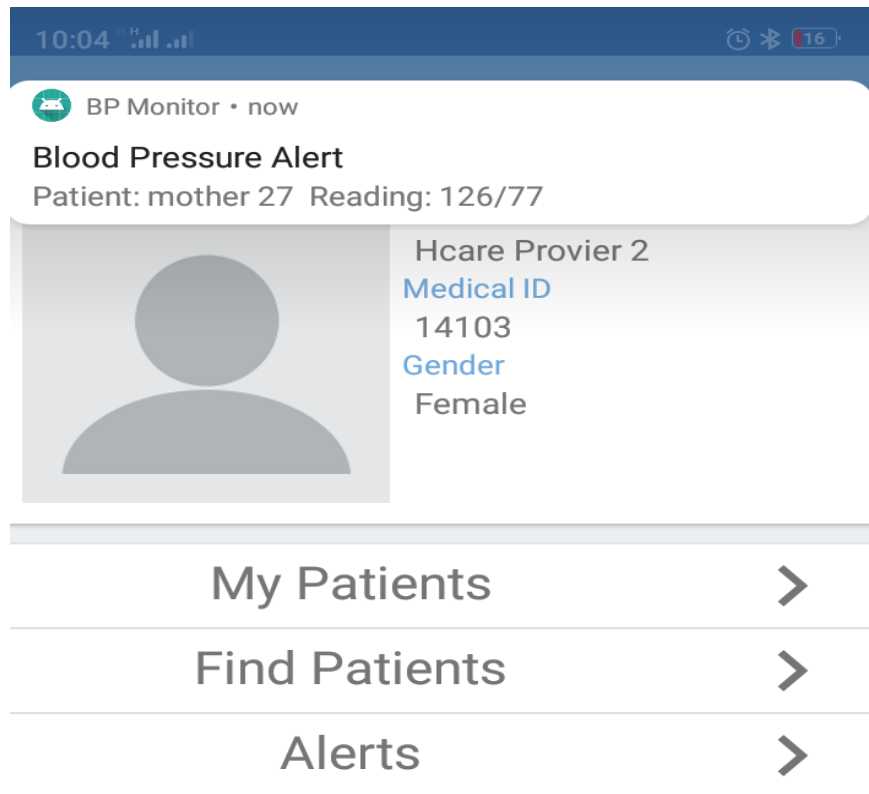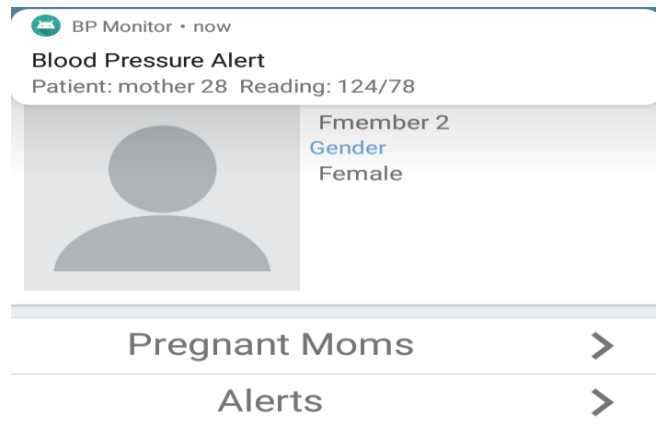
Figure 35: A pop up Alert notification received by family caregiver

In addition to alert notification pop up, when a family caregiver reads some pregnant mothers' blood pressure readings and fails to read others, the pregnant mother's blood pressure interface shows the unread notification by having the readings text with highlighted text while leaving the viewed with faded text as shown in Figure 36 below. The system keeps on popping up the alerts that were not yet read and even differentiating the unread with unread alerts.

Figure 36: List of blood pressures readings not viewed by family caregiver 1

In addition, the family caregiver can view the history of the pregnant mother to see how the blood pressure readings are fluctuating. This is depicted in Figure 37 shown below.
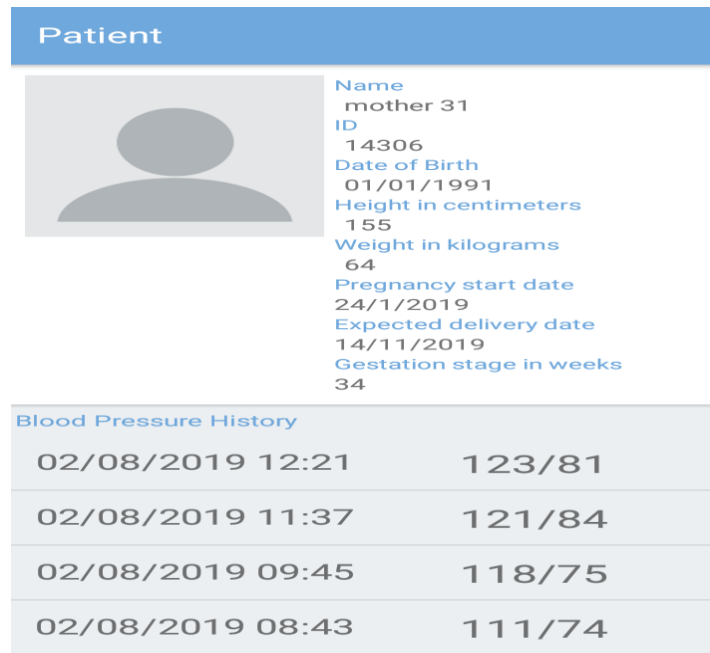
Figure 37: View pregnant mother's history by family caregiver

In the above figure, the family caregiver named FMember 1 accessed pregnant other's history named as Mother 31 as well as her other details.

ix.   Health care Provider as a user

Once the health care Provider has registered to the application, there are several functions that he/she can perform which include: Finding the patient; where the application displays the pregnant mothers who are registered and those are not attached to a specific health care providers. My patients; where the health care Provider can view all pregnant mothers he/she is connected to and can also remove them from the list. Alerts; which allow health care Provider to view any sent alert when the patient's blood pressure is taken. Figure 38 is a screen shot for health care provider in Thika Level 5 hospital while figure 39 is a screenshot for health care provider at Embu level 5 hospital.

Medical ID is a unique identification that has four digits; the first two digits are county code and last two digits are serial numbers.
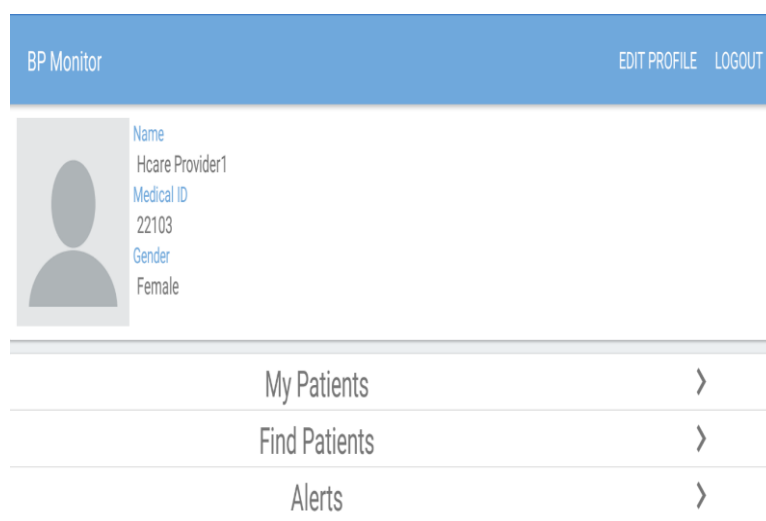
Figure 38: Health care Provider at Thika level 5 hospital
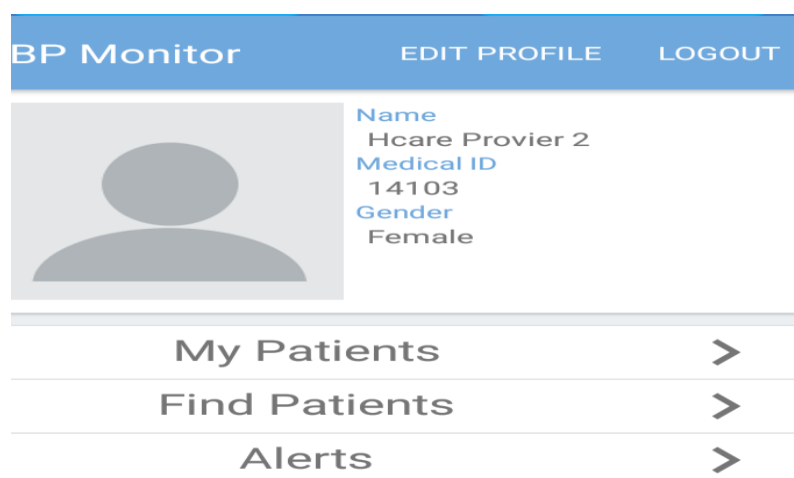
Figure 39: Health care Provider at Embu level 5 hospital

x.   **Pregnant Mother's Search**

The system will allow registered health care provider to search for pregnant mothers who are not yet connected/linked to health care provider for they will be receiving updates on blood pressure readings. All details for connected pregnant mothers will be

displayed on the health care provider's mobile application interface. The health care provider can click on "Find patients" on the app to search pregnant mothers who are not linked to any health care provider and are online. The healthcare provider can also view the details of the pregnant mother and also remove her from the list as shown in Figure 40 below.
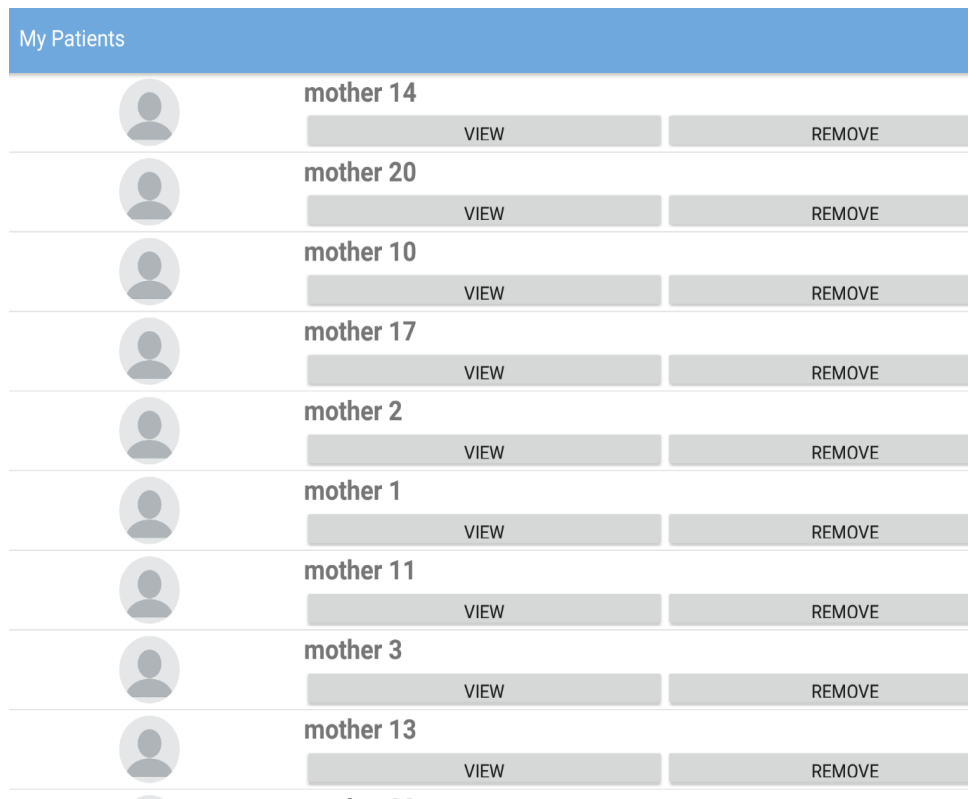
Figure 40: View Details for pregnant mothers

4.3.7 Discussion

This section presented a discussion on the development of IoT based prototype using rapid prototyping approach. The IoT based system prototype for preeclampsia monitoring was designed, implemented and tested successfully. After functional decomposition of IoT based model, the prototype was then developed following the rapid prototyping approach. During the implementation, a pilot prototype was developed and the actual testing was done in three pregnant mothers. The full IoT based

system was later developed and then tested in two level 5 hospitals; Embu level 5 and Thika level 5 hospitals with voluntary participation of 50 pregnant mothers who had over 20 week gestation period. The screen shots were described in this section to show the system functionalities worked as expected. The results from the system test showed that it is certainly feasible to get real time data on blood pressure readings from pregnant mothers by both health care provider and family members without the mother accessing hospitals.

With the advancement and rapid development of mobile application integraed in IoT technology, the remote patient monitoring are safer and more effective where decongestion, geographic, and mobility issues are well addressed (Hemavathy et al., 2014). This was achieved since the health care provider and family caregiver received real time blood pressure readings of the mother despite their physical distance.

4.4 Evaluation of the performance of the proposed Internet of Things based model for preeclampsia monitoring in antenatal care

4.4.1 Introduction

This section presents results of the study in analysis of data and also presents a discussion of the results of the study emanating from the research data.

4.4.2 Demographic Information

The study was carried out in two county level five hospitals that is; Thika level five hospital in Kiambu County and Embu level 5 hospital in Embu County. Whereas, the sample size formula computed a minimum of 41 pregnant mothers, in the study, 50

pregnant mothers were selected which indicated more data was collected for evaluation. The results obtained in evaluation of the system are presented in Table 5 shown below:

Table 5: Study areas

County	Hospital Name	Frequency	Percent (%)
Kiambu	Thika Level 5	25	50.0
Embu	Embu Level 5	25	50.0

A total of 50 participants were used in the research study. In Thika Level 5 hospital, 25 respondents were used to carry out the study representing 50% while Embu level 5 hospital 25 respondents were used representing 50% of the entire population. The pregnant mothers who are respondents were selected from health reproductive unit who came for monthly Ante natal care clinic.

4.4.3 Performance Metrics

After the IoT based prototype implementation of preeclampsia monitoring, an evaluation was conducted to confirm that the prototype performed as expected to satisfy the user's need, which is preeclampsia monitoring.

The performance of the application was monitored in real-time using the performance metrics. The results were then collected from the mobile application, cloud database, and electronic BP system used in the hospitals to measure the performance of the IoT model.

The performance metrics used for the study are analyzed as follows:

a) Consistency

System consistency was measured by taking two BP readings from the same pregnant mother within the same sitting to see the level of variation between the readings. The data taken is shown in Table 6 shown below.

Table 6: Consistency data from cloud database

Username	Date for sample 1	Systole, A1	Diastole, A1	date for sample 2	Systole,B1	Diastole,B1
Test 1	01/08/2019 11:13:27	124	86	01/08/2019 11:18:56	125	79
Test 2	02/08/2019 14:12:35	122	83	02/08/2019 14:14:24	117	83
Test 3	02/08/2019 17:18:18	114	71	02/08/2019 17:21:03	119	72
Test 4	02/08/2019 15:45:23	123	84	02/08/2019 15:47:24	126	78
Test 5	20/09/2019 20:52:40	127	78	20/09/2019 20:55:46	128	83
Test 6	31/07/2019 18:33:01	124	83	31/07/2019 18:33:01	127	79
Test 7	02/08/2019 18:09:23	126	81	02/08/2019 18:11:22	121	84
Test 8	02/08/2019 14:58:18	120	72	02/08/2019 16:00:12	123	72
Test 9	02/08/2019 16:42:06	120	76	02/08/2019 16:44:38	125	76
Test 10	02/08/2019 17:52:24	127	84	02/08/2019 17:54:17	123	81
Test 11	02/08/2019 16:58:54	127	78	02/08/2019 16:59:37	124	73
Test 12	31/07/2019 20:09:29	127	77	31/07/2019 20:11:33	127	82
Test 13	01/08/2019 07:55:09	93	93	01/08/2019 07:57:12	96	97
Test 14	31/07/2019 22:39:59	122	79	31/07/2019 22:41:59	127	78
Test 15	01/08/2019 15:42:28	124	84	01/08/2019 15:44:58	128	83

The sample test results are depicted in Table 7 shown below.

Table 7: Consistency performance Test

Pair		N	Mean	Correlation	Sig.	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
						Lower	Upper			
Pair 1	test1systole - test2systole	15	-1.067	.906	.000	-3.090	.957	-1.131	14	.277
Pair 2	test1diastole - test2diastole	15	.600	.793	.000	-1.532	2.732	.603	14	.556

It was found out that the blood pressure systole reading for test 1 and test 2 using the same Smart armband device and the mother sitting in same position were strongly and positively correlated (r=0. .906, p<0.000). Also the diastole reading for test 1 and test 2 using the same Smart armband device and the mother sitting in same position were strongly and positively correlated (r=0.793, p<0.000). This implies that both the blood pressure measurements collected was consistent that was taken immediately after the other.

On systole reading for test 1 and test 2 using the same Smart armband devices and mother sitting in the same position, there was no significant average difference between the two readings (t_{14}= -1.131, p<0.277). On diastole reading for test 1 and test 2 using the same Smart armband devices and mother sitting in the same position, there was no significant average difference between the two readings (t_{14}=0.603, p<0.556). This implies that the two readings gave almost the same readings which seemed logical.

On average, test 1 systole readings was less than test 2 systole by 1.067 readings (95% CI [-3.090, 0.957]. In addition, test 1 diastole readings was more than test 2 diastole by 0.600 readings (95% CI [-1.532, 2.732]. The difference between the tests was extremely minimal and thus the smart armband system produced consistent results. However, the readings may vary since blood pressure is recognized as a hemodynamic phenomenon which is influenced by many factors, not least being the circumstances of measurement itself no matter which device is used to measure the blood pressure (Beevers, Lip, & O'Brien, 2001).

b) **Response Rate**

Response rate performance indicator was used to compute the time difference between when the BP measurements were read and the time the message got to the health care provider/family caregiver. A sample test of 20 pregnant mothers was used to computer the response rate as presented in Table 8.

Table 8: Time difference data between pregnant mother and healthcare provider

Sample	Mother-BP Reading sent Date & Time	HCP - Reading received Date & Time	Time Difference	Systole	Diastole
mother 16	01/08/2019 08:02:00	01/08/2019 08:02:11	0:00:11	113	84
mother 16	01/08/2019 10:10:09	01/08/2019 10:10:27	0:00:18	127	78
mother 17	01/08/2019 08:04:10	01/08/2019 08:04:13	0:00:00	121	84
mother 17	01/08/2019 10:12:47	01/08/2019 10:12:56	0:00:09	126	82
mother 17	01/08/2019 15:30:10	01/08/2019 15:30:22	0:00:12	127	83
mother 18	01/08/2019 14:50:03	01/08/2019 14:50:17	0:00:14	122	86
mother 18	01/08/2019 15:42:28	01/08/2019 15:42:32	0:00:04	124	84
mother 18	01/08/2019 17:50:58	01/08/2019 17:51:02	0:00:04	126	82
mother 19	01/08/2019 14:52:17	01/08/2019 14:52:27	0:00:10	125	86
mother 19	01/08/2019 15:45:01	01/08/2019 15:45:23	0:00:22	120	87
mother 19	01/08/2019 17:04:09	01/08/2019 17:04:23	0:00:14	0	0
mother 20	01/08/2019 14:58:14	01/08/2019 14:58:31	0:00:17	113	75
mother 20	01/08/2019 15:47:53	01/08/2019 15:48:03	0:00:10	127	80
mother 20	01/08/2019 17:10:18	01/08/2019 17:10:28	0:00:10	128	75
mother 20	01/08/2019 18:25:43	01/08/2019 18:25:56	0:00:13	124	86
mother 21	01/08/2019 15:00:33	01/08/2019 15:00:42	0:00:09	125	75
mother 26	02/08/2019 10:54:03	02/08/2019 10:54:24	0:00:21	109	91
mother 26	02/08/2019 12:38:55	02/08/2019 12:39:08	0:00:13	127	80
mother 26	02/08/2019 10:54:03	02/08/2019 10:54:22	0:00:19	109	91
mother 27	02/08/2019 08:25:03	02/08/2019 08:25:18	0:00:15	0	0

Table 9: Descriptive Statistics for Response Time

	N	Minimum	Maximum	Mean	Std. Deviation
Time difference	20	0:00:03	0:00:22	0:00:12	0:00:05
Valid N (listwise)					

It was found out that the minimum time taken for the blood pressure to reach the health care provider was 3 seconds while the maximum time taken was 22 seconds. The mean for the 20 samples taken was 12 seconds. This implies that on average, the transfer of the BP measurements from the smart armband to the smartphone takes less than a minute. This shows the response rate of the device is high and can be used to measure blood pressure since it produces real time data without prolonged delay.

c) **Accuracy**

System accuracy was used to test comparison between the BP readings from the same pregnant mother using the proposed IoT system and those obtained from the electronic hospital device (Omron System).

Table 10 shown below presents the data collected from both the F1 smart arm band device and Omron System. A total of 21 pregnant mothers were used to collect data from both systems in order to test accuracy.

Table 10: Accuracy data from cloud database

TEST NAME	date/time	OMRON SYSTEM		SMART ARM BAND	
		Systole	Diastole	Systole	Diastole
Test 1	31-07-19 15:09	129	75	126	76
Test 2	01-08-19 8:58	89	96	92	96
Test 3	01-08-19 9:28	127	74	120	72
Test 4	01-08-19 15:47	124	81	127	80
Test 5	02-08-19 14:22	115	86	123	88
Test 6	02-08-19 15:50	125	81	126	76
Test 7	08-08-19 14:22	124	84	127	81
Test 8	08-08-19 14:24	126	76	125	71
Test 9	08-08-19 14:26	119	90	114	91
Test 10	08-08-19 14:29	126	88	123	85

Test 11	08-08-19 14:31	123	80	127	77
Test 12	20-09-19 20:17	125	78	128	82
Test 13	20-09-19 20:20	122	84	123	78
Test 14	20-09-19 20:26	126	80	123	77
Test 15	20-09-19 20:35	126	78	124	75
Test 16	20-09-19 20:37	121	78	121	80
Test 17	20-09-19 20:44	125	78	128	76
Test 18	20-09-19 20:49	121	81	124	83
Test 19	20-09-19 20:52	125	78	127	78
Test 20	20-09-19 20:55	125	81	128	83
Test 21	20-09-19 20:59	119	83	122	85

The data analyzed for Paired sample T-Test is shown in Table 11 below:

Table 11: Accuracy paired sample data

Pair			Paired Differences					T	df	Sig. (2-tailed)
		N	Mean	Correlation	Sig.	95% Confidence Interval of the Difference				
						Lower	Upper			
Pair 1	Manual systole – smartband systole	21	-.762	.903	.000	-2.377	.853	-.984	20	.337
Pair 2	Manual diastole – smartband diastole	21	.952	.889	.000	-.331	2.236	1.548	20	.137

It was found out that the blood pressure systole reading for Manual and Smart armband devices were strongly and positively correlated (r=0. .903, p<0.000). Also the diastole reading for Manual and Smart armband devices were strongly and positively correlated (r=0.889, p<0.000). This implies that both Blood pressure measurements for the two devices was logical and consistent. The readings were related and showed to be accuracy with the manual system being used as the control device since it is used in hospitals.

On systole reading for Manual and Smart armband devices, there was no significant average difference between the two readings (t_{20}= -0.984, p<0.337). On diastole reading for Manual and Smart armband devices, there was no significant average difference between the two readings (t_{20}=1.548, p<0.137). This implies that the two devices gave almost the same readings which seemed logical.

On average, the manual systole readings was less than smart band systole by 0.762 readings (95% CI [-2.377, 0.853]. in addition, the manual diastole readings was more than smart band systole by 0. 952 readings (95% CI [-0.331, 2.236]. the difference was extremely minimal and thus the smart armband system is also accurate when compared to the manual device.

d) Reliability

System reliability performance indicator was used to compute the percentage error rate produced during BP readings. A total of 218 readings were taken from 50 pregnant mothers. Out of the 218 readings, 12 readings showed zero readings. This shows that the error rate was 5.5% and the BP measurements that had a logical readings showed 94.5% as depicted in Table 12 shown below. This implied that the smart arm band was reliable with the minimal error rate percentage which could have been caused by external factors such as disconnecting of smartphone from the Internet.

Table 12: Reliability performance indicator

Value Number	Frequency	Percent (%)
Value with zero	12	5.5
Value greater than zero	206	94.5
Total	218	100.0

e) Output

Output is a performance indicator that showed the system produced a notification to family member, doctor, and pregnant mother when BP is above normal. All the 218 readings did not exceed normal though after readings from the pregnant mother, all the 218 readings were sent to the allocated health care providers and allocated family caregivers as presented in Table 13 shown below. This implies that the system produced the required output and thus operated as required with the aim of sending readings to both users.

Table 13: Output performance indicator

Notification	Frequency	Percent (%)
Health care provider	218	100.0
Family Care giver	218	100.0

4.4.4 Discussion

This section was used to evaluate performance of the IoT based model for preeclampsia monitoring in antenatal care. This is a vital activity as performances influence the success or failure of any information system (Balaban et al., 2006). In the evaluation, five performance metrics were used, which included: consistency, response rate, accuracy, reliability, and output. The study was conducted in Embu level 5 and Thika level 5 hospitals, where 50 pregnant mothers were involved in carrying out the study.

The F1 smart armband resulted in being consistent, whereby the two readings were taken from the same mother sitting in the same position. The difference between the tests was found to be extremely minimal; thus, the smart armband system produced consistent results. The device's response rate was found to be high. The average mean

for the time the data was taken from the band and the time it was received by the provider was found to be 12 seconds. Thus, there was no prolonged delay in the BP measurements.

The device was also found out to be accurate when compared to the Omron System used in the two hospitals. The BP measurements for the two devices were related and showed to be accurate. The manual system (Omron System) was used as the control device since it is used in hospitals. Besides, the F1 smart armband was found to be reliable with a minimal error rate percentage of 5.5%, which could have been caused by external factors such as the disconnecting of smartphones from the Internet. The smart armband produced the expected output where all the collected BP readings from the pregnant mothers, were as well displayed to the health care providers and family caregivers. The performance metrics showed that the F1 smart armband could be used in hospitals to measure blood pressure. The BP data can be shared with several health care providers and family caregivers without the challenge of proximity and data delay/loss challenges.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter presents a summary of the study findings, conclusions, and recommendations made from the findings of the study. The chapter has also presented suggestions for further studies.

5.1 Conclusions

The basic premise upon which this study was based on, is the lack of timely blood pressure data about pregnant mother by the health care provider and family caregivers. The study aimed at developing an Internet of Things based model for preeclampsia monitoring in antenatal care. The developed Internet of Things based prototype comprised of a BP monitor mobile application and cloud database that was integrated to help health care providers and family caregivers get an alert notification when blood pressure measurements are taken from the pregnant mother. This study also focused at developing an Internet of Things system that would perform as expected to fit in Kenyan structure. This study had four objectives that were achieved using different methodologies.

5.1.1 Identification of suitable smart arm band for blood pressure measuring

This objective sought to identify the suitable smart armband for preeclampsia monitoring in antenatal care. This study focused on exploratory approach where data

was retrieved from the specifications in device user guides. The objective involved review of three smart armband devices, study findings, and discussion of the three devices which were chosen using several criteria to help in development of Internet of Things based model for preeclampsia monitoring in Kenya. Four properties were identified as functionality, hardware, software, and affordability and led to ten sub properties: Bluetooth technology, waterproof, Blood Pressure measurement function, stand by after full charge of the battery, user operation, language, and material for the case, standards, alert messaging, and price in the market.

F1 smart armband had 8 properties rating excellent with a score of 8 out of 10. Both Huawei Band and Digicare smart armbands rated 6 properties excellent with scores of 6 out of 10. Therefore, the suitable device based on the categories was found to be F1 smart armband device since it had a capability to display blood pressure for both systolic and diastolic readings in the interface which is similar to the electronic blood pressure devices (Omron System) used in the hospitals unlike the other two that displayed systolic readings only. F1 smart armband has IPV67 waterproof material which is more suitable than 5 ATM material for the device can stay in water for 30 minutes used by pregnant mothers who may use water for longer period. Bluetooth Technology was also a key aspect and F1 smart armband has the latest Bluetooth 4.0 which connects smart devices in fast transmission of data.

In addition, the device made using Silicon +Pc material for protection from sweat, other greasy liquids, and also it is easy to sterilize the material. The device uses single touch operation that makes it to be small in size hence portable. F1 smart armband has both English and Chinese Language where English is the national language while Chinese is an added advantage in case of modification, the manufacturer can understand the

functionalities with ease. F1 smart armband has open source standards which allows software to be freely used, modified, and shared by the user. The purchase cost for F1 smart arm band was Kshs. 6,999 which is economical. The F1 smart armband could last for 7 days in use despite the documentation that indicated its battery charge lasts for 25 days which is very beneficial. The challenge with the device was that, the wearfit app developed for F1 smart armband does not have an alert messaging parameter which allows the BP readings to be sent to heath care providers and family caregivers.

The analysis of suitable smart armband devices has proved that, a huge number of smart armband cannot display data on themselves without the help of smartphones that act as transceivers to receive and transmit data in the cloud to fit as Internet of Things based systems. In addition, mobile phone storage to store and display the results from the cloud should be considered as well as the operating system versions.

For smartphones to act as transceivers they must possess Bluetooth Technology 4 and above to ensure effective connection between the smartphone and the smart armband. The cost of the smart armband that has Blood pressure sensors is high due to its sensor technology. The blood pressure monitoring applications are readily available for free in online stores such as Google Play Store but fit a specific device. Most of these applications are generally used for fitness tracking and for self-management.

At the moment, the market for smart armband devices is growing rapidly, which is now driving further development of the Internet of Things based systems to deliver the features and attributes demanded by consumers.

5.1.2 Development of Internet of Things based model for preeclampsia monitoring in antenatal care

This objective sought to identify a suitable process that was followed in the development of the final Internet of Things based model for preeclampsia monitoring in Antenatal Care. In the study, functional decomposition approach was used in achieving the system functionalities. The process involved the definition of system objective that was retrieved from statement of the problem. Specific system functionality were also identified as user authentication, user registration and deregistration, pregnant mother's search, blood pressure reading, and alert notification. The IoT system incorporated six main system components which include: users, F1 smart armband, pregnant mother's smartphone, health care providers and family caregiver's smart phone, cloud database systems, and interface between components. Moreover, the wireless communication that enabled interaction between system components was also identified as Bluetooth Technology, GRPS/3G/4G technologies, and the interface that brought components to communicate was Application Programming Interface protocols.

System components were identified to help in aligning the model and displaying the interactions between the components. Bluetooth technology and API were used in acquiring signal data and receiving blood pressure information from things that consumers are interested in to the world through the Internet. This system enables communication with intelligent devices. Users who are health care providers and family care givers can remotely access blood pressure details for pregnant mothers using their smart mobile phones. This Internet of Things based model can be applied in developing intelligent systems that are used in health care sector.

5.1.3 Implementation of the proposed Internet of Things based model for preeclampsia monitoring in antenatal care

The objective sought to implement the proposed Internet of Things based model for preeclampsia monitoring in antenatal care which adopted rapid prototyping approach. In this objective Blood Pressure Monitoring Mobile application and configuration with smart wrist band in preeclampsia monitoring was undertaken. The functionality was implemented using Java Programming Language using Android Studio and was integrated with Firebase database which is a Google open source software that stores real time data. During the implementation, a pilot prototype was developed and the actual system testing was done with three pregnant mothers. The full IoT based system was later developed and then tested in two level 5 hospitals; Embu level 5 and Thika level 5 hospitals with voluntary participation of 50 pregnant mothers who had over 20 week gestation period. The screen shots were processed and described in order to show the system functionalities worked as expected.

The developed IoT model provided an innovative way to develop the mobile application and provided a way of interaction between the intelligent devices. In addition, the model provided domain concepts and their representation in a graphical way to ease the development complexity and allow non-developers, who were testers of the prototype to actively participate in the implementation of the blood pressure mobile application.

5.1.4 Evaluation of the performance of the proposed Internet of Things based model for preeclampsia monitoring in antenatal care

The fourth objective sought to evaluate the performance of the proposed Internet of Things based model for preeclampsia monitoring in antenatal care. After the implementation of the Internet of Things based system, blood pressure data on the actual system was used to evaluate the system performance.

The blood pressure details collected from the pregnant mothers, data from health care providers and family caregivers was used to perform the performance evaluation. In the evaluation, five performance metrics were used which included: consistency, response rate, accuracy, reliability, and output. The F1 smart armband was found to be consistent where two readings were taken from the same mother sitting in the same position where the difference between the tests showed that the smart armband system produced consistent results. The device's response rate as found out to be high since the average mean for the time the data was read from the band and the time it reached to the provider was 12 seconds, thus there was no prolonged delay of the BP measurements. The device was also found out to be accurate when compared to the Omron System used in the two hospitals. The BP readings for the two devices were related and showed to be accurate with the manual system (Omron System) being used as the control device since it is used in hospitals. In addition, the F1 smart arm band was found to be reliable with the minimal error rate percentage of 5.5% which could have been caused by external factors such as disconnecting of smartphone from the Internet. The smart arm band produced the expected output where all the collected BP readings from the pregnant mothers, were as well displayed to the health care providers and family caregivers.

From the evaluation, it was concluded that the F1 smart armband can be used in hospitals to measure blood pressure and the data to be shared to several health care providers and family caregivers without the challenge of proximity and data delay/loss challenges.

5.2 Recommendations

The following recommendations were made based on the findings and conclusions of this study;

5.2.1 Adoption of Internet of Things based systems for preeclampsia monitoring in antenatal care

The hospitals should adopt the Internet of Things based systems based on IoT based model to help in preeclampsia monitoring during antenatal care period for pregnant mothers. This is because preeclampsia condition has caused high maternal mortality and complications to pregnant mothers.

To adopt the IoT system, the hospitals require to develop a mobile application and work in hand with Google to get a subscribed firebase database which ensure scalability for rapid growth. In addition, the developed system should be published with Google to help any other pregnant mother access and install the application with ease. This requires minimal cost for publishing. For full adoption of the IoT based system, there is also a need to create awareness to the pregnant mothers, their family caregivers, and health care providers on how to operate the application in preeclampsia monitoring in antenatal care.

5.2.2 Fabrication of suitable smart armband for preeclampsia monitoring

The F1 smart armband that was used to carry out the study was found to best fit the activity compared to the other two analyzed devices. However, during its use, the device had extra features that were not in use during the preeclampsia monitoring activity. With the removal of these additional features and retaining the features required for BP reading, then the smart armband's cost could reduce and hence become affordable for its purchase.

5.3 Recommendations for Further Study

The following suggestions were made for further research based on the findings of this study;

5.3.1 Evaluation of IoT based model on user acceptance Testing

The testing of the model was not subjected to user acceptance testing since it required extensive field study. This is vital to consider since there will be a feeling of ownership by users who have been involved in the testing. A positive user acceptance testing will lead to the commercialization of the IoT based model in preeclampsia monitoring in the health sector.

5.3.2 Implementation of SMS model for Preeclampsia monitoring

The study did not involve an SMS model that could be used to mitigate the lack of internet connectivity, especially from the client end. It could be an additional functionality where the blood pressure data could be transferred from the smart bracelet

to the smartphone and then converted to a format that can be sent via SMS to the health care provider and family caregiver at intervals.

5.3.3 Implementation of web based interface for Internet of Things based model in Preeclampsia monitoring

The study did not involve development of a web based application for IoT based model in preeclmpsia monitoring. It could be an additional functionality for data visualization and analytics to help the healthcare providers get a good access to data for pregnant mothers. The interface can also include Global Positioning System to locate the pregnant mother in case of an emergency when the health care provider is notified of abnormal blood pressure recording.

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APPENDICES

APPENDIX I: LETTER OF INTRODUCTION

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/12259/27297**

Date: **18ᵗʰ December, 2018**

Faith Mueni Musyoka
Kabarak University
Private Bag - 20157
KABARAK.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on *"Internet of things based model for preeclampsia management in antenatal care, Kenya"* I am pleased to inform you that you have been authorized to undertake research in **Embu, Kiambu and Nakuru Counties** for the period ending **18ᵗʰ December, 2019.**

You are advised to report to **the County Commissioners and the County Directors of Education, Embu, Kiambu and Nakuru Counties** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Embu County.

The County Director of Education
Embu County.

THIS IS TO CERTIFY THAT:
MS. FAITH MUENI MUSYOKA
of KABARAK UNIVERSITY, 450-90200
KITUI, has been permitted to conduct
research in *Embu , Kiambu , Nakuru*
Counties

on the topic: *INTERNET OF THINGS*
BASED MODEL FOR PREECLAMPSIA
MANAGEMENT IN ANTENATAL CARE,
KENYA

for the period ending:
18th December,2019

Permit No : NACOSTI/P/18/12259/27297
Date Of Issue : 18th December,2018
Fee Recieved :Ksh 2000

Applicant's
Signature

Director General
National Commission for Science,
Technology & Innovation

THE SCIENCE, TECHNOLOGY AND
INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science,
Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS
1. The License is valid for the proposed research, location and
   specified period.
2. The License and any rights thereunder are non-transferable.
3. The Licensee shall inform the County Governor before
   commencement of the research.
4. Excavation, filming and collection of specimens are subject to
   further necessary clearance from relevant Government Agencies.
5. The License does not give authority to transfer research materials.
6. NACOSTI may monitor and evaluate the licensed research project.
7. The Licensee shall submit one hard copy and upload a soft copy
   of their final report within one year of completion of the research.
8. NACOSTI reserves the right to modify the conditions of the
   License including cancellation without prior notice.

National Commission for Science, Technology and innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

National Commission for Science,
Technology and Innovation

RESEARCH LICENSE

Serial No.A 22495
CONDITIONS: see back page

COUNTY GOVERNMENT OF KIAMBU
DEPARTMENT OF HEALTH

Tel.Thika 067 21621/2 fax 21778
All correspondence should be addressed to
MED.SUPT.
When replying please quote

THIKA LEVEL 5 HOSPITAL
P.O. BOX 227
THIKA

Ref; NO. MOMS/TKA/ VOL. III (536)

Date: 5th February, 2019

APPROVAL TO CARRY OF RESEARCH

Principle investigator: FAITH MUENI MUSYOKA

RE: INTERNET OF THINGS BASED MODEL FOR PREECLAMPSIA MANAGEMENT IN ANTENATAL CARE, KENYA
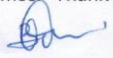
Following deliberations by Thika Level 5 hospital research committee, your proposal to carry out the above research at this facility has been approved. However, you will need to provide us with licence from NACOSTI before you can commence the data collection.

Take note that you are required to submit a copy of your research findings upon completion of the study to the hospital. It is also expected that the Ethical consideration and the research subjects confidentiality will be maintained as you have outlined in your proposal.

Any patient confidential information that you may access during your research should not be used without consent.

This letter is valid up to 30th July, 2019.

For any queries feel free to contact the committee chair through the Medical Superintendent's office. Thank you and all the best.

FOR

DR. J. WANGECHI
CHAIR TREC
THIKA LEVEL 5 HOSPITAL

0 5 FEB 2019

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APPENDIX IV: AUTHORIZATION LETTERS FROM KIAMBU AND EMBU COUNTIES

OFFICE OF THE PRESIDENT

MINISTRY OF INTERIOR AND CO-ORDINATION OF NATIONAL GOVERNMENT

COUNTY COMMISSIONER, KIAMBU

Telephone: 066-2022709
Fax: 066-2022644
E-mail: countycommkiambu@yahoo.com
When replying please quote

County Commissioner
Kiambu County
P.O. Box 32-00900
KIAMBU

Ref .No:**ED.12 (A) /1/VOL.II/66**

Date: 8th January, 2019

Faith Mueni Musyoka
Kabarak University
P. O. Box 20157
NAIROBI

RE: RESEARCH AUTHORIZATION

Reference is made to National Commission for Science, Technology and Innovation letter Ref No. **NACOSTI/P/18/12259/27297**dated **18th December, 2018.**

You have been authorized to conduct research on *"Internet of things based model for preeclampsia management in antenatal care, Kenya"* The research will be carried out in *Kiambu County for a period ending* **18th December, 2019.**

You are requested to share your findings with the County Education Office upon completion of your research.

Alice M. Nyathoko
For: County Commissioner
KIAMBU COUNTY

Cc   County Director of Education
            KIAMBU COUNTY

            National Commission for Science, Technology and Innovation
            P.O. Box 30623-00100
            NAIROBI

            All Deputy County Commissioner
            KIAMBU COUNTY

"Our Youth our Future. Join us for a Drug and Substance free County".

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REPUBLIC OF KENYA

THE PRESIDENCY

MINISTRY OF INTERIOR AND CO-ORDINATION OF NATIONAL GOVERNMENT

Telephone: Embu 0202310839
FAX 30040
Email: ccembu@gmail.com
When replying please quote

COUNTY COMMISSIONER
EMBU COUNTY
P.O.BOX 3-60100
EMBU

Ref: EBU.CC/ADM/3/37/VOL.11/ (263)

14th January, 2019

Deputy County Commissioner
EMBU WEST SUB COUNTY

RE: RESEARCH AUTHORIZATION

Please be informed that **Faith Mueni Musyoka, Research Permit No. NACOSTI/P/18/12259/27297 of Kabarak University, Kabarak** has been authorized to carry out research in your Sub County for a period ending **18th December, 2019.**

Her research is based on "**Internet of things based model for preeclampsia management in antenatal care, Kenya**"in Embu Level Five Hospital.

Kindly accord her the necessary assistance.

AMBROSE K. NJERU
FOR: COUNTY COMMISSIONER
EMBU COUNTY

Copy to.
Faith Mueni Musyoka

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MINISTRY OF EDUCATION

STATE DEPARTMENT OF EARLY LEARNING AND BASIC EDUCATION

Telegrams: "Provedu". Embu
Telephone: Embu 31711
Fax: 30956
E-mail: cde.embu@yahoo.com
When replying please quote:

OFFICE OF THE
COUNTY DIRECTOR OF EDUCATION
EMBU COUNTY
P. O. BOX 123-60100
EMBU

Ref. No: EBC/GA/32/VOL.IV/43

14th January, 2019

Faith Mueni Musyoka
Kabarak University
Private Bag - 20157
KABARAK

RE: RESEARCH AUTHORIZATION

Reference is made to NACOSTI/P/18/12259/27297 dated 18th December, 2018.

This office acknowledges receipt of your research authorization to carry out research on "**Internet of things based model for preeclampsia management in antenatal care, Kenya,**" for a period ending **18th December, 2019.**

This office has no objection and therefore wishes you success in this undertaking and requests prospective participants/respondents to accord you cooperation or support you may require.

GRACE W. MUGU
For: COUNTY DIRECTOR OF EDUCATION
EMBU COUNTY

Copy to: The Director Quality Assurance & Standards – MOEST, NAIROBI

The Secretary/CEO, NACOSTI – NAIROBI

The County Coordinator of Health, EMBU COUNTY

The Sub-County Directors of Education, EMBU COUNTY

EMBU COUNTY GOVERNMENT

OFFICE OF COUNTY DIRECTOR OF HEALTH

Mobile: +254 771 204 003/+254 707 192 924   Tel: 254 68 30686/30656
Address: P. O. Box 36 – 60100 Embu Town House Email: Info@embu.go.ke Web:www.embu.go.ke

Our Ref No: ECH/ADM/84/VOL.I/   Date: 16th January, 2019

AG C.E.O
Embu Level 5 Hospital

RE. RESEARCH AUTHORIZATION FOR FAITH MUENI MUSYOKA.

The above referenced student at Kabarak University has requested for authority from this office to conduct a research in your health facility.

Research Topic: "Internet of things based model for preeclampsia management in antenatal care, Kenya.

Duration of research - 1 year (18th December, 2018 to 18th December, 2019).

This office has no objection to her carrying out the research.

Kindly accord her the necessary cooperation and support required.

Thank you.

DR. STEPHEN KANIARU
COUNTY DIRECTOR OF HEALTH
EMBU COUNTY

- CEC – Health
- Chief Officer Health

EMBU COUNTY GOVERNMENT

OFFICE OF COUNTY DIRECTOR OF HEALTH

Mobile: +254 771 204 003/+254 707 192 924   Tel: 254 68 30686/30656
Address: P. O. Box 36 – 60100 Embu Town House Email: Info@embu.go.ke Web:www.embu.go.ke

Our Ref No: ECH/ADM/84/VOL.I/   Date: 16th January, 2019

AG C.E.O
Embu Level 5 Hospital

Received
Clerk . 23/1/19
ATT: IT department
I/C

RE. RESEARCH AUTHORIZATION FOR FAITH MUENI MUSYOKA.

The above referenced student at Kabarak University has requested for authority from this office to conduct a research in your health facility.

Research Topic: "Internet of things based model for preeclampsia management in antenatal care, Kenya.

Duration of research - 1 year (18th December, 2018 to 18th December, 2019).

This office has no objection to her carrying out the research.

Kindly accord her the necessary cooperation and support required.

Thank you.

DR. STEPHEN KANIARU
COUNTY DIRECTOR OF HEALTH
EMBU COUNTY

-   CEC – Health
-   Chief Officer Health

APPENDIX V: COMPARISON OF MANUAL AND SMART ARMBAND DEVICE

FOR BLOOD PRESSURE MEASUREMENTS

TEST NAME	date/time	SMART ARM BAND		MANUAL	
		Systole	Diastole	Systole	Diastole
Test 1	08/08/2019 14:22:06	124	84	127	81
Test 2	08/08/2019 14:24:08	126	76	125	71
Test 3	08/08/2019 14:26:58	119	90	114	91
Test 4	08/08/2019 14:29:24	126	88	123	85
Test 5	08/08/2019 14:31:34	123	80	127	77
Test 6	20/09/2019 20:17:55	125	78	128	82
Test 7	20/09/2019 20:20:17	122	84	123	78
Test 8	20/09/2019 20:26:00	126	80	123	77
Test 9	20/09/2019 20:35:23	126	78	124	75
Test 10	20/09/2019 20:37:43	121	78	121	80
Test 11	20/09/2019 20:44:53	125	78	128	76
Test 12	20/09/2019 20:49:21	121	81	124	83
Test 13	20/09/2019 20:52:40	125	78	127	78
Test 14	20/09/2019 20:55:46	125	81	128	83
Test 15	20/09/2019 20:59:01	119	83	122	85
Test 16	31/07/2019 15:09:55	129	75	126	76
Test 17	01/08/2019 08:58:49	89	96	92	96
Test 18	01/08/2019 09:28:37	127	74	120	72
Test 19	01/08/2019 15:47:53	124	81	127	80
Test 20	02/08/2019 14:22:37	115	86	123	88
Test 21	02/08/2019 15:50:33	125	81	126	76

Family username	Patient Name	Date	Systole	Diastole	Alert Viewed
fmember 2	mother 28	02/08/2019 08:29:16	123	79	No
fmember 2	mother 28	02/08/2019 09:33:03	125	83	No
fmember 2	mother 28	02/08/2019 10:48:15	127	76	No
fmember 2	mother 28	02/08/2019 12:30:19	124	78	No
fmember 2	mother 28	02/08/2019 08:29:16	123	79	No
fmember 2	mother 28	02/08/2019 09:33:03	125	83	No
fmember 2	mother 28	02/08/2019 10:48:15	127	76	No
fmember 2	mother 28	02/08/2019 12:30:19	124	78	No
fmember 2	mother 30	02/08/2019 08:45:22	117	72	No
fmember 2	mother 30	02/08/2019 09:48:25	123	72	No
fmember 2	mother 30	02/08/2019 11:35:25	126	79	No
fmember 2	mother 30	02/08/2019 12:24:12	124	76	No
fmember 2	mother 30	02/08/2019 08:45:22	117	72	No
fmember 2	mother 30	02/08/2019 09:48:25	123	72	No
fmember 2	mother 30	02/08/2019 11:35:25	126	79	No
fmember 2	mother 30	02/08/2019 12:24:12	124	76	No
fmember 2	mother 33	02/08/2019 13:34:04	126	80	No
fmember 2	mother 33	02/08/2019 14:32:08	128	76	No
fmember 2	mother 33	02/08/2019 15:28:32	119	76	No
fmember 2	mother 33	02/08/2019 17:43:28	104	94	No
fmember 2	mother 33	02/08/2019 13:34:04	126	80	No
fmember 2	mother 33	02/08/2019 14:32:08	128	76	No
fmember 2	mother 33	02/08/2019 15:28:32	119	76	No
fmember 2	mother 33	02/08/2019 17:43:28	104	94	No
fmember 2	mother 33	02/08/2019 13:34:04	126	80	No
fmember 2	mother 33	02/08/2019 14:32:08	128	76	No
fmember 2	mother 33	02/08/2019 15:28:32	119	76	No

fmember 2	mother 33	02/08/2019 17:43:28	104	94	No
fmember 2	mother 33	02/08/2019 13:34:04	126	80	No
fmember 2	mother 33	02/08/2019 14:32:08	128	76	No
fmember 2	mother 33	02/08/2019 15:28:32	119	76	No
fmember 2	mother 33	02/08/2019 17:43:28	104	94	No
fmember 2	mother 43	02/08/2019 13:38:47	122	76	No
fmember 2	mother 43	02/08/2019 14:37:57	119	74	No
fmember 2	mother 43	02/08/2019 16:32:15	120	76	No
fmember 2	mother 43	02/08/2019 17:49:30	78	98	No
fmember 2	mother 43	02/08/2019 13:38:47	122	76	No
fmember 2	mother 43	02/08/2019 14:37:57	119	74	No
fmember 2	mother 43	02/08/2019 16:32:15	120	76	No
fmember 2	mother 43	02/08/2019 17:49:30	78	98	No
fmember 2	mother 43	02/08/2019 13:38:47	122	76	No
fmember 2	mother 43	02/08/2019 14:37:57	119	74	No
fmember 2	mother 43	02/08/2019 16:32:15	120	76	No
fmember 2	mother 43	02/08/2019 17:49:30	78	98	No
fmember 2	mother 43	02/08/2019 13:38:47	122	76	No
fmember 2	mother 43	02/08/2019 14:37:57	119	74	No
fmember 2	mother 43	02/08/2019 16:32:15	120	76	No
fmember 2	mother 43	02/08/2019 17:49:30	78	98	No
fmember 2	mother 45	02/08/2019 13:41:09	119	75	No
fmember 2	mother 45	02/08/2019 14:42:32	125	79	No
fmember 2	mother 45	02/08/2019 16:37:03	126	77	No
fmember 2	mother 45	02/08/2019 17:55:13	104	94	No
fmember 2	mother 45	02/08/2019 13:41:09	119	75	No
fmember 2	mother 45	02/08/2019 14:42:32	125	79	No
fmember 2	mother 45	02/08/2019 16:37:03	126	77	No
fmember 2	mother 45	02/08/2019 17:55:13	104	94	No

fmember 2	mother 45	02/08/2019 13:41:09	119	75	No
fmember 2	mother 45	02/08/2019 14:42:32	125	79	No
fmember 2	mother 45	02/08/2019 16:37:03	126	77	No
fmember 2	mother 45	02/08/2019 17:55:13	104	94	No
fmember 2	mother 45	02/08/2019 13:41:09	119	75	No
fmember 2	mother 45	02/08/2019 14:42:32	125	79	No
fmember 2	mother 45	02/08/2019 16:37:03	126	77	No
fmember 2	mother 45	02/08/2019 17:55:13	104	94	No
fmember 2	mother 48	02/08/2019 14:27:02	94	93	No
fmember 2	mother 48	02/08/2019 15:53:22	86	93	No
fmember 2	mother 48	02/08/2019 16:44:37	126	79	No
fmember 2	mother 48	02/08/2019 18:03:40	82	95	No
fmember 2	mother 48	02/08/2019 14:27:02	94	93	No
fmember 2	mother 48	02/08/2019 15:53:22	86	93	No
fmember 2	mother 48	02/08/2019 16:44:37	126	79	No
fmember 2	mother 48	02/08/2019 18:03:40	82	95	No
fmember 2	mother 48	02/08/2019 14:27:02	94	93	No
fmember 2	mother 48	02/08/2019 15:53:22	86	93	No
fmember 2	mother 48	02/08/2019 16:44:37	126	79	No
fmember 2	mother 48	02/08/2019 18:03:40	82	95	No
fmember 2	mother 49	02/08/2019 14:58:18	120	72	No
fmember 2	mother 49	02/08/2019 17:01:12	123	84	No
fmember 2	mother 49	02/08/2019 18:06:50	127	78	No
fmember 2	mother 49	02/08/2019 19:28:02	125	77	No
fmember 2	mother 49	02/08/2019 14:58:18	120	72	No
fmember 2	mother 49	02/08/2019 17:01:12	123	84	No
fmember 2	mother 49	02/08/2019 18:06:50	127	78	No
fmember 2	mother 49	02/08/2019 19:28:02	125	77	No
fmember 2	mother 49	02/08/2019 14:58:18	120	72	No

fmember 2	mother 49	02/08/2019 17:01:12	123	84	No
fmember 2	mother 49	02/08/2019 18:06:50	127	78	No
fmember 2	mother 49	02/08/2019 19:28:02	125	77	No
fmember 2	mother 49	02/08/2019 14:58:18	120	72	No
fmember 2	mother 49	02/08/2019 17:01:12	123	84	No
fmember 2	mother 49	02/08/2019 18:06:50	127	78	No
fmember 2	mother 49	02/08/2019 19:28:02	125	77	No
fmember 2	mother 50	02/08/2019 15:00:35	117	93	No
fmember 2	mother 50	02/08/2019 17:03:31	125	80	No
fmember 2	mother 50	02/08/2019 18:09:23	126	81	No
fmember 2	mother 50	02/08/2019 19:30:22	116	90	No
fmember 2	mother 50	02/08/2019 15:00:35	117	93	No
fmember 2	mother 50	02/08/2019 17:03:31	125	80	No
fmember 2	mother 50	02/08/2019 18:09:23	126	81	No
fmember 2	mother 50	02/08/2019 19:30:22	116	90	No
fmember 2	mother 50	02/08/2019 15:00:35	117	93	No
fmember 2	mother 50	02/08/2019 17:03:31	125	80	No
fmember 2	mother 50	02/08/2019 18:09:23	126	81	No
fmember 2	mother 50	02/08/2019 19:30:22	116	90	No
fmember 2	mother 50	02/08/2019 15:00:35	117	93	No
fmember 2	mother 50	02/08/2019 17:03:31	125	80	No
fmember 2	mother 50	02/08/2019 18:09:23	126	81	No
fmember 2	mother 50	02/08/2019 19:30:22	116	90	No
fmember1	mother 2	29/07/2019 14:57:15	77	98	No
fmember1	mother 2	29/07/2019 16:03:07	89	94	No
fmember1	mother 2	29/07/2019 17:04:19	0	0	No
fmember1	mother 2	29/07/2019 17:06:14	97	95	No
fmember1	mother 2	29/07/2019 18:12:30	103	94	No
fmember1	mother 2	29/07/2019 14:57:15	77	98	No

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fmember1	mother 2	29/07/2019 16:03:07	89	94	No
fmember1	mother 2	29/07/2019 17:04:19	0	0	No
fmember1	mother 2	29/07/2019 17:06:14	97	95	No
fmember1	mother 2	29/07/2019 18:12:30	103	94	No
fmember1	mother 2	29/07/2019 14:57:15	77	98	No
fmember1	mother 2	29/07/2019 16:03:07	89	94	No
fmember1	mother 2	29/07/2019 17:04:19	0	0	No
fmember1	mother 2	29/07/2019 17:06:14	97	95	No
fmember1	mother 2	29/07/2019 18:12:30	103	94	No
fmember1	mother 2	29/07/2019 14:57:15	77	98	Yes
fmember1	mother 2	29/07/2019 16:03:07	89	94	Yes
fmember1	mother 2	29/07/2019 17:04:19	0	0	Yes
fmember1	mother 2	29/07/2019 17:06:14	97	95	Yes
fmember1	mother 2	29/07/2019 18:12:30	103	94	Yes

APPENDIX VII: TABLE FOR ALL REGISTERED USERS IN IOT BASED PROTOTYPE FOR PREECLAMPSIA MONITORING

Username	Email	First Name	Last Name	User Type	Height	Weight	Date of Birth	ID	Location	Gestation Start
fmember 2	fmember2@gmail.com	Fmember	2	Family Caregiver						
fmember1	fmember1@gmail.com	F	Member1	Family Caregiver						
hcare provider 1	hcareprovider1@gmail.com	Hcare	Provider1	Healthcare Provider					thika	
hcare provider 2	hcareprovider2@gmail.com	Hcare	Provier2	Healthcare Provider					embu	
mother 10	mother10@gmail.com	mother	10	Pregnant Mother	158	66	01/01/1988	223100	thika	25/11/2018
mother 11	mother11@gmail.com	mother	11	Pregnant Mother	161	72	01/01/1997	22311	thika	21/12/2018
mother 12	mother12@gmail.com	mother	12	Pregnant Mother	164	67	01/01/1991	22312	thika	2/12/2018
mother 13	mother13@gmail.com	mother	13	Pregnant Mother	168	89	01/01/1983	22313	thika	21/11/2018
mother 14	mother14@gmail.com	mother	14	Pregnant Mother	163	63	01/01/1988	22314	thika	9/11/2018
mother 15	mother15@gmail.com	mother	15	Pregnant Mother	165	55	01/01/1991	22315	thika	27/12/2018
mother 16	mother16@gmail.com	mother	16	Pregnant Mother	164	78	01/01/1992	22316	thika	24/1/2019
mother 17	mother17@gmail.com	mother	17	Pregnant Mother	154	49	01/01/1990	22317	thika	5/2/2019
mother 18	mother18@gmail.com	mother	18	Pregnant Mother	158	62	01/01/1992	22318	thika	2/1/2019
mother 19	mother19@gmail.com	mother	19	Pregnant Mother	159	69	01/01/1990	22319	thika	29/12/2018
mother 20	mother20@gmail.com	mother	20	Pregnant Mother	152	53	01/01/1994	22320	thika	17/1/2019

mother 21	mother21@gmail.com	mother	21	Pregnant Mother	163	73	01/01/1989	22321	thika	1/12/2018
mother 22	mother22@gmail.com	mother	22	Pregnant Mother	158	65	1/8/1996	22322	thika	7/11/2018
mother 23	mother23@gmail.com	mother	23	Pregnant Mother	158	54	01/01/1990	22323	thika	10/11/2018
mother 24	mother24@gmail.com	mother	24	Pregnant Mother	152	56	01/01/1992	22324	thika	6/12/2018
mother 25	mother25@gmail.com	mother	25	Pregnant Mother	156	56	01/01/1990	22325	thika	22/11/2018
mother 26	mother26@gmail.com	mother	26	Pregnant Mother	156	66	01/01/1990	14301	embu	2/11/2018
mother 27	mother27@gmail.com	mother	27	Pregnant Mother	164	72	01/01/1995	14302	embu	10/12/2018
mother 28	mother28@gmail.com	mother	28	Pregnant Mother	158	68	01/01/1989	14303	embu	19/11/2018
mother 29	mother29@gmail.com	mother	29	Pregnant Mother	158	62	01/01/1988	14304	embu	28/12/2018
mother 3	mother3@gmail.com	mother	3	Pregnant Mother	163	71	01/01/1988	22303	thika	8/12/2018
mother 30	mother30@gmail.com	mother	30	Pregnant Mother	167	83	01/01/1992	14305	embu	17/12/2018
mother 31	mother31@gmail.com	mother	31	Pregnant Mother	155	64	01/01/1991	14306	embu	24/1/2019
mother 32	mother32@gmail.com	mother	32	Pregnant Mother	158	64	01/01/1991	14307	embu	19/12/2018
mother 33	mother33@gmail.com	mother	33	Pregnant Mother	148	49	01/01/1990	14308	embu	20/12/2018
mother 34	mother34@gmail.com	mother	34	Pregnant Mother	157	66	01/01/1997	14309	embu	30/11/2018
mother 35	mother35@gmail.com	mother	35	Pregnant Mother	162	78	01/01/1989	14310	embu	2/1/2019

mother 36	mother36@gmail.com	mother	36	Pregnant Mother	159	66	01/01/1987	14311	embu	28/12/2018
mother 37	mother37@gmail.com	mother	37	Pregnant Mother	166	56	01/01/1988	14312	embu	9/1/2019
mother 38	mother38@gmail.com	mother	38	Pregnant Mother	148	54	01/01/1985	14313	embu	28/1/2019
mother 39	mother39@gmail.com	mother	39	Pregnant Mother	168	71	01/01/1987	14314	embu	14/2/2019
mother 4	mother4@gmail.com	mother	4	Pregnant Mother	158	56	01/01/1993	22304	thika	3/2/2019
mother 40	mother40@gmail.com	mother	40	Pregnant Mother	168	77	01/01/1982	14315	embu	11/2/2019
mother 41	mother41@gmail.com	mother	41	Pregnant Mother	170	88	01/01/1992	14316	embu	28/1/2019
mother 42	mother42@gmail.com	mother	42	Pregnant Mother	155	51	01/01/1990	14317	embu	4/3/2019
mother 43	mother43@gmail.com	mother	43	Pregnant Mother	171	67	01/01/1990	14318	embu	4/2/2019
mother 44	mother44@gmail.com	mother	44	Pregnant Mother	166	58	01/01/1994	14319	embu	14/1/2019
mother 45	mother45@gmail.com	mother	45	Pregnant Mother	155	52	01/01/1993	14320	embu	18/2/2019
mother 46	mother46@gmail.com	mother	46	Pregnant Mother	158	56	01/01/1990	14321	embu	4/3/2019
mother 47	mother47@gmail.com	mother	47	Pregnant Mother	171	67	01/01/1990	14322	embu	1/3/2019
mother 48	mother48@gmail.com	mother	48	Pregnant Mother	166	72	01/01/1994	14323	embu	4/2/2019
mother 49	mother49@gmail.com	mother	49	Pregnant Mother	159	52	01/01/1989	14324	embu	7/1/2019
mother 50	mother50@gmail.com	mother	50	Pregnant Mother	173	78	01/01/1981	14325	embu	11/2/2019

mother 6	mother6@gmail.com	mother	6	Pregnant Mother	154	49	01/01/1989	22306	thika	8/12/2018
mother 7	mother7@gmail.com	mother	7	Pregnant Mother	167	69	01/01/1992	22307	thika	30/11/2018
mother 8	mother8@gmail.com	mother	8	Pregnant Mother	160	52	01/01/1990	22308	thika	31/12/2018
mother 9	mother9@gmail.com	mother	9	Pregnant Mother	161	89	01/01/1986	22310	thika	18/1/2019
mother1	mother1@gmail.com	mother	1	Pregnant Mother	149	50	01/01/1992	22301	thika	18/2/2019
mother2	mother2@gmail.com	mother	2	Pregnant Mother	149	54	01/01/1987	22302	thika	29/12/2018
mother5	mother5@gmail.com	mother	5	Pregnant Mother	168	72	01/01/1995	22305	thika	31/12/2018

APPENDIX VI: MOBILE APPLICATION CORE SOURCE CODE

/*ALERTSACTIVITY.JAVA-the code is used to create a notification. When the BP readings exceed normal, the Pregnant mother id is noted from the firebase and a trigger is sent to the family caregiver & health care provider accounts*/

```java
package com.fmueni.bpmonitor.activities;

import android.content.Context;
import android.content.Intent;
import android.support.annotation.NonNull;
import android.support.v7.app.AppCompatActivity;
import android.os.Bundle;
import android.util.Log;
import android.view.Menu;
import android.view.View;
import android.widget.AdapterView;
import android.widget.ListView;

import com.google.firebase.auth.FirebaseAuth;
import com.google.firebase.auth.FirebaseUser;
import com.google.firebase.database.DataSnapshot;
import com.google.firebase.database.DatabaseError;
import com.google.firebase.database.DatabaseReference;
import com.google.firebase.database.FirebaseDatabase;
import com.google.firebase.database.ValueEventListener;
import com.fmueni.bpmonitor.R;
import com.fmueni.bpmonitor.models.AlertModel;
import com.fmueni.bpmonitor.models.Patient;

import java.util.ConcurrentModificationException;
import java.util.HashMap;

public class AlertsActivity extends AppCompatActivity {

    private static final String TAG = "EmailPassword";

    private FirebaseAuth mAuth;
    private FirebaseAuth.AuthStateListener mAuthListener;

    FirebaseDatabase database = FirebaseDatabase.getInstance();
    DatabaseReference userRef = database.getReference("users");

    private String userId;
    private Context context;

    //private AlertModel patient;

    private ListView listView;
    private AlertAdapter alertAdapter;
    @Override
    public void onStart() {
        super.onStart();
        mAuth.addAuthStateListener(mAuthListener);

        listView = (ListView) findViewById(R.id.listview);
        alertAdapter = new AlertAdapter(this);
        listView.setAdapter(alertAdapter);

        listView.setOnItemClickListener(new
```

```java
        AdapterView.OnItemClickListener() {
            @Override
            public void onItemClick(AdapterView<?> parent, View view,
int position, long id) {
                AlertModel alert = alertAdapter.getItem(position);


userRef.child(userId).child("alerts").child(alert.alert_id).child("vi
ewed").setValue(true);

                Intent intent = new Intent(AlertsActivity.this,
PatientMonitorActivity.class);
                intent.putExtra("patient_id", alert.patient_id);
                startActivity(intent);
                finish();
            }
        });
    }

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_alerts);

        context = getApplicationContext();

        mAuth = FirebaseAuth.getInstance();

        mAuthListener = new FirebaseAuth.AuthStateListener() {
            @Override
            public void onAuthStateChanged(@NonNull FirebaseAuth
firebaseAuth) {
                FirebaseUser user = firebaseAuth.getCurrentUser();
                if (user != null) {
                    userId = user.getUid();
                    getAlerts();
                } else {
                    Log.d(TAG, "onAuthStateChanged:signed_out");
                }

            }
        };
    }

    private void getAlerts(){

userRef.child(userId).child("alerts").addValueEventListener(new
ValueEventListener() {
            @Override
            public void onDataChange(@NonNull DataSnapshot
dataSnapshot) {
                if(dataSnapshot.exists()){
                    try{
                        HashMap<String, Object> alertMap =
(HashMap<String, Object>) dataSnapshot.getValue();
                        alertAdapter.invalidate();
                        for(String data : alertMap.keySet()){
                            HashMap<String, Object> dataMap =
(HashMap<String, Object>) alertMap.get(data);
```

```java
                                        AlertModel alert = new AlertModel();
                                        alert.alert_id = data;
                                        alert.patient_id = (String)
dataMap.remove("uid");
                                        alert.data_pushId = (String)
dataMap.remove("pushId");
                                        alert.viewed = (boolean)
dataMap.remove("viewed");

                                        getPatientData(alert);

                                    }
                            }catch (NullPointerException |
ConcurrentModificationException e){
                                    e.printStackTrace();
                            }
                    }
            }

            @Override
            public void onCancelled(@NonNull DatabaseError
databaseError) {

            }
        });
    }

    private void getPatientData(final AlertModel patient){

userRef.child(patient.patient_id).addListenerForSingleValueEvent(new
ValueEventListener() {
            @Override
            public void onDataChange(@NonNull DataSnapshot
dataSnapshot) {
                    try{
                        HashMap<String, Object> userMap =
(HashMap<String, Object>) dataSnapshot.getValue();

                            patient.fname = (String) userMap.remove("fname");
                            patient.lname = (String) userMap.remove("lname");
                            patient.dob = (String) userMap.remove("dob");
                            patient.weight = (int) (long)
userMap.remove("weight");
                            patient.height = (int) (long)
userMap.remove("height");
                            patient.description = (String)
userMap.remove("description");
                            patient.id = (String) userMap.remove("id");
                            patient.photo = (String) userMap.remove("photo");

                            HashMap<String, Object> dataMap =
(HashMap<String, Object>) userMap.remove("data");
                            HashMap<String, Object> latestDataMap =
(HashMap<String, Object>) dataMap.remove(patient.data_pushId);

                            patient.systole = (int) (long)
latestDataMap.remove("systol");
                            patient.diastole = (int) (long)
latestDataMap.remove("diastol");
```

```java
                    //String reading = systol + "/" + diastol;

                    alertAdapter.addItem(patient);

                    //String message = "Patient: " + name +
"\nReading: "+ systol + "/" + diastol;

                }catch (NullPointerException e){
                    e.printStackTrace();
                }
            }

            @Override
            public void onCancelled(@NonNull DatabaseError
databaseError) {

            }
        });
    }

    @Override
    public void onStop() {
        super.onStop();
        if (mAuthListener != null) {
            mAuth.removeAuthStateListener(mAuthListener);
        }
    }
}
```

//CAREGIVERACTIVITY.JAVA-the code is used to create an interface and keep the pregnant mother's details

```java
public class CaregiverActivity extends AppCompatActivity {

    private static final String TAG = "EmailPassword";

    private FirebaseAuth mAuth;
    private FirebaseAuth.AuthStateListener mAuthListener;

    FirebaseDatabase database = FirebaseDatabase.getInstance();
    DatabaseReference userRef = database.getReference("users");

    Menu mainMenu=null;
    private String userId;

    private Caregiver caregiver;

    private ImageView dp;
    private TextView name, id, gender;
    private ListView listView;

    private Context context;

    @Override
    public void onStart() {
        super.onStart();
        mAuth.addAuthStateListener(mAuthListener);
    }

    @Override
    protected void onCreate(Bundle savedInstanceState) {
```

```java
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_caregiver);

        context = this;
        caregiver = new Caregiver();
        name = (TextView) findViewById(R.id.name);
        id = (TextView) findViewById(R.id.id);
        gender = (TextView) findViewById(R.id.gender);
        dp = (ImageView) findViewById(R.id.profile_pic);

        listView = (ListView) findViewById(R.id.listview);
        String[] items = {"My Patients", "Find Patients", "Alerts"};
        listView.setAdapter(new GridAdapter(this, items));

        mAuth = FirebaseAuth.getInstance();

        mAuthListener = new FirebaseAuth.AuthStateListener() {
            @Override
            public void onAuthStateChanged(@NonNull FirebaseAuth
firebaseAuth) {
                FirebaseUser user = firebaseAuth.getCurrentUser();
                if (user != null) {
                    userId = user.getUid();
                    initUserData();
                } else {
                    startActivity(new Intent(CaregiverActivity.this,
LoginActivity.class));
                    finish();
                    Log.d(TAG, "onAuthStateChanged:signed_out");
                }

            }
        };

        listView.setOnItemClickListener(new
AdapterView.OnItemClickListener() {
            @Override
            public void onItemClick(AdapterView<?> parent, View view,
int position, long id) {
                Intent intent;

                switch (position){
                    case 0:
                        intent = new Intent(CaregiverActivity.this,
MyPatientsActivity.class);
                        break;
                    case 1:
                        intent = new Intent(CaregiverActivity.this,
FindPatientsActivity.class);
                        break;
                     default:
                         intent = new Intent(CaregiverActivity.this,
AlertsActivity.class);

                }

                startActivity(intent);
            }
        });
```

```java
        dp.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                Intent intent = new Intent(CaregiverActivity.this,
SettingsActivity.class);
                intent.putExtra("photo", caregiver.photo);
                startActivity(intent);
            }
        });
    }

    public void initUserData(){
        userRef.child(userId).addValueEventListener(new
ValueEventListener() {
            @Override
            public void onDataChange(DataSnapshot dataSnapshot) {
                try{
                    HashMap<String, Object> userMap =
(HashMap<String, Object>) dataSnapshot.getValue();
                    caregiver.fname = (String)
userMap.remove("fname");
                    caregiver.lname = (String)
userMap.remove("lname");
                    caregiver.gender = (String)
userMap.remove("gender");
                    caregiver.medical_id = (String)
userMap.remove("medical_id");
                    caregiver.photo = (String)
userMap.remove("photo");
                    caregiver.location = (String)
userMap.remove("location");

                    updateUI();
                }catch(NullPointerException e){
                    e.printStackTrace();
                }
            }

            @Override
            public void onCancelled(DatabaseError databaseError) {

            }
        });
    }

    private void updateUI(){
        name.setText(caregiver.fname + " " + caregiver.lname);
        id.setText(caregiver.medical_id);
        gender.setText(caregiver.gender);

        Picasso.with(this).load(caregiver.photo).into(dp);
    }

    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
        // Inflate the menu; this adds items to the action bar if it
is present.
        getMenuInflater().inflate(R.menu.menu_main, menu);
        mainMenu=menu;
        return true;
```

```java
        }

        @Override
        public boolean onKeyDown(int keyCode, KeyEvent event) {
            if (keyCode== KeyEvent.KEYCODE_MENU) {
                getMenuInflater();
                return true;
            }
            return super.onKeyDown(keyCode, event);
        }

        @Override
        public boolean onOptionsItemSelected(MenuItem item) {
            //mAuth = FirebaseAuth.getInstance();
            switch (item.getItemId()) {

                case R.id.logout:
                    mAuth.signOut();
                    return true;

                default:
                    // If we got here, the user's action was not
recognized.
                    // Invoke the superclass to handle it.
                    return super.onOptionsItemSelected(item);

            }
        }

        @Override
        public void onBackPressed() {
            super.onBackPressed();
        }

        @Override
        public void onStop() {
            super.onStop();
            if (mAuthListener != null) {
                mAuth.removeAuthStateListener(mAuthListener);
            }
        }
}
```

//MYPATIENTACTIVITY.JAVA-the code is used to add and keep record of new members

```java
public class MyPatientsActivity extends AppCompatActivity {

    private static final String TAG =
MyPatientsActivity.class.getSimpleName();
    private FirebaseAuth mAuth;
    private FirebaseAuth.AuthStateListener mAuthListener;

    FirebaseDatabase database = FirebaseDatabase.getInstance();
    DatabaseReference userRef = database.getReference("users");
    public static String userId;

    private ListView patients_list;
    private MyPatientsAdapter myPatientsAdapter;

    private Patient patient;
```

```java
    @Override
    public void onStart() {
        super.onStart();
        mAuth.addAuthStateListener(mAuthListener);
    }

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_my_patients);


        patient = new Patient();
        myPatientsAdapter = new MyPatientsAdapter(this, userRef);
        patients_list = (ListView) findViewById(R.id.patients_list);
        patients_list.setAdapter(myPatientsAdapter);



        mAuth = FirebaseAuth.getInstance();

        mAuthListener = new FirebaseAuth.AuthStateListener() {
            @Override
            public void onAuthStateChanged(@NonNull FirebaseAuth
firebaseAuth) {
                FirebaseUser user = firebaseAuth.getCurrentUser();
                if (user != null) {
                    userId = user.getUid();
                    setPatientsListener();
                } else {
                    startActivity(new Intent(MyPatientsActivity.this,
LoginActivity.class));
                    finish();
                    Log.d(TAG, "onAuthStateChanged:signed_out");
                }

            }
        };
    }

    private void setPatientsListener(){
        Query query =
userRef.orderByChild("caregiver_id").equalTo(userId);
        query.addValueEventListener(new ValueEventListener() {
            @Override
            public void onDataChange(DataSnapshot dataSnapshot) {
                if(dataSnapshot.exists()){
                    HashMap<String, Object> dataMap =
(HashMap<String, Object>) dataSnapshot.getValue();

                    //ArrayList<String> patients = new ArrayList<>();
                    myPatientsAdapter.clearList();


                    for(String user_id : dataMap.keySet()){

                        myPatientsAdapter.addItem(user_id);
                    }
                }
            }
```

```java
            @Override
            public void onCancelled(DatabaseError databaseError) {

            }
        });
    }

    @Override
    public void onStop() {
        super.onStop();
        if (mAuthListener != null) {
            mAuth.removeAuthStateListener(mAuthListener);
        }
    }
}
```

//BPMEASUREACTIVITY.JAVA-the code is used to save the new BP readings for both systole and diastole for a specific pregnant mother. it configures the Bluetooth device with the smartphone that is displaying the data

```java
public class BPMeasureActivity extends AppCompatActivity {

    private final static String TAG =
BPMeasureActivity.class.getSimpleName();

    BluetoothAdapter bluetoothAdapter;
    private int REQUEST_ENABLE_BT = 1;

    private PrefsManager prefsManager;
    private String mDeviceName;
    private String mDeviceAddress;

    private BluetoothLeService mBluetoothLeService;
    private boolean mConnected = false;
    private boolean connecting = false;
    private BluetoothGattCharacteristic mNotifyCharacteristic;

    private BluetoothAdapter mBluetoothAdapter;

    private Button btnRead;
    private TextView resultView, infoView;

    private FirebaseAuth mAuth;
    private FirebaseAuth.AuthStateListener mAuthListener;

    private LocationManager locationManager;
    private String provider;

    FirebaseDatabase database = FirebaseDatabase.getInstance();
    DatabaseReference userRef = database.getReference("users");

    private String userId;

    private final ServiceConnection mServiceConnection = new
ServiceConnection() {

        @Override
        public void onServiceConnected(ComponentName componentName,
IBinder service) {
```

```java
            mBluetoothLeService = ((BluetoothLeService.LocalBinder)
service).getService();
            if (!mBluetoothLeService.initialize()) {
                Log.e(TAG, "Unable to initialize Bluetooth");
                startActivity(new Intent(BPMeasureActivity.this,
DeviceScanActivity.class));
                finish();
            }
            // Automatically connects to the device upon successful
start-up initialization.
            connecting = true;
            mBluetoothLeService.connect(mDeviceAddress);
            invalidateOptionsMenu();
        }

        @Override
        public void onServiceDisconnected(ComponentName
componentName) {
            mBluetoothLeService = null;
        }
    };

    // Handles various events fired by the Service.
    // ACTION_GATT_CONNECTED: connected to a GATT server.
    // ACTION_GATT_DISCONNECTED: disconnected from a GATT server.
    // ACTION_GATT_SERVICES_DISCOVERED: discovered GATT services.
    // ACTION_DATA_AVAILABLE: received data from the device.  This
can be a result of read
    //                       or notification operations.
    private final BroadcastReceiver mGattUpdateReceiver = new
BroadcastReceiver() {
        @Override
        public void onReceive(Context context, Intent intent) {
            final String action = intent.getAction();
            if
(BluetoothLeService.ACTION_GATT_CONNECTED.equals(action)) {
                mConnected = true;

                btnRead.setEnabled(true);
                connecting = false;

                invalidateOptionsMenu();
            } else if
(BluetoothLeService.ACTION_GATT_DISCONNECTED.equals(action)) {
                mConnected = false;
                connecting = false;
                btnRead.setEnabled(false);
                invalidateOptionsMenu();

            } else if
(BluetoothLeService.ACTION_GATT_SERVICES_DISCOVERED.equals(action)) {


if(mBluetoothLeService.getService(Constants.UART_SERVICE_UUID) ==
null){
                    Toast.makeText(BPMeasureActivity.this, "Bluetooth
device not supported!", Toast.LENGTH_LONG).show();
                }else{
                    btnRead.setEnabled(true);
                }
```

```java
            } else if
(BluetoothLeService.ACTION_DATA_AVAILABLE.equals(action)) {
                final byte[] data =
intent.getByteArrayExtra(BluetoothLeService.EXTRA_DATA);
                byte[] data_id = Arrays.copyOfRange(data, 0, 6);
                if(Arrays.equals(data_id, Constants.BP_RESULT_ID)){
                    int systal = Math.abs((int) Array.getByte(data,
6));
                    int diastole = Math.abs((int) Array.getByte(data,
7));

                    resultView.setText(String.valueOf(systal) + " / "
+ String.valueOf(diastole));

                    saveData(systal, diastole);
                }

                //Log.i(TAG, "Value: " + data);
            }
        }
    };

    private void saveData(int systol, int diastol){
        DateFormat dateFormat = new SimpleDateFormat("dd/MM/yyyy
HH:mm:ss");
        Date date = new Date();

        HistoryData data = new HistoryData(systol, diastol,
dateFormat.format(date));

        userRef.child(userId).child("data").push().setValue(data);
    }

    @Override
    protected void onStart() {
        super.onStart();
        mAuth.addAuthStateListener(mAuthListener);
    }

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_bpmeasure);

        btnRead = (Button) findViewById(R.id.take_reading);
        resultView = (TextView) findViewById(R.id.reading);
        infoView = (TextView) findViewById(R.id.label);

        final BluetoothManager bluetoothManager =
                (BluetoothManager)
getSystemService(Context.BLUETOOTH_SERVICE);
        mBluetoothAdapter = bluetoothManager.getAdapter();

        // Checks if Bluetooth is supported on the device.
        if (mBluetoothAdapter == null) {
            Toast.makeText(this,
R.string.error_bluetooth_not_supported, Toast.LENGTH_SHORT).show();
            finish();
        }
```

```java
        mAuth = FirebaseAuth.getInstance();

        mAuthListener = new FirebaseAuth.AuthStateListener() {
            @Override
            public void onAuthStateChanged(@NonNull FirebaseAuth
firebaseAuth) {
                FirebaseUser user = firebaseAuth.getCurrentUser();
                if (user != null) {
                    userId = user.getUid();

                } else {
                    startActivity(new Intent(BPMeasureActivity.this,
LoginActivity.class));
                    finish();
                    Log.d(TAG, "onAuthStateChanged:signed_out");
                }


            }
        };

        btnRead.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {

mBluetoothLeService.sendCommand(Constants.SINGLE_READING_COMMAND);


getWindow().addFlags(WindowManager.LayoutParams.FLAG_KEEP_SCREEN_ON);
                btnRead.setEnabled(false);
                infoView.setText("Reading. Please wait...");
                resultView.setText("- / -");

                Handler handler = new Handler();
                handler.postDelayed(new Runnable() {
                    @Override
                    public void run() {

mBluetoothLeService.sendCommand(Constants.STOP_SINGLE_READING_COMMAND
);
                        infoView.setText("Result:");

                        btnRead.setEnabled(true);

getWindow().clearFlags(WindowManager.LayoutParams.FLAG_KEEP_SCREEN_ON
);
                    }
                }, 100000);
            }
        });

        prefsManager = new PrefsManager(BPMeasureActivity.this);
        mDeviceName = prefsManager.getDeviceName();
        mDeviceAddress = prefsManager.getDeviceAddress();

        if(mDeviceAddress == null){
            startActivity(new Intent(BPMeasureActivity.this,
DeviceScanActivity.class));
            finish();
        }
```

```java
        Intent gattServiceIntent = new Intent(this,
BluetoothLeService.class);
        bindService(gattServiceIntent, mServiceConnection,
BIND_AUTO_CREATE);
    }

    @Override
    protected void onResume() {
        super.onResume();

        if (!mBluetoothAdapter.isEnabled()) {
            if (!mBluetoothAdapter.isEnabled()) {
                Intent enableBtIntent = new
Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);
                startActivityForResult(enableBtIntent,
REQUEST_ENABLE_BT);
            }
        }

        locationManager = (LocationManager)
getSystemService(Context.LOCATION_SERVICE);

        provider = locationManager.getBestProvider(new Criteria(),
false);

        registerReceiver(mGattUpdateReceiver,
makeGattUpdateIntentFilter());
        if (mBluetoothLeService != null) {
            final boolean result =
mBluetoothLeService.connect(mDeviceAddress);
            Log.d(TAG, "Connect request result=" + result);
        }
    }

    @Override
    protected void onPause() {
        super.onPause();
        unregisterReceiver(mGattUpdateReceiver);
    }

    @Override
    protected void onDestroy() {
        super.onDestroy();
        unbindService(mServiceConnection);
        mBluetoothLeService = null;
    }

    @Override
    protected void onStop() {
        super.onStop();

        if (mAuthListener != null) {
            mAuth.removeAuthStateListener(mAuthListener);
        }
    }

    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
        getMenuInflater().inflate(R.menu.gatt_services, menu);
        if (mConnected) {
```

```java
                    menu.findItem(R.id.menu_connect).setVisible(false);
                    menu.findItem(R.id.menu_connecting).setVisible(false);
                    menu.findItem(R.id.menu_disconnect).setVisible(true);
                    menu.findItem(R.id.menu_refresh).setActionView(null);
            } else {
                if(connecting){
                    menu.findItem(R.id.menu_connect).setVisible(false);
                    menu.findItem(R.id.menu_connecting).setVisible(true);

menu.findItem(R.id.menu_disconnect).setVisible(false);
                    menu.findItem(R.id.menu_refresh).setActionView(
                            R.layout.actionbar_indeterminate_progress);
                }else{
                    menu.findItem(R.id.menu_connect).setVisible(true);

menu.findItem(R.id.menu_connecting).setVisible(false);

menu.findItem(R.id.menu_disconnect).setVisible(false);
                    menu.findItem(R.id.menu_refresh).setActionView(null);
                }

            }

            return true;
        }


        @Override
        public boolean onOptionsItemSelected(MenuItem item) {
            switch(item.getItemId()) {
                case R.id.menu_connect:
                    connecting = true;
                    mBluetoothLeService.connect(mDeviceAddress);
                    invalidateOptionsMenu();
                    return true;
                case R.id.menu_disconnect:
                    mBluetoothLeService.disconnect();
                    return true;
                case android.R.id.home:
                    onBackPressed();
                    return true;
            }
            return super.onOptionsItemSelected(item);
        }

        private static IntentFilter makeGattUpdateIntentFilter() {
            final IntentFilter intentFilter = new IntentFilter();

intentFilter.addAction(BluetoothLeService.ACTION_GATT_CONNECTED);

intentFilter.addAction(BluetoothLeService.ACTION_GATT_DISCONNECTED);

intentFilter.addAction(BluetoothLeService.ACTION_GATT_SERVICES_DISCOV
ERED);

intentFilter.addAction(BluetoothLeService.ACTION_DATA_AVAILABLE);
            return intentFilter;
        }

}
```

```java
public class BluetoothLeService extends Service {

    private final static String TAG =
BluetoothLeService.class.getSimpleName();

    private BluetoothManager mBluetoothManager;
    private BluetoothAdapter mBluetoothAdapter;
    private String mBluetoothDeviceAddress;
    private BluetoothGatt mBluetoothGatt;
    private int mConnectionState = STATE_DISCONNECTED;
    private boolean enabled = true;

    private static final int STATE_DISCONNECTED = 0;
    private static final int STATE_CONNECTING = 1;
    private static final int STATE_CONNECTED = 2;

    public final static String ACTION_GATT_CONNECTED =
            "com.fmueni.bpmonitor.ACTION_GATT_CONNECTED";
    public final static String ACTION_GATT_DISCONNECTED =
            "com.fmueni.bpmonitor.ACTION_GATT_DISCONNECTED";
    public final static String ACTION_GATT_SERVICES_DISCOVERED =
            "com.fmueni.bpmonitor.ACTION_GATT_SERVICES_DISCOVERED";
    public final static String ACTION_DATA_AVAILABLE =
            "com.fmueni.bpmonitor.ACTION_DATA_AVAILABLE";
    public final static String EXTRA_DATA =
            "com.fmueni.bpmonitor.EXTRA_DATA";

    // Implements callback methods for GATT events that the app cares
about.  For example,
    // connection change and services discovered.
    private final BluetoothGattCallback mGattCallback = new
BluetoothGattCallback() {
        @Override
        public void onConnectionStateChange(BluetoothGatt gatt, int
status, int newState) {
            String intentAction;
            if (newState == BluetoothProfile.STATE_CONNECTED) {
                intentAction = ACTION_GATT_CONNECTED;
                mConnectionState = STATE_CONNECTED;
                broadcastUpdate(intentAction);
                Log.i(TAG, "Connected to GATT server.");
                // Attempts to discover services after successful
connection.
                Log.i(TAG, "Attempting to start service discovery:" +
                        mBluetoothGatt.discoverServices());

            } else if (newState ==
BluetoothProfile.STATE_DISCONNECTED) {
                intentAction = ACTION_GATT_DISCONNECTED;
                mConnectionState = STATE_DISCONNECTED;
                Log.i(TAG, "Disconnected from GATT server.");
                broadcastUpdate(intentAction);
            }
        }

        @Override
        public void onServicesDiscovered(BluetoothGatt gatt, int
status) {
```

```java
            if (status == BluetoothGatt.GATT_SUCCESS) {

                Log.w(TAG, "Number of discovered services: " +
gatt.getServices().size());

                BluetoothGattService uartService =
gatt.getService(Constants.UART_SERVICE_UUID);

                if(uartService == null){
                    Log.w(TAG, "UART service not found!");
                    return;
                }

                BluetoothGattCharacteristic txCharacteristic =
uartService.getCharacteristic(Constants.TX_CHAR_UUID);

                gatt.setCharacteristicNotification(txCharacteristic,
enabled);

                BluetoothGattDescriptor descriptor =
txCharacteristic.getDescriptor(Constants.BP_DESCRIPTOR_UUID);

descriptor.setValue(BluetoothGattDescriptor.ENABLE_NOTIFICATION_VALUE
);

                gatt.writeDescriptor(descriptor);


                broadcastUpdate(ACTION_GATT_SERVICES_DISCOVERED);

            } else {
                Log.w(TAG, "onServicesDiscovered received: " +
status);
            }
        }

        @Override
        public void onCharacteristicRead(BluetoothGatt gatt,
                                        BluetoothGattCharacteristic
characteristic,
                                        int status) {
            if (status == BluetoothGatt.GATT_SUCCESS) {
                Log.i(TAG, "Characteristic read.");

            }else{
                Log.w(TAG, "onCharacteristicRead received: " +
status);
            }
        }

        @Override
        public void onCharacteristicChanged(BluetoothGatt gatt,

BluetoothGattCharacteristic characteristic) {
            // broadcastUpdate(ACTION_DATA_AVAILABLE,
characteristic);
            Log.i(TAG, "Characteristic changed!");

            broadcastUpdate(ACTION_DATA_AVAILABLE, characteristic);
        }
```

```java
        };

    private void broadcastUpdate(final String action) {
        final Intent intent = new Intent(action);
        sendBroadcast(intent);
    }

    private void broadcastUpdate(final String action,
                                 final BluetoothGattCharacteristic
characteristic) {
        final Intent intent = new Intent(action);

        if(TX_CHAR_UUID.equals(characteristic.getUuid())){
            final byte[] data = characteristic.getValue();

            //intent.putExtra(EXTRA_DATA, new String(data) + "\n" +
getByteString(data));
            intent.putExtra(EXTRA_DATA, data);
            sendBroadcast(intent);
        }
    }

    public class LocalBinder extends Binder {
        public BluetoothLeService getService() {
            return BluetoothLeService.this;
        }
    }

    @Override
    public IBinder onBind(Intent intent) {
        return mBinder;
    }

    @Override
    public boolean onUnbind(Intent intent) {
        // After using a given device, you should make sure that
BluetoothGatt.close() is called
        // such that resources are cleaned up properly.  In this
particular example, close() is
        // invoked when the UI is disconnected from the Service.
        close();
        return super.onUnbind(intent);
    }

    private final IBinder mBinder = new LocalBinder();

    /**
     * Initializes a reference to the local Bluetooth adapter.
     *
     * @return Return true if the initialization is successful.
     */
    public boolean initialize() {
        // For API level 18 and above, get a reference to
BluetoothAdapter through
        // BluetoothManager.
        if (mBluetoothManager == null) {
            mBluetoothManager = (BluetoothManager)
getSystemService(Context.BLUETOOTH_SERVICE);
            if (mBluetoothManager == null) {
                Log.e(TAG, "Unable to initialize BluetoothManager.");
```

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```java
                return false;
            }
        }

        mBluetoothAdapter = mBluetoothManager.getAdapter();
        if (mBluetoothAdapter == null) {
            Log.e(TAG, "Unable to obtain a BluetoothAdapter.");
            return false;
        }

        return true;
    }

    /**
     * Connects to the GATT server hosted on the Bluetooth LE device.
     *
     * @param address The device address of the destination device.
     *
     * @return Return true if the connection is initiated
successfully. The connection result
     *          is reported asynchronously through the
     *          {@code
BluetoothGattCallback#onConnectionStateChange(android.bluetooth.Bluet
oothGatt, int, int)}
     *          callback.
     */
    public boolean connect(final String address) {
        if (mBluetoothAdapter == null || address == null) {
            Log.w(TAG, "BluetoothAdapter not initialized or
unspecified address.");
            return false;
        }

        // Previously connected device.  Try to reconnect.
        if (mBluetoothDeviceAddress != null &&
address.equals(mBluetoothDeviceAddress)
                && mBluetoothGatt != null) {
            Log.d(TAG, "Trying to use an existing mBluetoothGatt for
connection.");
            if (mBluetoothGatt.connect()) {
                mConnectionState = STATE_CONNECTING;
                return true;
            } else {
                return false;
            }
        }

        final BluetoothDevice device =
mBluetoothAdapter.getRemoteDevice(address);
        if (device == null) {
            Log.w(TAG, "Device not found.  Unable to connect.");
            return false;
        }
        // We want to directly connect to the device, so we are
setting the autoConnect
        // parameter to false.
        mBluetoothGatt = device.connectGatt(this, false,
mGattCallback);
        Log.d(TAG, "Trying to create a new connection.");
        mBluetoothDeviceAddress = address;
```

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```java
            mConnectionState = STATE_CONNECTING;
            return true;
        }

        /**
         * Disconnects an existing connection or cancel a pending
connection. The disconnection result
         * is reported asynchronously through the
         * {@code
BluetoothGattCallback#onConnectionStateChange(android.bluetooth.Bluet
oothGatt, int, int)}
         * callback.
         */
        public void disconnect() {
            if (mBluetoothAdapter == null || mBluetoothGatt == null) {
                Log.w(TAG, "BluetoothAdapter not initialized");
                return;
            }
            mBluetoothGatt.disconnect();
        }

        /**
         * After using a given BLE device, the app must call this method
to ensure resources are
         * released properly.
         */
        public void close() {
            if (mBluetoothGatt == null) {
                return;
            }
            mBluetoothGatt.close();
            mBluetoothGatt = null;
        }

        /**
         * Request a read on a given {@code BluetoothGattCharacteristic}.
The read result is reported
         * asynchronously through the {@code
BluetoothGattCallback#onCharacteristicRead(android.bluetooth.Bluetoot
hGatt, android.bluetooth.BluetoothGattCharacteristic, int)}
         * callback.
         *
         * @param characteristic The characteristic to read from.
         */
        public void readCharacteristic(BluetoothGattCharacteristic
characteristic) {
            if (mBluetoothAdapter == null || mBluetoothGatt == null) {
                Log.w(TAG, "BluetoothAdapter not initialized");
                return;
            }
            mBluetoothGatt.readCharacteristic(characteristic);
        }

        public void sendCommand(byte[] command){
            if (mBluetoothAdapter == null || mBluetoothGatt == null) {
                Log.w(TAG, "BluetoothAdapter not initialized");
                return;
            }

            BluetoothGattCharacteristic rxCharacteristic = mBluetoothGatt
```

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```java
                .getService(Constants.UART_SERVICE_UUID)
                .getCharacteristic(Constants.RX_CHAR_UUID);

        rxCharacteristic.setValue(command);
        mBluetoothGatt.writeCharacteristic(rxCharacteristic);

        //mBluetoothGatt.executeReliableWrite();

        //Log.w(TAG, "Sent command: " + getByteString(command));
    }

    /**
     * Enables or disables notification on a give characteristic.
     *
     * @param characteristic Characteristic to act on.
     * @param enabled If true, enable notification.  False otherwise.
     */
    public void
setCharacteristicNotification(BluetoothGattCharacteristic
characteristic,
                                              boolean enabled) {
        if (mBluetoothAdapter == null || mBluetoothGatt == null) {
            Log.w(TAG, "BluetoothAdapter not initialized");
            return;
        }
        mBluetoothGatt.setCharacteristicNotification(characteristic,
enabled);
    }

    /**
     * Retrieves a list of supported GATT services on the connected
device. This should be
     * invoked only after {@code BluetoothGatt#discoverServices()}
completes successfully.
     *
     * @return A {@code List} of supported services.
     */
    public List<BluetoothGattService> getSupportedGattServices() {
        if (mBluetoothGatt == null) return null;

        return mBluetoothGatt.getServices();
    }

    public BluetoothGattService getService(UUID uuid){
        return mBluetoothGatt.getService(uuid);
    }

}
```

//PATIENTSACTIVITY.JAVA-is a code for manipulating data for pregnant mothers except the one auto generated by the database and the bp readings

```java
public class PatientActivity extends AppCompatActivity {

    private static final String TAG = "EmailPassword";

    private FirebaseAuth mAuth;
```

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```java
    private FirebaseAuth.AuthStateListener mAuthListener;

    FirebaseDatabase database = FirebaseDatabase.getInstance();
    DatabaseReference userRef = database.getReference("users");


    Menu mainMenu=null;
    private String userId;
    private Patient patient;

    private ImageView dp;
    private TextView name, dob, height, weight, location,
gestation_start, delivery, gestationStage, id;

    private Context context;

    @Override
    public void onStart() {
        super.onStart();
        mAuth.addAuthStateListener(mAuthListener);
    }

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_patient);

        mAuth = FirebaseAuth.getInstance();
        patient = new Patient();

        context = this;

        dp = (ImageView) findViewById(R.id.profile_pic);
        name = (TextView) findViewById(R.id.name);
        id = (TextView) findViewById(R.id.id);
        dob = (TextView) findViewById(R.id.dob);
        weight = (TextView) findViewById(R.id.weight);
        height = (TextView) findViewById(R.id.height);
        gestation_start = (TextView) findViewById(R.id.startdate);
        delivery = (TextView) findViewById(R.id.deliverydate);
        gestationStage = (TextView)
findViewById(R.id.gestationperiod);

        mAuthListener = new FirebaseAuth.AuthStateListener() {
            @Override
            public void onAuthStateChanged(@NonNull FirebaseAuth
firebaseAuth) {
                FirebaseUser user = firebaseAuth.getCurrentUser();
                if (user != null) {
                    userId = user.getUid();
                    Constants.userId = userId;
                    setDatabaseListener();
                } else {
                    startActivity(new Intent(PatientActivity.this,
LoginActivity.class));
                    finish();
                    Log.d(TAG, "onAuthStateChanged:signed_out");
                }

            }
```

```java
            };

        ListView listView = (ListView) findViewById(R.id.listview);
        String[] items = { "Take a reading", "History", "Manage
Device", "Caregiver"};
        listView.setAdapter(new GridAdapter(PatientActivity.this,
items));

        listView.setOnItemClickListener(new
AdapterView.OnItemClickListener() {
            public void onItemClick(AdapterView<?> parent, View v,
                                    int position, long id) {

                Intent intent;
                switch (position){
                    case 0:
                        intent = new Intent(PatientActivity.this,
BPMeasureActivity.class);
                        break;

                    case 1:
                        intent = new Intent(PatientActivity.this,
HistoryActivity.class);
                        break;
                    case 2:
                        intent = new Intent(PatientActivity.this,
DeviceScanActivity.class);
                        break;

                    default:
                        intent = new Intent(PatientActivity.this,
CaregiverInfoActivity.class);
                }

                startActivity(intent);
            }
        });

        dp.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                Intent intent = new Intent(PatientActivity.this,
SettingsActivity.class);
                intent.putExtra("photo", patient.photo);
                startActivity(intent);
            }
        });

    }

    private void setDatabaseListener(){
        userRef.child(userId).addValueEventListener(new
ValueEventListener() {
            @Override
            public void onDataChange(DataSnapshot dataSnapshot) {
                try{
                    HashMap<String, Object> userMap =
(HashMap<String, Object>) dataSnapshot.getValue();
                    patient.fname = (String) userMap.remove("fname");
                    patient.lname = (String) userMap.remove("lname");
```

```java
                    patient.dob = (String) userMap.remove("dob");
                    patient.weight = (int) (long)
userMap.remove("weight");
                    patient.height = (int) (long)
userMap.remove("height");
                    patient.description = (String)
userMap.remove("description");
                    patient.id = (String) userMap.remove("id");
                    patient.photo = (String) userMap.remove("photo");
                    patient.gestation_start = (String)
userMap.remove("gestationStart");

                    if(patient.gestation_start != null){
                        DateFormat dateFormat = new
SimpleDateFormat("dd/MM/yyyy");

                        Calendar calendar = Calendar.getInstance();

                        try{
                            Date start_date =
dateFormat.parse(patient.gestation_start);

                            Date current_date =
dateFormat.parse(dateFormat.format(calendar.getTime()));
                            calendar.setTime(start_date);

                            patient.diff_weeks =
Constants.getWeeksBetween(start_date, current_date) > 42 ?
                                    42 :
Constants.getWeeksBetween(start_date, current_date);
                        }catch (ParseException e){
                            e.printStackTrace();
                        }finally {
                            calendar.add(Calendar.DAY_OF_MONTH, 294);
                            patient.delivery_date =
dateFormat.format(calendar.getTime());
                        }

                    }

                    updateUI();

                }catch (NullPointerException e){
                    e.printStackTrace();
                }
            }

            @Override
            public void onCancelled(DatabaseError databaseError) {

            }
        });
    }

    public void showDatePickerDialog(View v) {
        DialogFragment newFragment = new DateFragment();
        newFragment.show(getSupportFragmentManager(), "datePicker");
    }

    private void updateUI(){
```

```java
        name.setText(patient.fname + " " + patient.lname);
        id.setText(patient.id);
        dob.setText(patient.dob);
        weight.setText(String.valueOf(patient.weight));
        height.setText(String.valueOf(patient.height));
        gestation_start.setText(patient.gestation_start);
        delivery.setText(patient.delivery_date);
        gestationStage.setText(String.valueOf(patient.diff_weeks));

        Picasso.with(context).load(patient.photo).into(dp);
    }

    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
        // Inflate the menu; this adds items to the action bar if it
is present.
        getMenuInflater().inflate(R.menu.menu_main, menu);
        mainMenu=menu;
        return true;
    }

    @Override
    public boolean onKeyDown(int keyCode, KeyEvent event) {
        if (keyCode== KeyEvent.KEYCODE_MENU) {
            getMenuInflater();
            return true;
        }
        return super.onKeyDown(keyCode, event);
    }

    @Override
    public boolean onOptionsItemSelected(MenuItem item) {
        //mAuth = FirebaseAuth.getInstance();
        switch (item.getItemId()) {

            case R.id.logout:
                mAuth.signOut();
                return true;

            default:
                // If we got here, the user's action was not
recognized.
                // Invoke the superclass to handle it.
                return super.onOptionsItemSelected(item);

        }
    }

    @Override
    public void onBackPressed() {
        super.onBackPressed();
    }

    @Override
    public void onStop() {
        super.onStop();
        if (mAuthListener != null) {
            mAuth.removeAuthStateListener(mAuthListener);
        }
```

```
        }
}


//DEVICESCANACTIVITY.JAVA-is a code for scanning all available smart watches
for configuration
package com.fmueni.bpmonitor.activities;

import android.Manifest;
import android.app.Activity;
import android.bluetooth.BluetoothAdapter;
import android.bluetooth.BluetoothDevice;
import android.bluetooth.BluetoothManager;
import android.content.Context;
import android.content.DialogInterface;
import android.content.Intent;
import android.content.pm.PackageManager;
import android.os.Bundle;
import android.os.Handler;
import android.support.v4.app.ActivityCompat;
import android.support.v4.content.ContextCompat;
import android.support.v7.app.AlertDialog;
import android.support.v7.app.AppCompatActivity;
import android.view.LayoutInflater;
import android.view.Menu;
import android.view.MenuItem;
import android.view.View;
import android.view.ViewGroup;
import android.widget.AdapterView;
import android.widget.BaseAdapter;
import android.widget.ListView;
import android.widget.TextView;
import android.widget.Toast;

import com.fmueni.bpmonitor.Constants;
import com.fmueni.bpmonitor.PrefsManager;
import com.fmueni.bpmonitor.R;

import java.util.ArrayList;

public class DeviceScanActivity extends AppCompatActivity {

    private LeDeviceListAdapter mLeDeviceListAdapter;
    private BluetoothAdapter mBluetoothAdapter;
    private boolean mScanning;
    private Handler mHandler;

    private static final int REQUEST_ENABLE_BT = 1;
    // Stops scanning after 10 seconds.
    private static final long SCAN_PERIOD = 10000;
```

```java
    private ListView deviceList;

    private BluetoothAdapter.LeScanCallback mLeScanCallback =
        new BluetoothAdapter.LeScanCallback() {

            @Override
            public void onLeScan(final BluetoothDevice device, int rssi, byte[]
scanRecord) {
                runOnUiThread(new Runnable() {
                    @Override
                    public void run() {
                        mLeDeviceListAdapter.addDevice(device);
                        mLeDeviceListAdapter.notifyDataSetChanged();
                    }
                });
            }


        };

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_device_scan);

        //getActionBar().setTitle(R.string.title_devices);

        deviceList = (ListView) findViewById(R.id.device_list);
        mHandler = new Handler();

        // Use this check to determine whether BLE is supported on the device.  Then you
can
        // selectively disable BLE-related features.
        if
(!getPackageManager().hasSystemFeature(PackageManager.FEATURE_BLUETOO
TH_LE)) {
            Toast.makeText(this, R.string.ble_not_supported,
Toast.LENGTH_SHORT).show();
            finish();
        }

        // Initializes a Bluetooth adapter.  For API level 18 and above, get a reference to
        // BluetoothAdapter through BluetoothManager.
        final BluetoothManager bluetoothManager =
            (BluetoothManager)
getSystemService(Context.BLUETOOTH_SERVICE);
        mBluetoothAdapter = bluetoothManager.getAdapter();
```

```java
    // Checks if Bluetooth is supported on the device.
    if (mBluetoothAdapter == null) {
        Toast.makeText(this, R.string.error_bluetooth_not_supported,
Toast.LENGTH_SHORT).show();
        finish();
    }

    checkLocationPermission();

}


@Override
public boolean onCreateOptionsMenu(Menu menu) {
    getMenuInflater().inflate(R.menu.lescan_menu, menu);
    if (!mScanning) {
        menu.findItem(R.id.menu_stop).setVisible(false);
        menu.findItem(R.id.menu_scan).setVisible(true);
        menu.findItem(R.id.menu_refresh).setActionView(null);
    } else {
        menu.findItem(R.id.menu_stop).setVisible(true);
        menu.findItem(R.id.menu_scan).setVisible(false);
        menu.findItem(R.id.menu_refresh).setActionView(
                R.layout.actionbar_indeterminate_progress);
    }
    return true;
}


@Override
public boolean onOptionsItemSelected(MenuItem item) {
    switch (item.getItemId()) {
        case R.id.menu_scan:
            mLeDeviceListAdapter.clear();
            scanLeDevice(true);
            break;
        case R.id.menu_stop:
            scanLeDevice(false);
            break;
    }
    return true;
}

public static final int MY_PERMISSIONS_REQUEST_LOCATION = 99;

public boolean checkLocationPermission() {
    if (ContextCompat.checkSelfPermission(this,
            Manifest.permission.ACCESS_COARSE_LOCATION)
            != PackageManager.PERMISSION_GRANTED) {

        // Should we show an explanation?
```

```java
        if (ActivityCompat.shouldShowRequestPermissionRationale(this,
                Manifest.permission.ACCESS_COARSE_LOCATION)) {

            // Show an explanation to the user *asynchronously* -- don't block
            // this thread waiting for the user's response! After the user
            // sees the explanation, try again to request the permission.
            new AlertDialog.Builder(this)
                    .setTitle("Location Access")
                    .setMessage("Location access is required to find bluetooth
devices!")
                    .setPositiveButton("Okay", new DialogInterface.OnClickListener() {
                        @Override
                        public void onClick(DialogInterface dialogInterface, int i) {
                            //Prompt the user once explanation has been shown
                            ActivityCompat.requestPermissions(DeviceScanActivity.this,
                                    new
String[]{Manifest.permission.ACCESS_COARSE_LOCATION},
                                    MY_PERMISSIONS_REQUEST_LOCATION);
                        }
                    })
                    .create()
                    .show();


        } else {
            // No explanation needed, we can request the permission.
            ActivityCompat.requestPermissions(this,
                    new String[]{Manifest.permission.ACCESS_COARSE_LOCATION},
                    MY_PERMISSIONS_REQUEST_LOCATION);
        }
        return false;
    } else {
        return true;
    }
}

@Override
public void onRequestPermissionsResult(int requestCode,
                    String permissions[], int[] grantResults) {
    switch (requestCode) {
        case MY_PERMISSIONS_REQUEST_LOCATION: {
            // If request is cancelled, the result arrays are empty.
            if (grantResults.length > 0
                    && grantResults[0] == PackageManager.PERMISSION_GRANTED)
{

                // permission was granted, yay! Do the
                // location-related task you need to do.
                if (ContextCompat.checkSelfPermission(this,
```

```java
                    Manifest.permission.ACCESS_FINE_LOCATION)
                    == PackageManager.PERMISSION_GRANTED) {

                //Request location updates:
            }

        } else {

            new AlertDialog.Builder(this)
                    .setTitle("Location Permissions")
                    .setMessage("Location permissions are required when searching
bluetooth devices!")
                    .setCancelable(false)
                    .setPositiveButton("Okay", new DialogInterface.OnClickListener()
{

                        @Override
                        public void onClick(DialogInterface dialog, int which) {
                            dialog.dismiss();
                        }
                    }).show();

        }
        return;
    }

}

private void scanLeDevice(final boolean enable) {
    if (enable) {
        // Stops scanning after a pre-defined scan period.
        mHandler.postDelayed(new Runnable() {
            @Override
            public void run() {
                mScanning = false;
                mBluetoothAdapter.stopLeScan(mLeScanCallback);
                invalidateOptionsMenu();
            }
        }, SCAN_PERIOD);

        mScanning = true;
        mBluetoothAdapter.startLeScan(mLeScanCallback);
    } else {
        mScanning = false;
        mBluetoothAdapter.stopLeScan(mLeScanCallback);
    }
    invalidateOptionsMenu();
}
```

```java
    @Override
    protected void onResume() {
        super.onResume();

        // Ensures Bluetooth is enabled on the device.  If Bluetooth is not currently enabled,
        // fire an intent to display a dialog asking the user to grant permission to enable it.
        if (!mBluetoothAdapter.isEnabled()) {
            if (!mBluetoothAdapter.isEnabled()) {
                Intent enableBtIntent = new Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);
                startActivityForResult(enableBtIntent, REQUEST_ENABLE_BT);
            }
        }

        // Initializes list view adapter.
        mLeDeviceListAdapter = new LeDeviceListAdapter();
        deviceList.setAdapter(mLeDeviceListAdapter);

        deviceList.setOnItemClickListener(new AdapterView.OnItemClickListener() {
            @Override
            public void onItemClick(AdapterView<?> parent, View view, int position,
long id) {
                final BluetoothDevice device =
mLeDeviceListAdapter.getDevice(position);
                if (device == null) return;

                PrefsManager prefsManager = new
PrefsManager(DeviceScanActivity.this);
                prefsManager.setDeviceName(device.getName());
                prefsManager.setDeviceAddress(device.getAddress());

                final Intent intent = new Intent(DeviceScanActivity.this,
BPMeasureActivity.class);

                if (mScanning) {
                    mBluetoothAdapter.stopLeScan(mLeScanCallback);
                    mScanning = false;
                }
                startActivity(intent);
                finish();
            }
        });
        scanLeDevice(true);
    }

    @Override
    protected void onActivityResult(int requestCode, int resultCode, Intent data) {
```

```java
        // User chose not to enable Bluetooth.
        if (requestCode == REQUEST_ENABLE_BT && resultCode ==
Activity.RESULT_CANCELED) {
            finish();
            return;
        }
        super.onActivityResult(requestCode, resultCode, data);
    }

    @Override
    protected void onPause() {
        super.onPause();
        scanLeDevice(false);
        mLeDeviceListAdapter.clear();
    }

    private class LeDeviceListAdapter extends BaseAdapter {
        private ArrayList<BluetoothDevice> mLeDevices;
        private LayoutInflater mInflator;

        public LeDeviceListAdapter() {
            super();
            mLeDevices = new ArrayList<BluetoothDevice>();
            mInflator = DeviceScanActivity.this.getLayoutInflater();
        }

        public void addDevice(BluetoothDevice device) {
            if(!mLeDevices.contains(device)) {
                mLeDevices.add(device);
            }
        }

        public BluetoothDevice getDevice(int position) {
            return mLeDevices.get(position);
        }

        public void clear() {
            mLeDevices.clear();
        }

        @Override
        public int getCount() {
            return mLeDevices.size();
        }

        @Override
        public Object getItem(int i) {
            return mLeDevices.get(i);
        }
```

```java
    @Override
    public long getItemId(int i) {
        return i;
    }

    @Override
    public View getView(int i, View view, ViewGroup viewGroup) {
        ViewHolder viewHolder;
        // General ListView optimization code.
        if (view == null) {
            view = mInflator.inflate(R.layout.listitem_device, null);
            viewHolder = new ViewHolder();
            viewHolder.deviceAddress = (TextView)
view.findViewById(R.id.device_address);
            viewHolder.deviceName = (TextView)
view.findViewById(R.id.device_name);
            view.setTag(viewHolder);
        } else {
            viewHolder = (ViewHolder) view.getTag();
        }

        BluetoothDevice device = mLeDevices.get(i);
        final String deviceName = device.getName();
        if (deviceName != null && deviceName.length() > 0)
            viewHolder.deviceName.setText(deviceName);
        else
            viewHolder.deviceName.setText(R.string.unknown_device);
        viewHolder.deviceAddress.setText(device.getAddress());

        return view;
    }
}

    static class ViewHolder {
        TextView deviceName;
        TextView deviceAddress;
    }
}
```

//Index file-it is a file that connects the firebase system with the application. It consists of function to analyze when the blood pressure is above the expected level (140/90). Then a notification is sent to the health care provider and family caregiver. The pregnant mother also gets a notification message.

```javascript
const functions = require('firebase-functions');
const admin = require('firebase-admin');

admin.initializeApp(functions.config().firebase);
```

```
// // Create and Deploy Your First Cloud Functions
// // https://firebase.google.com/docs/functions/write-firebase-functions
//
// exports.helloWorld = functions.https.onRequest((request, response) => {
//  response.send("Hello from Firebase!");
// });

exports.sendNotification = functions.database
        .ref('users/{uid}/data/{pushId}')
        .onCreate((snap, context) => {
                const uid = context.params.uid;
                const pushId = context.params.pushId;

                return snap.ref.once("value", function(snapshot){
                        const diastol = snapshot.child("diastol").val();
                        const systol = snapshot.child("systol").val();

                        if (diastol > 90 || systol > 140) {
                                // Get care giver id
                                var careRef = admin.database().ref(`users/${uid}`);
                                return careRef.once("value", function(snapshot){
                                        const             caregiver_id             =
snapshot.child("caregiver_id").val();
                                        const fname = snapshot.child("fname").val();
                                        const lname = snapshot.child("lname").val();

                                        if (caregiver_id == null) {
                                                return;
                                        }

                                        //Get caregiver instance id

                                        var             ref             =
admin.database().ref(`users/${caregiver_id}/instanceId`);

                                        return ref.once("value", function(instance){
                                                var instance_id = instance.val();
                                                var message = "{"
                                                        +" \"uid\": \"" + uid
+ "\", "
                                                        +"\"pushId\" : \"" +
pushId + "\" "
                                                        + "}";

                                                const payload = {
                                        data: {
                                                title: 'Blood Pressure alert',
                                                body: message
```

```
                    }
                    };
                    var current_date = new Date();

        admin.database().ref(`users/${caregiver_id}/alerts`)
                            .push({
                                    "uid": uid,
                                    "pushId": pushId,
                                    "viewed": false
                            });
                            admin.messaging().sendToDevice(instance_id,
payload);
                            });
                    });
            }else{
                    return;
            }
        });
    });
```