UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

A MOBILE-PHONE TELE-MEDICINE SYSTEM THAT PROMOTES SELF-MANAGEMENT OF BLOOD PRESSURE AMONG HYPERTENSIVE PATIENTS IN KIRINYAGA SUBCOUNTY

BY

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Submitted as Partial Fulfillment of the Requirement for the Award of Masters of Science in Computer Science, School of Computing and Informatics, University of Nairobi

DECLARATION

This thesis is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

This work was done under the guidance of Dr. KAHONGE ANDREW MWAURA, from the School of Computing and Informatics at the University of Nairobi.

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In my capacity as supervisor of the candidate's thesis, I certify that the work reported in this research was carried out by the candidate under my supervision.

Supervisor: DR. KAHONGE ANDREW MWAURA

Signature………………………………. **Date………………………………..**

DEDICATION

There are a number of people without whom this thesis might not have been written, and to whom I am greatly indebted.

First I dedicate my dissertation work to my family and many friends. A special feeling of gratitude goes to my loving parents, LUCY and JOSEPH MUGOH, whose words of encouragement and push for tenacity ring in my ears. My brothers ERICK and PATRICK have never left my side and are very special.

I also dedicate this dissertation to my many friends who have supported me throughout the process. I will always appreciate all what they have done especially for the many hours of proofreading.

Finally I dedicate this work and give special thanks to Dr. KARIITHI and all the patients who agreed to be involved in this research work. All of you have been my best cheerleaders.

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ABSTRACT

Hypertension, also known as high or raised BP, is a condition in which the blood vessels have persistently raised pressure. If left uncontrolled, hypertension can lead to a heart attack, an enlargement of the heart and eventually heart failure. The pressure in the blood vessels can cause blood to leak out into the brain and cause a stroke. By realizing the devastating consequences and effects of elevated BP levels, it is therefore important to emphasize on the prevention and systematic observation to fight against this disease. Through recording and quality management of BP by the patient will provide valuable information to the medical specialists. On the other hand the doctor can monitor the short-term and long-term course of the disease, develop a complete treatment procedure and assess in detail the performance of a specific medication. The current practice adopted by hypertensive patients in managing and monitoring hypertension is making frequent visits to a health center as recommended by medical specialists. However, very few patients adhere to this practice as it is time consuming and tiresome especially if they have to travel for long distances to have their BP checked. This practice is also not feasible for critically-ill patients. Consequently, most patients neglect BP check-ups and therefore focus on medication alone. This puts the patient's at risk as uncontrolled BP can lead to fatal complications.

The overall objective of this research was to design, develop and pilot-test a mobile telemedicine system that helps patients' to self-manage their BP condition from the comfort of their homes. Participatory action research design was used in this study. Purposeful sampling technique was used for the recruitment of participants. Testing for usability, utility and performance of the tele-medicine system was conducted. In order to collect reliable and valid information for usability and utility, patients and medical specialist were actively engaged using the E-Delphi method.

The system has proved to be usable and useful in helping patients achieve better control of their BP. Performance metrics namely Uptime, Downtime, MTBF, Reliability, Response time and Availability were evaluated. The results showed that the system achieved an Uptime of 98.46%, Downtime of 0.37 %, MTBF of 9.85,Reliability of 0.9, Average Response Time of 4 seconds, and overall availability of 99.82 % during the 5-days testing period. Through self-management, a number of patients experienced some improvement in their BP. However due to limitation of testing period this fact cannot be substantially quantified .Nevertheless the results of this study are quite encouraging and a long-term trial is therefore recommended.

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ABBREVIATIONS

BP	-	Blood Pressure
WHO	-	World Health Organization
PHM	-	Personal Health Monitor
ABP	-	Ambulatory BP monitoring
HR	-	Heart Rate
MOVE-IT	-	Metrics Network Monitoring of Vital Events
UCRC	-	Ugunja Community Resource Center
KENTEL	-	Kenya Telecentre Network
CHW	-	Community Health Workers
PLWA	-	People Leaving with HIV/AIDS
EHRs	-	Electronic Health Records
SDK	-	Android Software Development Kit
RDMS	-	Relational Database Management System
APIs	-	Application Program Interfaces
ADT	-	Android Development Tools
JDK	-	Java Development Kit
IDE	-	Integrated Development Environment
PHP	-	Hypertext Preprocessor
WAMP	-	Windows, Apache, MySQL and PHP
SMS	-	Short Message Service
AVD	-	Android Virtual Device
JSON	-	JavaScript Object Notation
ISO	-	International Organization for Standardization

SUS	-	System Usability Scale
MTTF	-	Mean Time to Failure
MTBF	-	Mean Time between Failures
MTTR	-	Mean Time to Repair

CHAPTER ONE: INTRODUCTION

1.1 PROBLEM STATEMENT

John D. Piette, Professor of internal medicine at U-M Medical School once said "What some people may not realize is that the biggest health threats in less-developed countries aren't just communicable diseases like HIV. Chronic diseases and high BP are the biggest killers”.

Hypertension, also known as high or raised BP, is a condition in which the blood vessels have persistently raised pressure. Normal adult BP is defined as a BP of 120 mm Hg when the heart beats (systolic) and a BP of 80 mm Hg when the heart relaxes (diastolic). When systolic BP is equal to or above 140 mm Hg and/or a diastolic BP equal to or above 90 mm Hg the BP is considered to be raised or high. If left uncontrolled, hypertension can lead to a heart attack, an enlargement of the heart and eventually heart failure. Blood vessels may develop bulges (aneurysms) and weak spots that make them more likely to clog and burst. The pressure in the blood vessels can cause blood to leak out into the brain and cause a stroke. Hypertension can also lead to kidney failure, blindness, and cognitive impairment. Uncontrolled high BP is a major public health concern and leading cause of cardiovascular disease worldwide (Lorraine, 2011).

The WHO projects that in the next 10 years, the African continent will experience the highest death rates related to chronic diseases like hypertension. The high death rate is attributed to factors like lifestyle change, poverty, urbanization etc. (Aikins et al., 2010). Also WHO statistics shows that at least 12.5 per cent of people in Sub Saharan Africa die from Cardiovascular Diseases compared to HIV/AIDS (12.3 per cent) or malaria at 7.3 per cent. In Kenya between 37 to 44 percent of the Kenyan adult population has hypertension.

With pervasive high speed wireless networks and powerful mobile devices, there is no doubt it is going to transform how health care is delivered. Consequently, this is likely to lower the cost of accessing professional health care and improve patients-physicians interaction. The rising utilization of mobile technology will help in the management of these chronic diseases and provision of health care to isolated areas. It is predicted that more than 100 million people will own android phones by the end of 2012. The rapid development of mobile internet service and cloud computing will offer innovative method to monitor health status (Yang et al., 2010). Mobile technology is helping with chronic disease management, extending service to underserved areas, and improving health outcomes and medical system efficiency (Parameswari at.al, 2012).

One strategy, according to Gaede at.al (2013) cited by Alexander et al (2007), to improve hypertension control in the community involves the use of specialized clinics. This approach partitions health care into undesirable silos and is neither cost effective nor practical for highly prevalent conditions such as hypertension and diabetes mellitus. As a consequence, new health care delivery models that promote patient self-management and incorporate advanced communication systems are being developed and tested. Recent surveys indicate that patients are willing to become more actively involved in managing their own care, and that self-monitoring at home is one way to increase their involvement.

In this research therefore we have developed and evaluated the usability, utility and performance of an interactive mobile phone-based system for use in supporting patients in their efforts to monitor and self-manage their hypertension condition. The self-management system used is person-centered, where the patient is actively involved in the treatment and care.

This study has developed a mobile tele-medicine system that provides an end-to-end solution:

1. Through enabling patients to regularly collect and transmit their BP readings through their mobile phones to doctors, at the comfort of their premises.
2. Through enabling doctors access and analyze patients' BP data on their mobile phones.
3. Through enabling doctors to manage the chronic condition by providing feedback on the BP status to the patients remotely.

It is crucial to be aware of the problems that are related to high BP (Mersini et al, 2012). Increased BP is an important clinical problem as it is quite common. Also the effects of high BP are severally devastating and remain asymptomatic for a relatively long period of time. As their no clear distinction between normal and high BP, the definition of high BP is arbitrary. This is because it not only takes into account the diastolic and systolic pressure but other factors like gender, age, body weight, alcohol consumption, heredity etc. are also considered. By realizing the devastating consequences and effects elevated BP levels, it is therefore important to emphasize on the prevention and systematic observation to fight against this disease. Through recording and quality management of BP by the patient will provide valuable information to the medical specialist. On the other hand the doctor can monitor the short-term and long-term course of the disease, develop a complete treatment and assess in detail the performance of a specific medication.

By engaging the patient in the process of self-monitoring it will increase the level of awareness of the disease, it causes and effects and how it can be managed. As a result the patient will become responsible in preserving the integrity of his/her health. This procedure will become a strong incentive to adopt a course of conduct like improving on eating habits, exercising regularly and regular intake of treatment to achieve normal BP values.

1.2 OBJECTIVES

The main objective of this this research work was to develop and evaluate the usability, utility and performance of an interactive mobile phone-based system for use in supporting patients in their efforts to self-manage their hypertension treatment. The self-management system used is person-centered, where the patient is actively involved in the treatment and care.

The mobile tele-medicine system was intended to help patients with hypertension access professional medical services and monitor and manage their condition at the comfort of their homes.

1.3 SPECIFIC OBJECTIVES

In this study, we have attempted to offer a feasible solution to hypertension management by:-

1. Designing and developing an integrated android application with a common interface to be used by both hypertensive patients and medical specialist.
2. Deploying the android application to remote hypertensive patients to help them interact with remote medical specialists, by inputting and transmitting vital BP data through their hand-set devices from the comfort of their homes and presenting the vital parameters to the prescribed doctor’s mobile devices.
3. Testing to evaluate the performance, usability and utility (usefulness) of an interactive mobile phone-based system for use in supporting patients in their efforts to self-manage their hypertension treatment.

To meet the above objectives this research aims to answer the following research questions:-

1. How can hypertensive patients use BP monitors and mobile application to help them regularly monitor and manage their BP condition from the comfort of their homes?
2. How can doctors use their mobile devices to help them continuously monitor BP condition of remote hypertensive patients?
3. What is the usability of using mobile telemedicine system in helping hypertensive patients monitor and manage their BP condition from home?
4. What is the utility (usefulness) of using mobile telemedicine system in helping hypertensive patients monitor and manage their BP condition from home?

1.4 PROBLEM JUSTIFICATION

Hypertension is a chronic disease that needs to regularly be monitored to keep the BP levels within normal ranges (Mashael, Mznah,2013). This monitoring depends on the BP treatment plan that is periodically reviewed by the medical specialists. The frequent visit to the main hospital seems to be tiring and time consuming for both the medical specialists and hypertension patients. The patient may have to incur expenses as they travel distant places to seek medical attention. Those expenses can be reduced by remotely monitoring the patients with the help of mobile devices. In this research, we have introduced the implementation of an integrated remote management and monitoring system for the hypertension patients.

In fact, hypertension needs to be treated either by just modifying life style, or by medications and injections. This treatment is very important to prevent fatal complications. Also, patients who have hypertension need to measure their BP level daily using a BP monitor.

Due to change in lifestyle, many people in Kenya are suffering from hypertension. Two major reasons contributing to these problems are the increasingly busy lifestyle and working pressure. Therefore, people have no time to monitor their health although and this has resulted to serious health problems. According to Wolf-Maier et al. (2004) cited by Alexander et al.(2007), survey on BP in most countries show that only 25% of patients with hypertension are under good BP control. Some of the reasons include patient-related factors, inadequacies of the health care system, and the clinical inertia of health care providers (Alexander et. al, 2007).

At the same time due to stretched resources in our Kenyan hospitals most patients are required to receive treatment from home. The burden is even higher to the rural population since they are not able to access professional medical care.

This problem may be settled with the development of mobile communication. (Sparsh, Chiew Tong, 2010). This study has implemented a mobile tele-medicine system that provides an end-to-end solution:-

1. Through enabling patients collect and transmit their BP readings through their mobile phones.
2. Through enabling doctors access and analyze patients' data through a mobile interface.
3. Through enabling doctors to manage the chronic condition by providing feedback to the patients remotely.

CHAPTER TWO: LITERATURE REVIEW

In an attempt to manage chronic diseases like hypertension, a research by Kiura and Waema (2011) proposed the introduction of remotely hosted medical records of patients to enable health service providers make references to a patient's medical history for an informed therapy plan. They argued that long term therapeutic management of these diseases requires availability of medical records to a provider when a patient presents him/herself at a medical facility. In this research study we have not only focused on just managing patient records but rather actively engaging the patients in the management of the hypertension. The patients were able to self-monitor and manage their condition by collecting their BP readings and transmitting them via their mobile phones to a medical specialist for analysis. Also the patients can at any time be able to view their medical history.

In this research study we have borrowed some concepts from a research by Kai Liu (2013). In his research he contemplated to implement two m-health solutions for diabetes and hypertension management .He attempts to construct a close-loop for medical information transmission that connects patients , doctors and the cloud database in real time. The doctors would receive patients alerts and respond before the disease deteriorates into a more severe or costly situation. In his project, electronic monitors were connected to the patient to measure the heart rate and BP. Using blue-tooth the measurements were received by a mobile phone which then transmits them to a cloud database. At the cloud end, a clinical decision system analyzes the measurements using parameters of age, gender, weight, family history and medications in use and consequently evaluates the risks. Warning alerts are then sent to the doctors in case the risk score passes the threshold. This project will be completed by March 2014. If successful the project would have many medical and economic benefits. However it is limited by the fact that strong infrastructures of healthcare IT and wireless communication are required. In this project we would not use the cloud computing technology as the health sector in Kenya has not fully embraced it. At the same time due to cost and time constraints, this research did not focus on using electronic monitors. But the patients were required to get the BP measurements manually and send them using their mobile phones.

This research work is closely related to the one conducted by Alexander et.al (2007). In their work, they proposed to develop and pilot-test a home BP tele-management system that actively engages patients in the process of care. Their research was carried in two phases. Phase 1 involved a series of meetings with the patients and primary care providers in order to gather data to be used in the development of the system. Phase 2 involved enrolling patients in a four month pilot study in order to assess its effectiveness in lowering BP, its acceptability to users, and the reliability of home BP measurements. After the pilot test, the system proved to be effective and was accepted by the patients.

In another research by University of Michigan (2012), they evaluated the impact of automated calls from a U.S.-based server to the mobile phones of patients with high BP in Honduras and Mexico. In this project patients were provided with home BP monitors and were to report about their pressure status, medication use and symptoms during the weekly automated calls. After the pilot test, it was clear that patients who received a weekly 12 minute call for six weeks reported that they understood how to take their medication, that they experienced fewer depressive symptoms and were generally impressed by the care. As a result BP decreased to a large extent particularly to those patients with the dire need for education about management of high BP. This project is limited by the fact information were disseminated through phone calls and it cannot be retrieved for future reference. At the same too long phone calls time provided the patient with too much information which they could be comprehend. In this research work, information dissemination would be through web services and it wase stored in a remote database. It would therefore be possible to retrieve this information when need arise.

A research by Kamrul et al. (2012) had proposed to design and implement a reliable, cheap, low powered, non-intrusive, and accurate system that can be worn on a regular basis and monitors the vital signs and displays the output to the user's cell phone. The project specifically dealt with the signal conditioning and data acquisition of BP. In their attempt to measure BP they combined the methodologies of Electrocardiography to continuously monitor the systolic and diastolic BP. The BP data was transferred to a central monitoring station using a wireless sensor network for displaying and storing. Each of the patients was connected to a remote monitoring system, which allowed the medical staff to track the patient's vital signs. The vital sign readings were then transmitted wirelessly from the patient through a fixed infrastructure of routing nodes to the base station. Depending on the patient's distance from the base station, messages would pass through multiple router nodes to reach the base station. The base station was connected to a host mobile running an android-based GUI to interpret and display the data. Even though the project was to use BMP sensors they were unable to use them because they were unavailable in Bangladesh. Instead the data was input manually. Moreover in their implementation they preferred Android 2.2 operating system version for Android cell phones that addressed performance issues and expands upon several usability features. However since then different versions of Android OS have emerged which addresses performance issues in a better way. In this research project we have developed an android application for BP monitoring using Android 4.2.2 which can able to run on normal android phones as well as smartphones and tablets.

In a review by Azzah et al (2010), they researched to find out the impact of BP telemonitoring on hypertension outcomes. They searched five databases (PubMed, CINAHL, PsycINFO,EMBASE, and ProQuest) from 1995 to September 2009 to collect evidence on the impact of BP telemonitoring on BP control and other outcomes in telemonitoring studies targeting patients with hypertension as a primary diagnosis. In their research fifteen articles were reviewed. Their review found that BP telemonitoring resulted in reduction of BP in all but two studies; systolic BP declined by 3.9 to 13.0 mm Hg and diastolic BP declined by 2.0 to 8.0 mm Hg across these studies. These magnitudes of effect were comparable to those observed in efficacy trials of some antihypertensive drugs. Although BP control was the primary outcome of these studies, some included secondary outcomes such as healthcare utilization and cost. Evidence of the benefits of BP tele-monitoring on these secondary outcomes was less robust. Compliance with BP tele-monitoring among patients was favorable, but compliance among participating healthcare providers was not well documented. In order to determine which articles needed to be included in the review (inclusion criteria): a community-based empirical study that involved a defined BP tele-monitoring technology; the number of subjects was at least 20; BP was self-measured and transmitted by participants; participants were identified as essential (primary) hypertensive patients (regardless of presence of other chronic diseases/comorbidities); and study examined patient and healthcare outcomes. Some of the reviewed studies suggested that the potential of BP 3 to facilitate achievement of BP control can be enhanced by its use to manage medications and to increase patient self-confidence, knowledge, and involvement in their own care management. Equally important, they noted that BP tele-monitoring affords healthcare providers with reliable, frequent BP information, which offers opportunities for timely interventions in a timeframe that is not linked to routine office visits.

A research by Luis et al (2013) proposed a Mobile Personal Health System for Ambulatory BP Monitoring. In their project they developed an ARVmobile v1.0 which was a multiplatform mobile PHM application for ABP that had the potential to aid in the acquisition and analysis of detailed profile of ABP and HR improve the early detection and intervention of hypertension, and detect potential abnormal BP and HR levels for timely medical feedback. The PHM system consisted of ABP sensor to detect BP and HR signals and smartphone as receiver to collect the transmitted digital data and process them to provide immediate personalized information to the user. Android and Blackberry platforms were developed to detect and alert of potential abnormal values, offer friendly graphical user interface for elderly people, and provide feedback to professional healthcare providers via e-mail. ABP data were obtained from twenty-one healthy individuals aged 51 years and above to test the utility of the PHM application. The ARVmobile v1.0 was able to reliably receive and process the ABP readings from the volunteers. The preliminary results demonstrated that the ARVmobile 1.0 application could be used to perform a detailed profile of ABP and HR in an ordinary daily life environment, bedsides of estimating potential diagnostic thresholds of abnormal BP variability measured as average real variability. However with the use of sensors it is likely to increase the cost of BP monitoring. This is because such systems are very expensive and therefore may be unaffordable to the patients. Moreover in order to truly deliver personalized health care, the biosensors must be invisible to the user, avoiding activity restriction or behavior modification. Biosensors should be small and lightweight, which depends largely on the size and weight of batteries.

Janet (2011) carried out a research on prevention and management of hypertension focused on knowledge and attitudes of women of childbearing age. She stated that in developing countries prevention of high blood pressure is recognized as the controlling key to hypertension. Identification of the level of knowledge and attitude of the population is however, an optimum steps to prevention. The purpose of her study was to assess the level of knowledge of women of child bearing age on preventive measures of high BP. Quantitative descriptive method was used for the study. Hundred participants both closed and open ended questionnaires in Eastern region, Ghana. Her results suggested that general knowledge of high BP is adequate. Participants lacked understanding in the etiology of high BP. For instance 82% considered high level of stress, tension or over thinking as hypertension. She stated that focus should be on the public's education in understanding high BP by helping to control it. Moreover findings could assist in health planning programs on the knowledge and attitudes of the population. At the same time medical specialists need to educate the public on the effect of high BP disease. Awareness must be created that detection of hypertension is only by screening. The effect of salt reduction can be emphasized on preventing high blood pressure that may intend prevent other cardiovascular diseases. Medical specialists can also increase the individuals control over own live through self-empowerment tool and educational approach. In this research work we have developed mobile systems that can help patients self-manage their hypertension condition as well provide information to create awareness about the disease to the patients. Apart from the quantitative method used by Janet we have also used the qualitative method to measure the perceptions of the patients in using the system to manage their condition.

Another research on mobile in Kenya was carried in 2011 by WHO.A Health MOVE-IT was a project that introduced the use of mobile phone technology to speed up and improve the registration of births and deaths in three districts. The project was using RapidSMS, a free and open-source framework for dynamic data collection. In this project, mobile phones text messages were to be used to record vital events at the community level. The community health worker would use a SMS to notify a registration agent about when a birth or death takes place in an area. In this research work, we have focused on hypertension self-management and data was not only sent using SMS but also through web services.

UCRC is a non-governmental organization located in Ugunja town, Ugunja Division, Ugunja District of Siaya County in Western Kenya region. They launched a mobile health project, FrontlineSMS, in collaboration with St.Pauls Methodis Health Centre in Ugunja and KENTEL. The project was aimed at researching how mobile phones can be applied in managing HIV/AIDS related issues. The project was aimed at developing a database-driven web application integrated with SMS to enable CHW, PLWA, their families, support groups, and home-based care providers to increase prevention literacy, general awareness, dialogue and interaction among healthcare providers and their clients. They demonstrated how frontlineSMS tool could be used to send bulk SMS to PLWA. The project is still operational up to date.

MedAfrica is another project that was done by Shimba technologies, a Nairobi-based company founded by two locally educated entrepreneurs, Stephen Kyalo and Keziah Mumo. They developed a web-based application that could help users get information about health information in Kenya. This platform provides a suite of health services (health widgets) such as symptom checkers, first-aid information, doctor & hospital directories as well as relevant alert services. The main objective was to make healthcare information affordable and accessible to Kenyans. The application is available in several widgets which include lists of available hospitals, certified doctors and pharmacies in the country. Users are given the choice on the widgets they wish to download. It can be accessed directly through Safaricom portal on the website.

2.1 CONCEPTUAL DESIGN

The specification of this research project was to deliver a smart medical system for hypertension monitoring based on mobile platform. The system was to consist of the following components:-

a. Patient's data collection component
b. Data repository and Decision support component
c. Alert generation and transmission component
d. Physician reporting component

After taking the BP readings, the patients would feed it on his/her mobile phone and then transmit that data to a secure remote database. Patients can be able to retrieve the stored data on their mobile phone in a tabular or list format. After the readings are sent a number of clinical rules would be applied in order to determine the BP status and generate automatic alerts to the doctor and also the patient.

From his/her mobile phone, the doctor would retreive patients data from the remote database, analyze it and then provide feedback to the patients on the course of action.

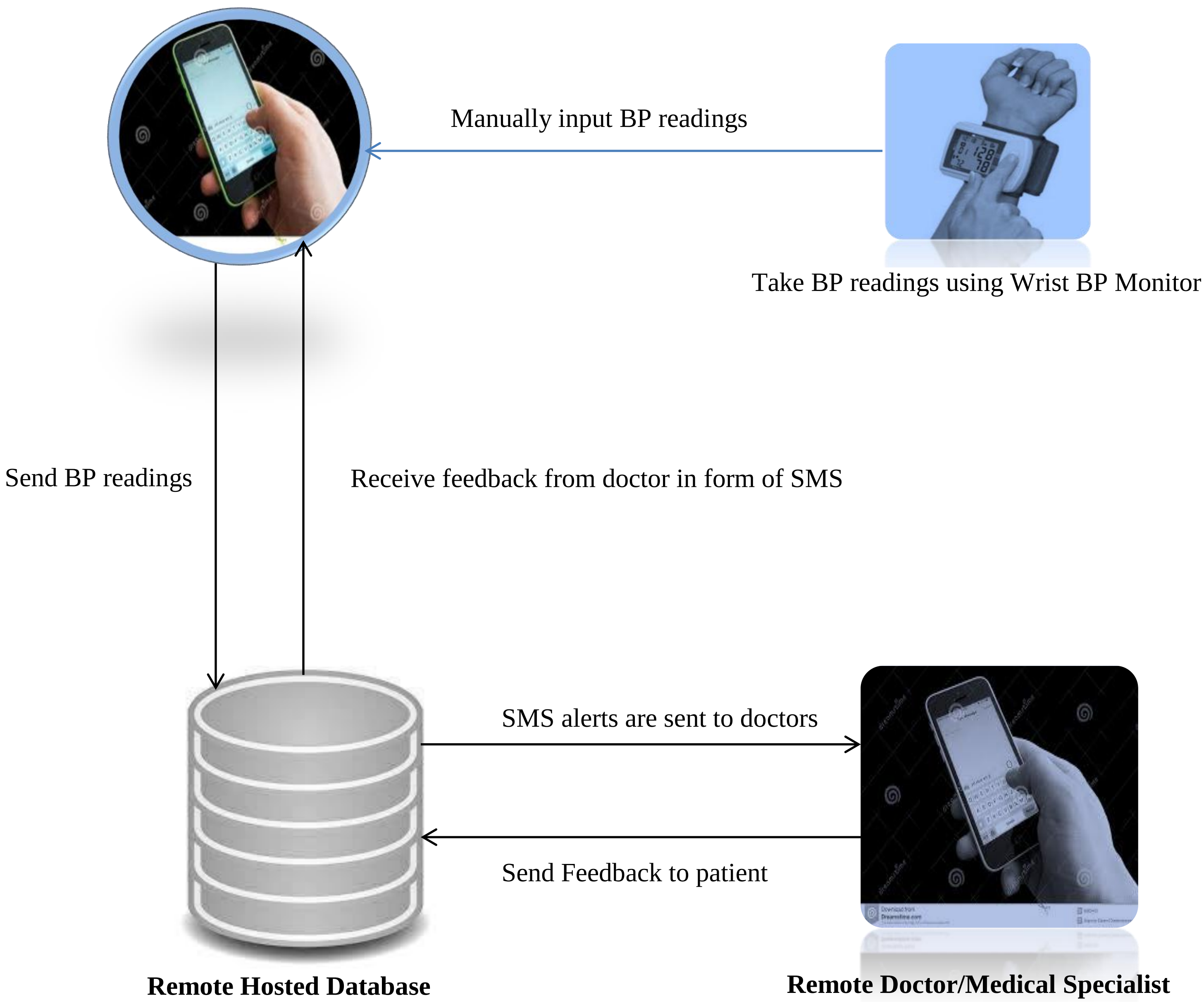

Figure 1: Conceptual design of the Mobile Tele-medicine system

2.2 USABILITY EVALUATION

In order to ensure the system is successful, first is to ensure that the system is usable so that the users can achieve the target goal easily. The usability is important in e-health system because if the system is not usable, the patient will never get the benefit of the system (Kamrul, Nova and Saifu, 2012). Cost implications are important in evaluation mhealth applications (Q. Le, 2007).

As the target user for this mobile application is hypertension patients, the design was easy to use and flexible. We took into account that the patient may have eyesight problems or may be an elderly. Therefore we adhered to mobile application usability check list, in the user interfaces design (www.keepitusable.com/keepitusable-mobile-app-usability-checklist.pdf).

Table 1: A table showing usability evaluation checklist

No.	Standard	Application in my project
1.	Clear and consistent way to go back on every screen	Back button is applied in the activity to go one step back word. Home button is applied in the activity to go the home screen.
2.	Labels and buttons text are clear and concise	I will avoid using much word to explain labels and buttons. I will just use the simplest word and well known to the public.
3.	Retains overall consistency and behavior with the mobile platform	Android phones have touch screens. I will therefore take this consideration in the design and ensure that the touch are working well in the application
4.	Minimalist design - excess features removed	I will not offer more tasks than the minimums the application specification needs.
5.	Content is concise and clear	I will ensure that advices, recommendations and alerts are understandable and easy to apply.
6.	Provides feedback to the user of system status	The system will tell the patient if his/her SMS was send successfully or not. The patient will also get notifications in form of SMS or Web inbox messages.
7.	Number of buttons / links is reasonable	Only significant and reasonable buttons/links shall be used.
8.	UI elements provide visual feedback when pressed	The labels shall prompt the users about what to insert. If the patient put invalid input, he/she will also be prompted about this.
9.	Colors used provide good contrast	In the design, I will put in into consideration the patient cases. Minimal colors, at least 3, will be

		used. These colors will be consistently used to help the patient remember tasks easily.
10.	Colors used provide good readability	Using wooded, striped, nor dotted icons or buttons in the design will be avoided
11.	Font size and spacing ensures good readability	Since the patient may have vision problems, medium font size that is easy to read will be used.
12.	If changes can be made, ensure there is a Save button	The patient or medical specialists can alter some specific information related to them. In each activity there is a Save button that applies the changes and connect to the database to store the results.
13.	Present users with a confirmation option when deleting	Any action that will involve deletion will have a confirmation dialog box.
14.	Speak the users' language (not technical)	Simple language that is understandable to the user will be used.
15.	Error messages are free of technical language	Use of technical words to illustrate the errors will be avoided Simple language that is understandable to the user will be used.

2.3 SYSTEM STRENGTHS

The design of this system was based on the client server architecture. It has numerous strengths namely:-

Resource sharing: This application uses a remote database hosted on a remote server. This means that the resources in this database are shared between the patient-side application as well as doctor-side application.

Database security/Data integrity: Data stored in the remote database is very critical. As a result different user rights for system access were assigned. For instance the patients will be able to insert medical data but not edit or delete. The medical specialist is responsible for entering or updating critical medical information, such as: BP parameters, urgent appointment etc. In short this ensures the right person is dealing with the right information.

Cost benefit: The implementation cost of this system is system is feasible. Most of the resources required are readily available.

Scalability: This application can be easily integrated with already existing applications being used in the health institutions like EHRs.

CHAPTER THREE: METHODOLOGY

In this chapter the research methodology used in the study is described. The geographical area where the study was conducted, the study design and the population and sample are described. The instrument used in data collection, including methods implemented to maintain validity and reliability of the instrument are described.

3.1 RESEARCH APPROACH AND DESIGN

In this research Participatory Action Research Design was used. Action research is a term used to describe research in which the researcher work explicitly with and for people rather than undertake research on them. The main pros of action research is that it focuses on generating solutions to practical problems and its ability to empower practitioners by engaging them in the research and subsequent development or implementation activities.

The reason for using qualitative approach is because the research questions could not be answered using quantitative methods. The nature of my study requires profound access to expert information which could not be acquired through a standardized questionnaire with predetermined answer categories as used in quantitative approach. The aim was not to measure or quantify something, but to improve understanding of the phenomena by obtaining information from experts on personal experiences and critical incidents.

3.2 RESEARCH SETTING

In order to collect valid and trustworthy data, participant's involvement approach was used. This research study was conducted in Kirinyaga Sub County.

3.3 STUDY POPULATION AND SAMPLE

In this study purposeful sampling was used for the recruitment of participants. Purposeful sampling involves selecting research participants according to the needs of the study. The researcher chooses participants who give a richness of information that is suitable for detailed research .The selection criteria for inclusion will be professional medical doctors and patients who can articulate their experiences related to hypertension.

In order to determine the sample size to be used in the study DELPHI technique was used. As a rule of thumb Clayton (1997) proposes 15 to 30 people for homogeneous groups. However Ziglo (1996) stated that 10 to15 people produce good results in a homogeneous panel. On the other hand, for heterogeneous groups, that is, people with expertise on a topic but from different social or professional groups, Clayton (1997) reported that only 5 to10 experts are needed. Gordon (1994) indicated that most Delphi studies use panels of 15 to 35 people. It was concluded that the larger the group, the more reliable their aggregate judgment will tend to be. However, groups beyond sizes of 20 to 25, showed only minimal improvements in reliability. It appeared that panels of experts who also had a diversity of perspectives produced more accurate judgments than experts who were more homogeneous.

From the above literature, the study population used in this research study involved one professional medical doctor and 20 hypertensive patients.

3.4 DATA COLLECTION

Data collection is the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes. Accurate data collection is essential in order to maintain the integrity of research.

In this research study data collection was divided into 3 phases:-

1. The first phase involved collecting data from medical specialists /doctors about the parameters required for BP management. This data was useful in deriving the design principles of the proposed system. To collect this data semi-structured direct and telephone interviews were used.
2. The second phase involved conducting system and performance testing on the proposed system and collect data on Uptime, Downtime, MTBF, System Reliability Responsiveness and System Availability.
3. The third phase involved collecting data from patients and medical specialist after testing the proposed system. These helped in gathering information about patients' experience with high BP and probably seek their opinions on the usability and utility of mobile phone self-monitoring system.

In order to collect reliable and valid information for usability and utility patients and medical specialist were actively engaged using the E-Delphi method.

E-Delphi Method

The Delphi method was developed in the 1950s by Dalkey and Helmer at the RAND Corporation (Gordon, 1994). The intent of the Delphi, as it was originally conceived, was to create a method, using expert opinions, to forecast long-range trends related to the military potential of future science and technology and their effects on political issues.

Delphi involves an iterative process that involves using a series of questionnaires to collect data from a panel of experts. Through multiple iterations it is possible to achieve a convergence of opinion on a specific area under study. The Delphi is a flexible method built on four basic features: structured questioning, iteration, controlled feedback, and anonymity of responses (Jerry, 2008).

One disadvantage of traditional DELPHI method is being time-consuming and laborious. This bottle-neck can be resolved with the use of an electronic version of the Delphi method, called the **E-DELPHI.**

3.5 SYSTEM DESIGN AND DEVELOPMENT

In order to successfully develop the proposed system, WATERFALL methodology, which is a linear approach to software development, was used. A true Waterfall development project follows distinct stages of software development, and each stage generally finishes before the next one can begin.

Waterfall methodology was chosen for 3 reasons:-

1. Since the approach is linearly structured, it would be easier to measure project progress by reference to clearly defined milestones.
2. It would be possible to accurately estimate the total cost of the project after the requirements have been defined (via the functional and user interface specifications).
3. Due to limitation of time resource, it would not allow for any constant system changes during development. Therefore the development phase would be faster as it would strictly follow the initial requirements gathered.

Data collected from phase 1 was used in deriving the design principles of the system. According to British hypertension society it is impossible to provide a definition of hypertension as BP is a continuous variable within the population, having a skewed normal distribution. As a result in the design stage, the following parameters were used as the yardstick to measure the hypertension level of the patient.

Table 2: A table showing hypertension stages

BP Category	Systolic mm Hg (upper #)		Diastolic mm Hg (lower #)
Normal	less than 120	and	less than 80
Prehypertension	120 – 139	or	80 – 89
Stage 1 hypertension (High BP)	140 – 159	or	90 – 99
Stage 2 hypertension (High BP)	160 or higher	or	100 or higher
Hypertensive Crisis (Emergency care needed)	Higher than 180	or	Higher than 110

3.6 PILOT-TESTING OF THE SYTEM

3.6.1 PERFOMANCE TESTING

In order to build a high performing mobile application first is to ensure that it is stable and responsive. Crittercism, a mobile application monitoring company based in San Francisco, California monitors over 30 billion mobile app sessions and have found that the two most important mobile app performance metrics are uptime and responsiveness. Since this tele-medicine system is a mobile application it therefore needs work all the time. As a result performance testing was conducted on the system for a period of 5 days in order to determine Uptime, Downtime, MTBF, Reliability, Response Time, and Availability before it was deployed to the users.

1. **Uptime vs. Downtime**: This is a measure of the time a system has been working and available. Alternatively, it represents the percentage of time a system is successfully operational. On the other hand, downtime refers to when a system is not working.
2. **MTBF**: This the predicted elapsed time between inherent failures of a system during operation. It can be calculated as the arithmetic mean (average) time between failures of a system. It consists of the following parameters:-

- MTTF: This is the difference of time between two consecutive failures or average time between observed failures.
- MTTR: This is the time required to fix the failure.
- MTBF= Sum of the operational periods / number of observed failures

3. **Reliability**: This is the probability that a system will function as expected without failure(s) within a specified period of time. It measures the system's ability to function, given environmental conditions, for a particular amount of time. It is measured in terms of MTBF.

   Reliability = MTBF / (1+MTBF)

4. **Response Time**: This is the time that elapses for a server to process user request and send result to the user.
5. **Availability**: Is the probability that the system is operating at a specified time t. or it is the measure of the probability that the system will be up.

   Availability = MTBF / (MTBF+MTTR) or Uptime/ (Uptime + Downtime)

In order to measure the above metrics several trials were conducted. At least 100 trials were conducted each day, for 5 days. The independent variable was testing time while the dependent variables were the response time, time to repair and downtime.

Why the number of trials: The determination of the number of trials in this study was based on 3 rules of thumb by Dr. Shawn:-

Rule of Thumb #1: In general, for most experiments that involves studying how one variable depends on another, conduct as many trails as you reasonably can. Of course, the goal is to change the independent variable enough to cause a measurable change in the dependent variable, but beyond that it's good to get as much data as you can to the limits of your time, money, materials etc.

Rule of Thumb #2: Spread your measurements out evenly between the smallest value of the independent variable, and the largest value you are testing. For example, if your independent variable starts at zero and goes to say 100 units, you might select the values 0, 20, 40, 60, 80, and

100 to test. This strategy provides the best way to establish the relationship between the independent and dependent variables over the range of values you are studying in your experiment.

Rule of Thumb #3: Whatever you do, make sure you conduct at least 5 trails. This should not only be able to establish whether or not the dependent variable changes in some regular fashion with the independent variable, it should also let you see if the data fall along a straight line or a curve.

3.6.2 SYSTEM TESTING

Before deploying the mobile tele-medicine system, system testing was done to confirm that all code modules worked as specified, and that the system as a whole performed adequately on the mobile device. Reasonable test cases were used.

3.6.3 USABILITY AND UTILITY TESTING

In this phase, 20 patients and one medical specialist were enrolled for the study for duration of 4 weeks to assess the usability and utility of the mobile tele-medicine system. To be able measure the usability of the system SUS questionnaire was administered to all patients. Utility on the other hand, was measured using a tailor-made questionnaire.

Patients were required to take at least 3 BP readings per day, in the morning hours, mid-day hours and evening hours respectively, for a period of 4 weeks. The doctor would receive an SMS notification for every reading sent by the patients. On the other hand the doctor provided feedback to the patient depending on the status of their BP. The response was in form of appointment request, general health tips or change of medication.

3.7 POST-STUDY ANALYSIS

Data analysis is process of inspecting, cleaning, transforming, and modeling data with the goal of discovering useful information, suggesting conclusions, and supporting decision making. Also it is a body of methods that help to describe facts, detect patterns, develop explanations, and test hypotheses.

In the attempt to analyze data from this research study we used the following methods:-

Content analysis: This method categorizes, synthesizes and interprets qualitative text data by describing. It was be used to analyze interview data. This involved giving descriptive account of the data. Data was reviewed after the interview, analyzed, and interpreted into themes and meanings to lay the foundation of codification.

Quasi-Statistics: This method involves counting the number of times/ frequency of occurrence of something and report the times found in numerical form.

This method was used to analyze data collected from the testing of proposed system.

3.8 DATA VALIDATION STRATEGIES

In order to maximize the trustworthiness of research findings we intend used **Participants Involvement Approach:** This involves feeding findings of the analysis back to the participants, through focus groups for example, and assessing how far they consider them to reflect the issues from their perspective.

In this research, participants were actively engaged using the E-DELPI technique.

CHAPTER FOUR: PROTOTYPE IMPLEMENTATION

In this chapter we present a mobile application prototype that can help patients with high BP manage their condition at home. The development of this prototype was based on the understanding from the literature review and the scenario of how BP monitoring and reporting systems work in the developing world.

We have also introduced the service-orientated system architecture, the software design and implementation of each component used in the system and communication technologies among different components. Since the prototype was to be used on smart phones, Java-Android for mobile client and PHP for server side communication was used. The technologies that were used for development of the proposed prototype are:

- Java SDK and Eclipse IDE for creating Android executable application
- Java which a general-purpose, concurrent, strongly typed, class-based object-oriented language
- XML for designing android interface layouts
- MySQL RDMS for database administration.
- PHP for handling server side processing

4.1 TECHNOLOGIES

4.1.1 MYSQL RDMS

In the attempt to store BP data sent by patients, MySQL database was used. MySQL RDMS is the world's most popular open source database server, enabling the cost-effective delivery of reliable, high-performance and scalable Web-based and embedded database applications. It very commonly used in conjunction with PHP scripts to create powerful and dynamic server-side applications.

In the attempt to create the database for the application MySQL browser IDE was used. MySQL Query Browser is a graphical tool provided by MySQL AB for creating, executing, and optimizing queries in a graphical environment. It is designed to help you query and analyze data stored within your MySQL database.

4.1.2 PHP

In order for the android mobile client to connect with the MySQL database, server scripting language, PHP, was used. PHP is a general-purpose scripting language that is especially suited to server-side web development where PHP generally runs on a web server. Any PHP code in a requested file is executed by the PHP runtime, usually to create dynamic web page content.

PHP is integrated with a number of popular databases, including MySQL, PostgreSQL, Oracle, Sybase, Informix, and Microsoft SQL Server.

4.1.3 ECLIPSE IDE AND ANDROID SDK

Android SDK is software development kit that enables developers to create applications for the Android platform. The Android SDK includes sample projects with source code, development tools, an emulator, debugger, required libraries, relevant documentation for the Android APIs, tutorials for the Android OS to build Android applications. Applications are written using the Java programming language and run on Dalvik, a custom virtual machine designed for embedded use which runs on top of a Linux kernel.

Even though the SDK can be used to write Android programs in the command prompt, the most common method is by using an IDE. The recommended IDE is Eclipse with the Android ADT plug-in. Other IDEs, such as NetBeans or IntelliJ, can also work. Most of these IDEs provide a graphical interface enabling developers to perform development tasks faster. Since Android applications are written in Java code, a user should have the JDK installed.

4.1.4 ANDROID FRAMEWORK

This is an android software stack that describes how android device components interact. It is divided into five layers consisting of the Kernel and low level tools, native libraries, the Android Runtime, the framework layer and on top of all the applications.

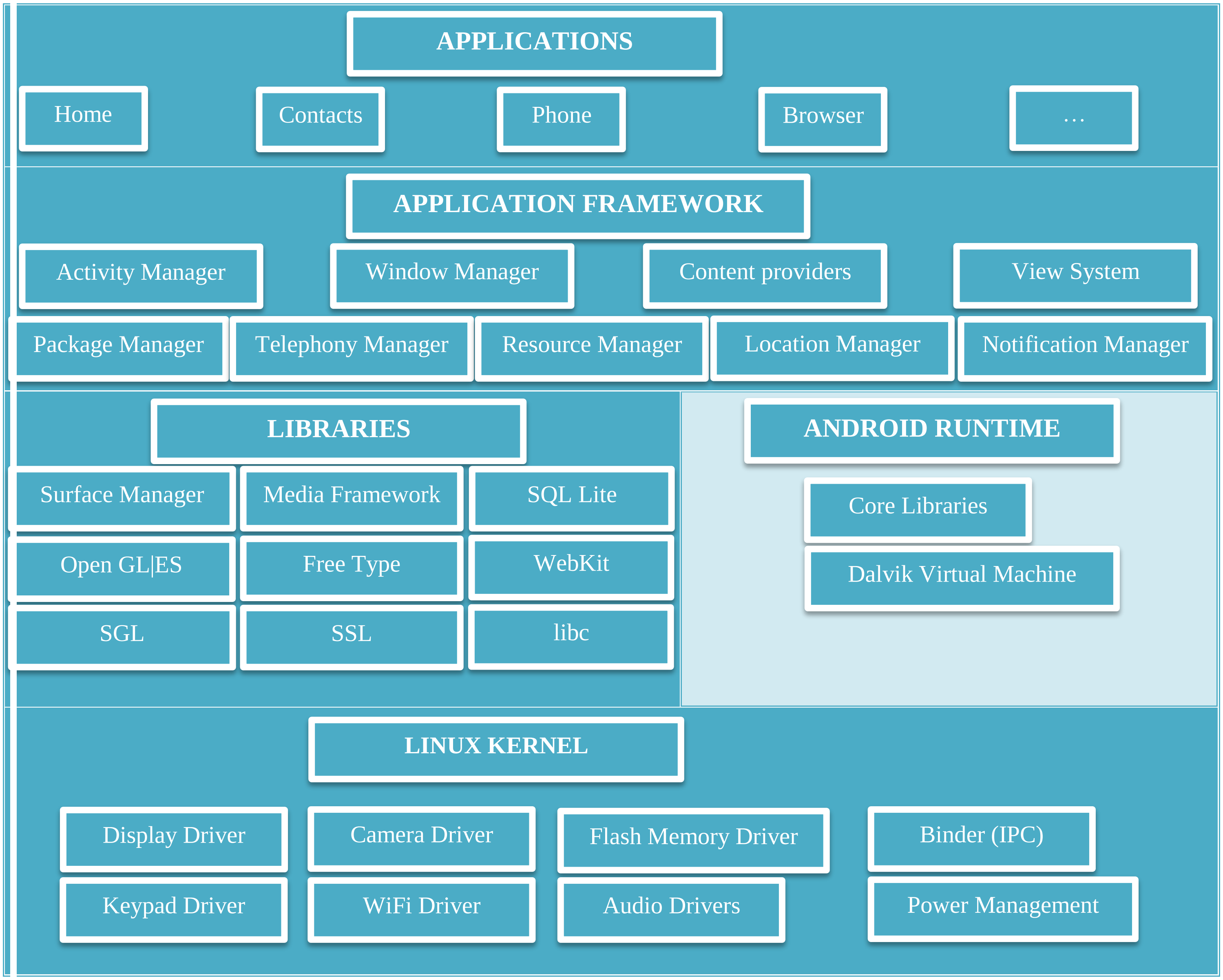

Figure 2: Android system framework

4.2 SYSTEM FUNCTIONALITY

The functions of the tele-monitoring system can be divided into three categories namely:-data collection and transmission, data presentation/visualization and SMS alert generation.

4.2.1 DATA COLLECTION

Data collection is mainly done through the android application interface. On successful login the patient's accesses the BP READINGS tabs from where he/she can input the vital parameters collected from the Wrist BP Monitor and send them to a remote database hosted on a remote server. Data transmission is possible after an HTTP connection has been established with the webserver. PHP is responsible for handling server-side processing. The data collected is inserted into **bp_readings** table within the **MHYPER** database.

4.2.2 DATA PRESENTATION/VISUALIZATION

All the system data is stored on a remote database hosted on a remote server. For instance when a patient/doctor/admin tries to login, an HTTP connection is established with the webserver. The PHP routine retrieves username and password from the users table and sends it to the android client inform of JSON object. Then the android application decodes the received JSON object and displays a status message.

On the other hand, when a doctor wants to view the BP history of a patient, he will select a particular patient and request for information from the webserver. The PHP routine retrieves the patient BP data from the bp_readings table based on the patient ID and encodes it into JSON object. The android client will then decode the information using the JSON Parser class and display it on a ListView widget or Table layout.

4.2.3 SMS GENERATION

The android application also generates SMS alerts. These alerts are generated from the patients and doctors module. For the patients, SMS are generated at the point of sending the BP parameters. Every time a patient sends the BP readings the system notifies the doctor. The doctor can then analyze the patients BP history and provide feedback on the course of action. The feedback is sent in form of SMS and the patient will receive alert on his/her mobile phone.

4.3 SYSTEM DESCRIPTION

4.3.1 CLIENT SIDE

The client processing is handled by the android platform. The client is accessed by the patient, doctor or administrator. Mobile device supporting android operating system was used in the actual testing of the system. During the development process testing was achieved by setting up an AVD emulator to run the android application.

4.3.2 SERVER SIDE

In order to handle server side processing an open source web server (WAMP) which can operate on any operating system such as Windows, Linux and UNIX is used. The Web server allows a computer to host Web pages. In the local testing process of the system we used WAMP version 2.2 as a web server.

4.3.3 DATABASE ADMINISTRATION

The system database was built on using MySQL database. Database creation and management was achieved using PHP MyAdmin which is a component of WAMP server. The database is called **MHYPER** and it contains the 3 tables: - users, bp_reading and appointment table. The users table would contain basic and login information about the different users registered by either the administrator or doctor to access the system. On the other hand, the bp_reading table would handle all the vital data (BP information) sent by the patient. The appointment table would handle all the appointment requests made by either the doctor or the patient.

As stated earlier this study proposed a mobile tele-monitoring system that provides an end-to-end solution:

1. Through enabling patients to regularly collect and transmit their BP readings through their mobile phones to doctors, at the comfort of their premises.
2. Through enabling doctors access and analyze patients' BP data on their mobile phones.
3. Through enabling doctors to manage the chronic condition by providing feedback on the BP status to the patients remotely.

Therefore in this mobile tele-medicine system patients were able to collect their BP via the Android application interface. The data collection form consists of three parameters:-systolic, diastolic and pulse rate readings collected from the BP monitor machine. After they collect their data, they would send it to a remote central database server. When any one of the vital parameters of the patient goes out of normal range then the system automatically send a SMS Alert to the doctor's mobile. The doctor can then analyze the patient's BP history and respond immediately.

4.4 SYSTEM ARCHITECTURE

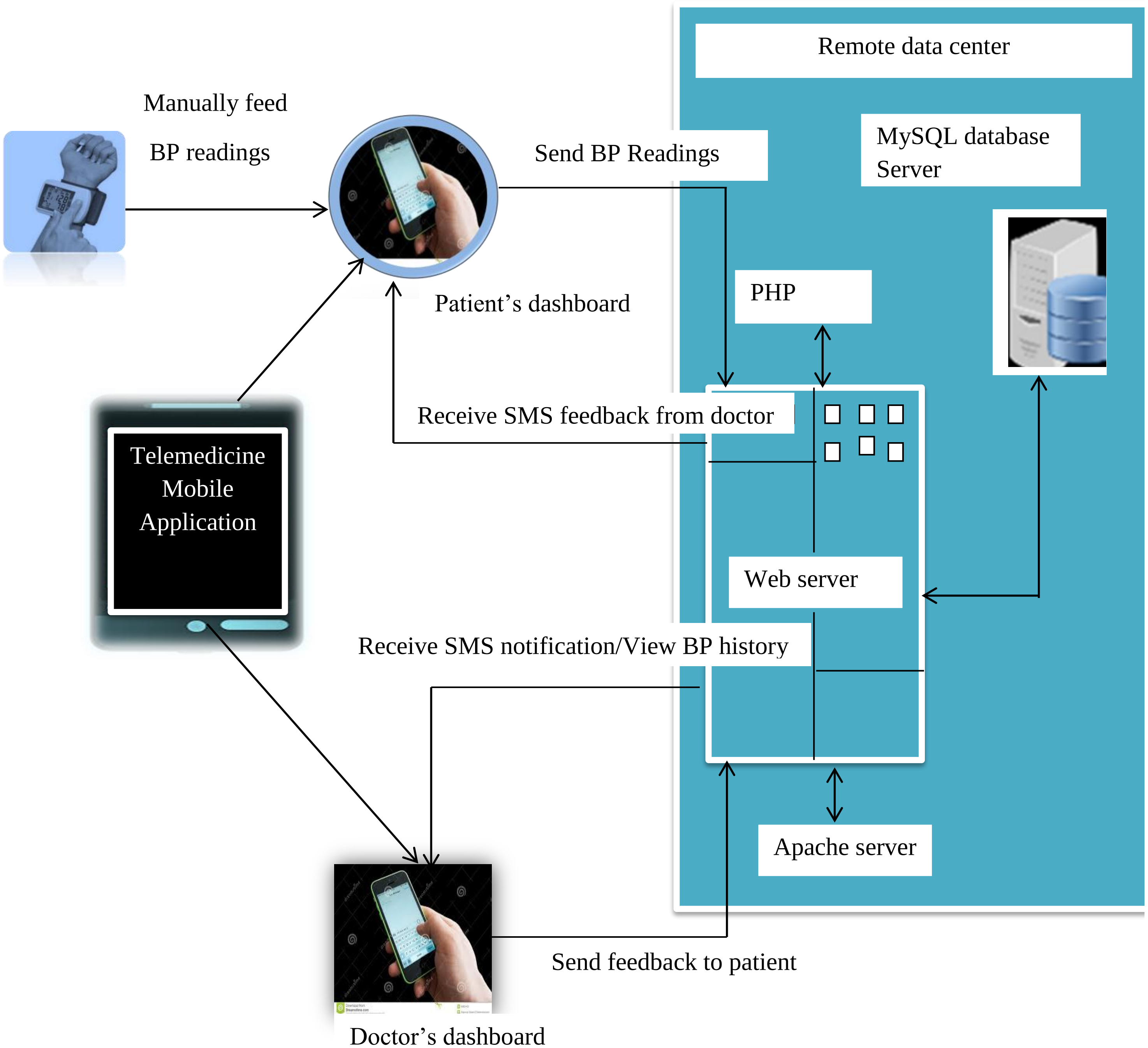

Figure 3: Actual Mobile Tele-medicine system architecture

Figure 3 shows the basic architecture of the mobile tele-medicine system for hypertension management. The system consists of different components such as web server which is basically known as a WAMP server and it is completely open source. This web server is the central part of the entire system.

Before using the system all the users must be registered via the user registration interface in the mobile application. Firstly the administrator will register a doctor and provide him/her will a registration id and password. The doctor would then login the system using the credentials given in order to access the doctors module. On a successful login the doctor would then register all the patients who shall be reporting to him. He also would provide each patient with a unique username and password. The patient would use the details given to access the patient's module. Under the patient's module, the patient would access a form for sending BP readings. Vital parameters collected are systolic, diastolic and pulse rate readings. The data collected from patients via the mobile application is sent to the web server. The Web server will then process the collected data and stores it to the MySQL database server.

Every time the patient sends the vital parameters the doctor would receive a notification in form of an SMS. The doctor would review the history of the patient's BP and consequently provide feedback on the condition.

4.4 PROTOTYPE DESIGN

This section describes the implementation of the Mobile Tele-monitoring system for hypertension management. This application has been developed purely on android platform. The Android SDK provides all the library packages which are used to interact with hardware and make the Android application. The application is coded in Java language and Eclipse IDE provides the developing environments

This tele-monitoring system is purely an executable android application which is installed on the mobile phone. This application handles all the client-side processing. The client can be a patient, doctor or an administrator. When the administrator logs in to the system he/she is able to access the administrator's dashboard from where he/she can register new doctor and view all the users of the system. On the other hand, the doctors will access the doctor's dashboard where he/she can register new patients and review the vital signs of each patient and provide feedback. The patients are able to access the patient’s dashboard from where they can send BP readings and also view their BP history.

The development of this prototype was based on Google Android operating system. Android API 4.2.2 (Jelly bean) was used. Jelly bean is the latest refinement by Google and it now the world's most popular OS on new smart phones. Android 4.2.2 is only found on very few devices including Google Nexus 4 phone, Google Nexus 7 and Google Nexus 10.However the mobile application was able to run on Android 2.3.

Android Manifest File

Every android application must have an AndroidManifest.xml file (with precisely that name) in its root directory. This file presents essential information about the application to the Android system, information the system must have before it can run any of the application's code. Among other things, the manifest does the following:

- ❖ It names the Java package for the application. The package name serves as a unique identifier for the application.
- ❖ It describes the components of the application — the activities, services, broadcast receivers, and content providers that the application is composed of. It names the classes that implement each of the components and publishes their capabilities (for example, which Intent messages they can handle). These declarations let the Android system know what the components are and under what conditions they can be launched.
- ❖ It determines which processes will host application components.
- ❖ It declares which permissions the application must have in order to access protected parts of the API and interact with other applications.
- ❖ It also declares the permissions that others are required to have in order to interact with the application's components.
- ❖ It lists the Instrumentation classes that provide profiling and other information as the application is running. These declarations are present in the manifest only while the application is being developed and tested; they're removed before the application is published.
- ❖ It declares the minimum level of the Android API that the application requires.

- ❖ It lists the libraries that the application must be linked against.

4.4.1 INTERFACE LAYOUTS

During Android application development the View and View Group objects are used to build the user interface. A view object represents data structure whose properties store the layout parameters and content on a given specific area of the screen. The layout for different activities in an application can be defined using the XML based layout file.

This application consists of a number of XML based layout files for different user interfaces namely: - activity_admin_main.xml, activity_doctors_main.xml, activity_patients_main.xml, activity_register_user.xml, activity_send_bpreading.xml, activity_login.xml etc. Each of the XML layout file is linked to a certain Activity class files. Some Activity class files include AdminMainActivity, DoctorMainActivity , PatientMainActivity, RegisterUserActivity, SendBPReadingActivity, LoginActivity etc. Code segment of all the class files and XML files are given in Appendix section. When the application is launched the LoginActivity class is called. This class is implemented as the first screen in the AndroidManifestfileand and is represented by the activity_login.xml layout file.

In the login screen there are several components. First it consist of 3 radio buttons showing different user categories i.e. whether a patient, doctor or admin. Then there are two edit texts for username and password respectively and a login button. When the Administrator enters the login credentials and clicks on the Login button AdminMainActivity is called as represented by the activity_doctors_main.xml file. If the credentials were correct he/she would then access the admin dashboard. On the other hand the doctor and patient would access the doctor's dashboard and patient's dashboard respectively.

4.4.2 PROCESS FLOW

When any users launch the android application, a login screen is started. This screen contains 3 radio buttons for user categories and two edit texts for username and password. For instance if the patient enters the login credentials and clicks on the login button a web connection is established with the remote PHP sever. The username and password are then sent to the server for validation. If the credentials are correct, the server sends a successful login message in the form of JSON objects to the mobile device. The application then launches a welcome screen and then starts the patient's dashboard. The patient's dashboard consists of BP READING, APPOINTMENT and BP HISTORY tabs. On the BP READING tab the patient will be able to enter the BP readings and send them to the remote server. The APPOINTMENT tab provides a form where the patient can book an appointment with the doctor if need arises. On the BP HISTORY tab the patient to view his/her BP history.

On the other hand, the doctors will access the doctor's dashboard. The doctor's dashboard consists of REGISTRATION and PATIENTS tabs. The REGISTRATION tab will be used for registering new patients. The PATIENTS tab will show a list of patients from where the doctor can be able to review the BP history of each patient and provide feedback.

The administrator will access the admin dashboard. This consists of REGISTRATION and USERS tabs. The registration TAB is for registering new users while the USERs tab will show a list of all registered users.

Mobile Tele-monitoring System Process diagram

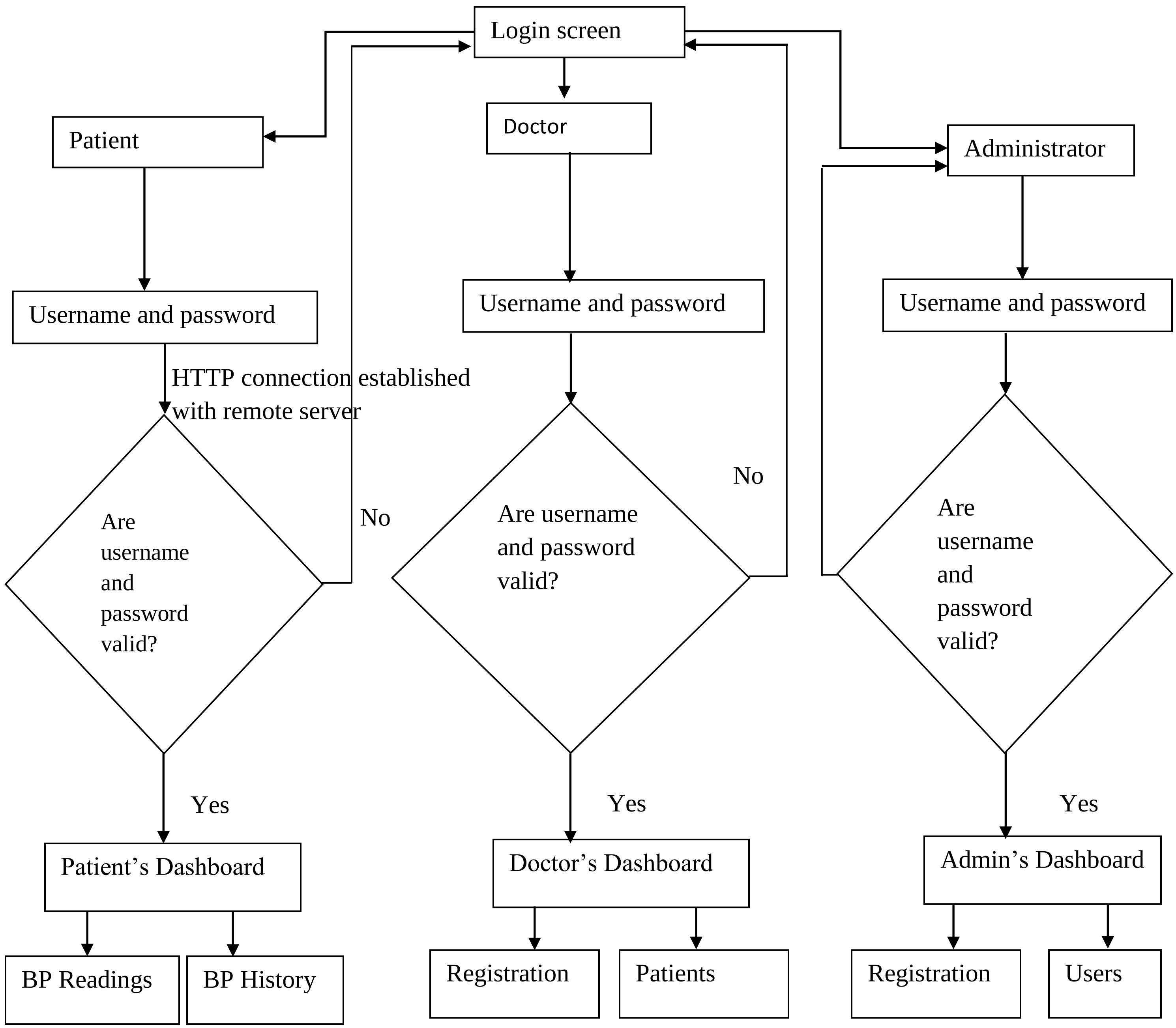

Figure 4: Mobile Tele-monitoring System Process diagram

LOGIN MODULE

In the development of this module, eclipse IDE was used in the design of the XML interface layouts and writing Java code. The prototype was tested in a both Android virtual device and real device. I retrieved the executable Android file (MHYPER.apk file) from the project folder (bin sub folder) and installed it in a real Android device. In this study, I have tested this prototype on Android mobile phones.

This module consisted of the following items:-Radio buttons for patient, doctor and admin. This will help each of the different user access a different module altogether. For patient they would access the Patients module, doctors would access the doctors module while the administrator would access the admin module.

The login screen also has a username and password edit text and a login button.

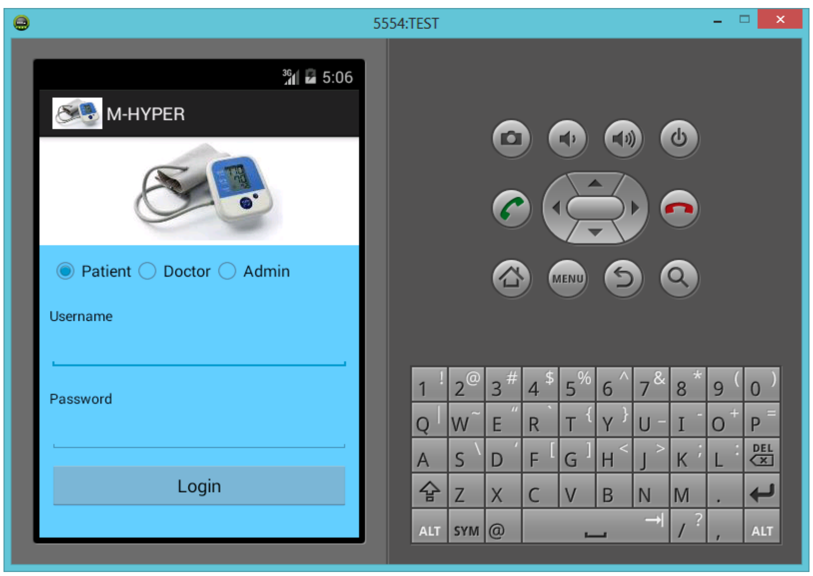

Figure 5: Login Design on Eclipse AVD

Patient Login process on Real Android Device

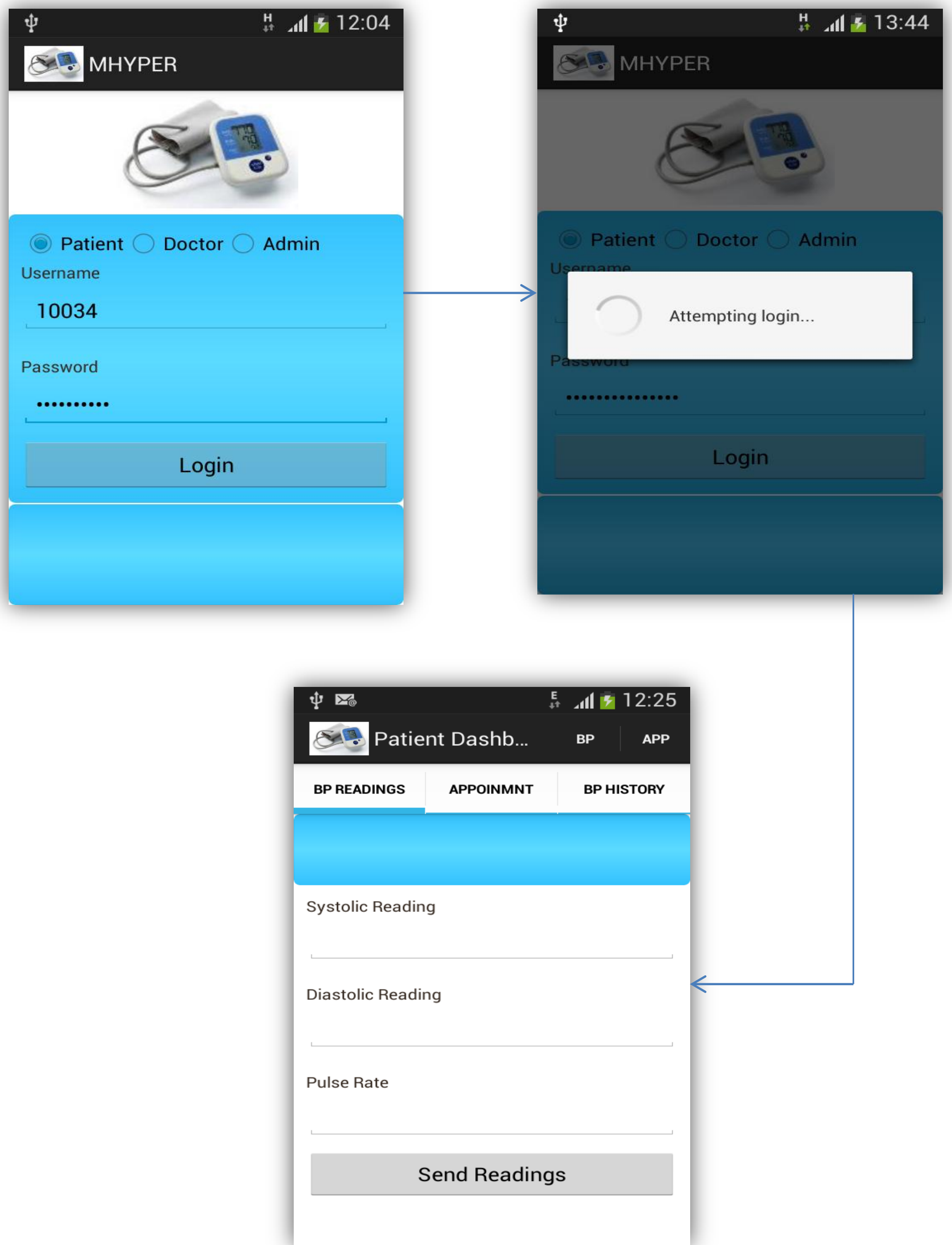

Figure 6: Patient Login Process on real android mobile device

DOCTOR'S MODULE

This module would only be accessed by professional medical doctors. The doctor has the options of registering new patients and also reviewing the patient's BP history and thus providing feedback.

This module has 2 tabs namely: - Registration and BP history tab as shown

Doctor's Dashboard Real Android Device

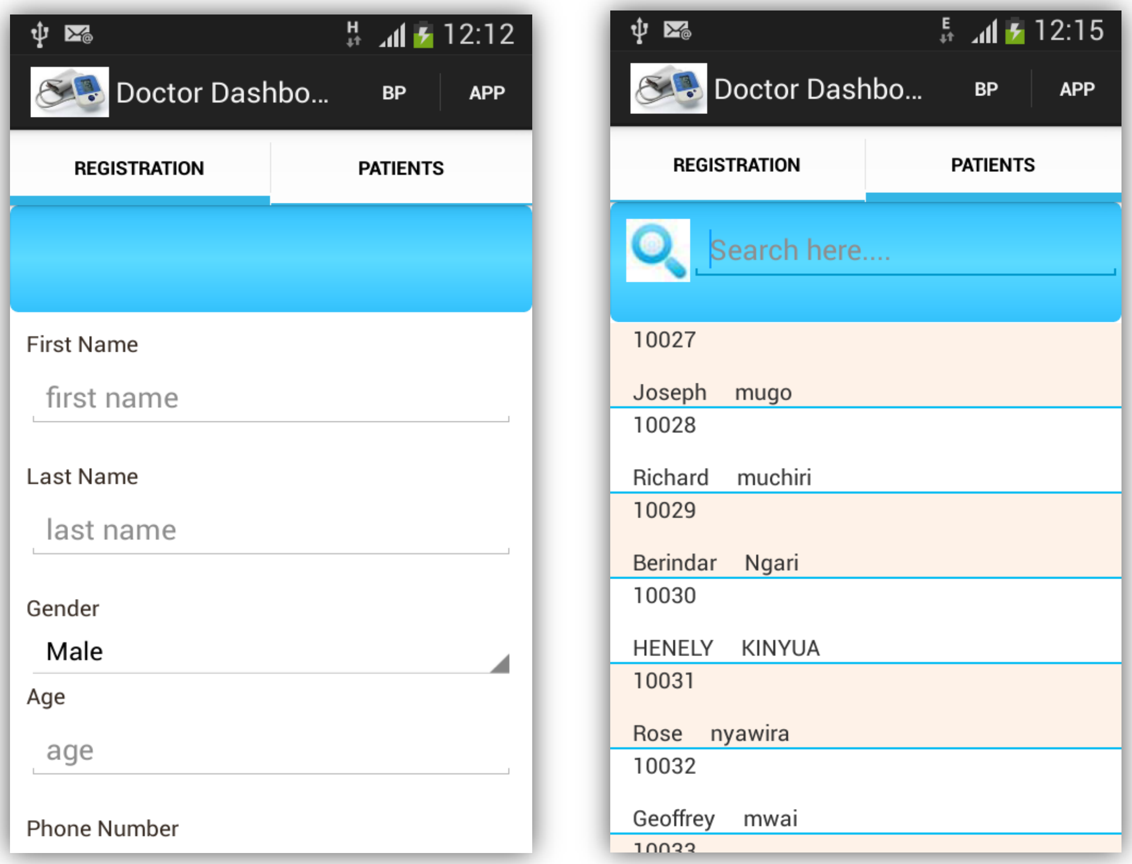

Figure 7: Doctor's dashboard on real mobile device

Doctor's Feedback Transmission process

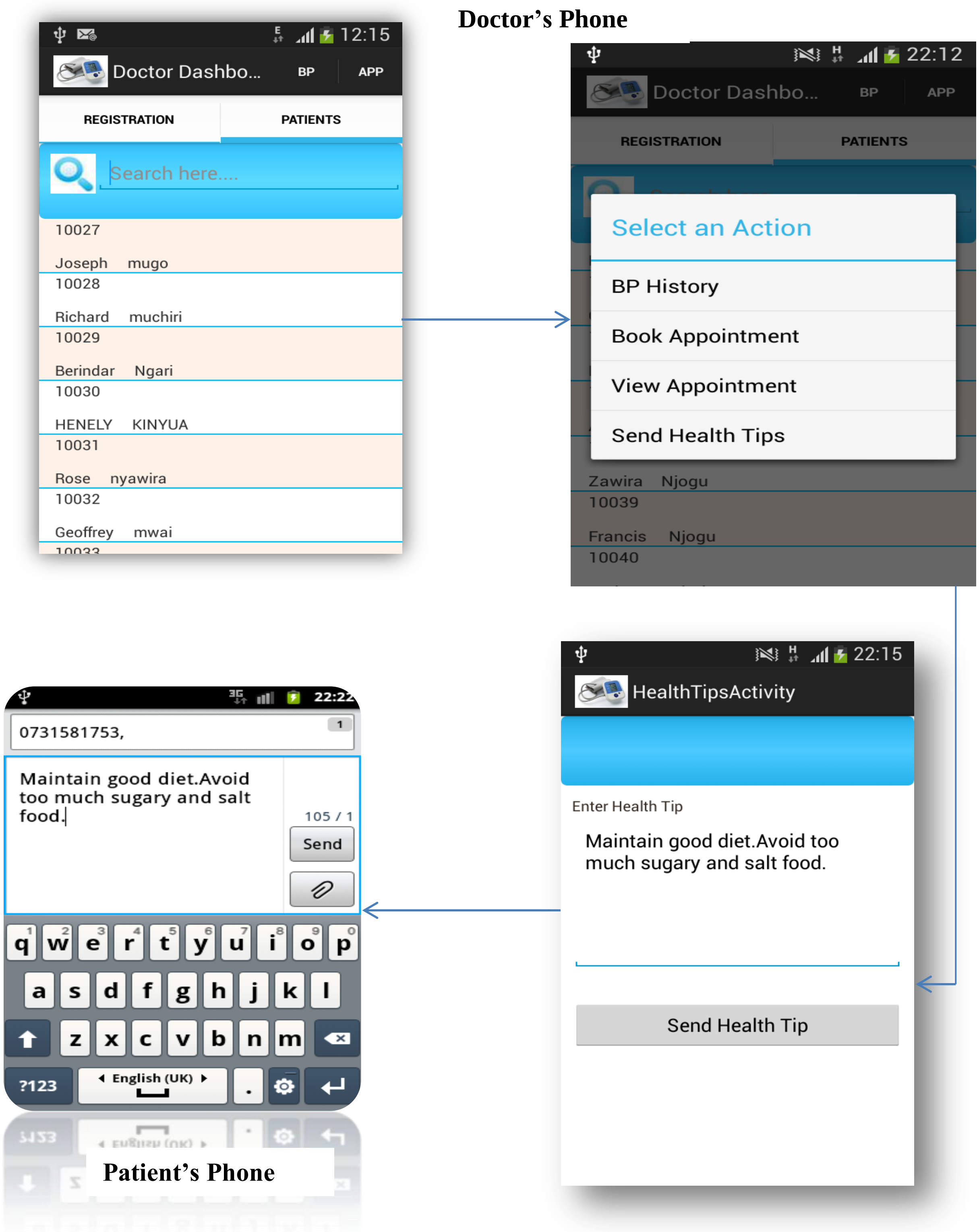

Figure 8: Doctor's Feedback Transmission process

PATIENT'S MODULE

This module is accessed by patients with high BP. The patient can be able to send BP readings to the designated doctor. The patient is also able to know the status of his/her BP using the BP History tab.

Patient's BP Data Transmission Process

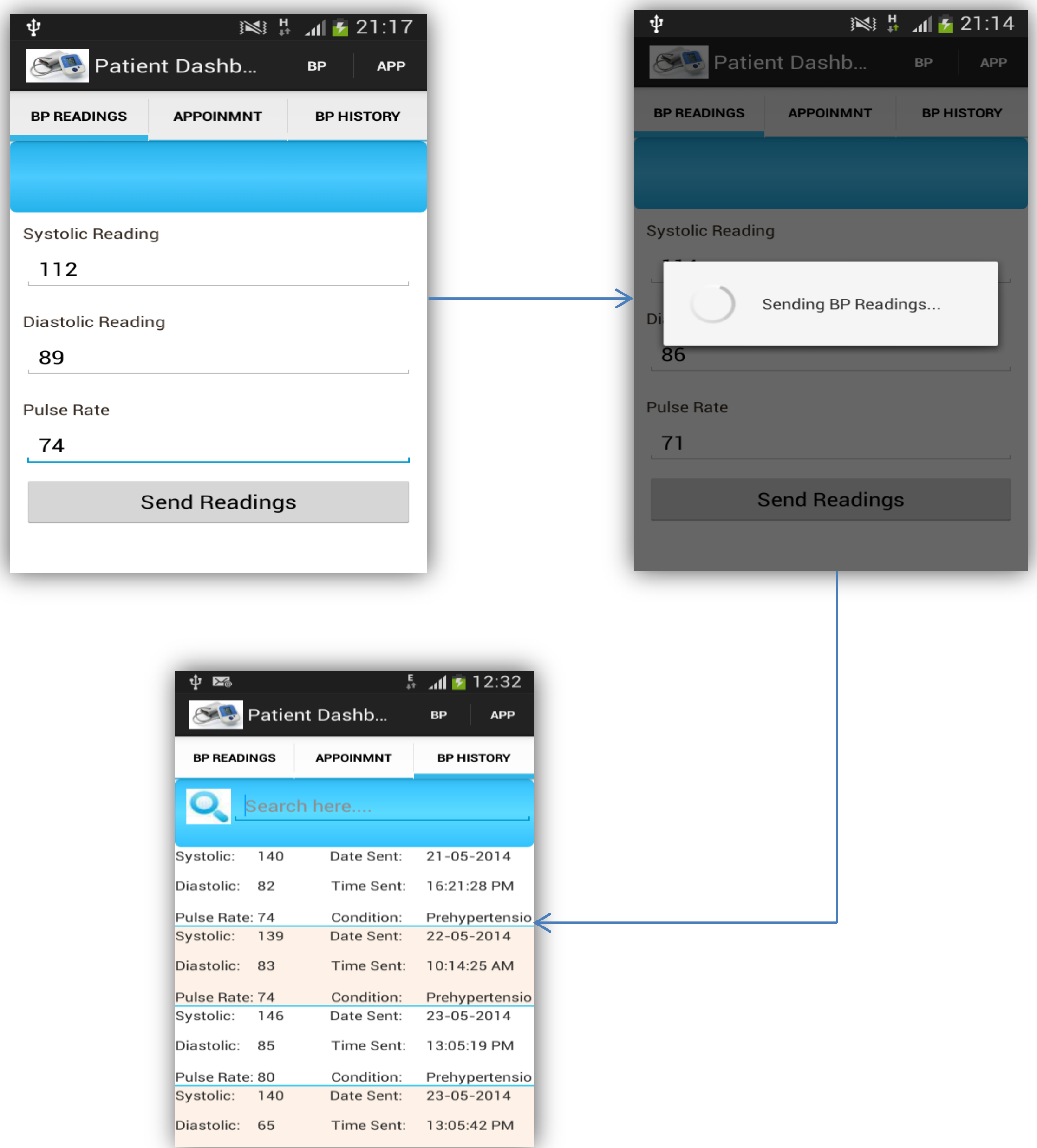

Figure 9: Patient's BP Data Transmission Process

Patient's Data Retrieval Process from Remote Database

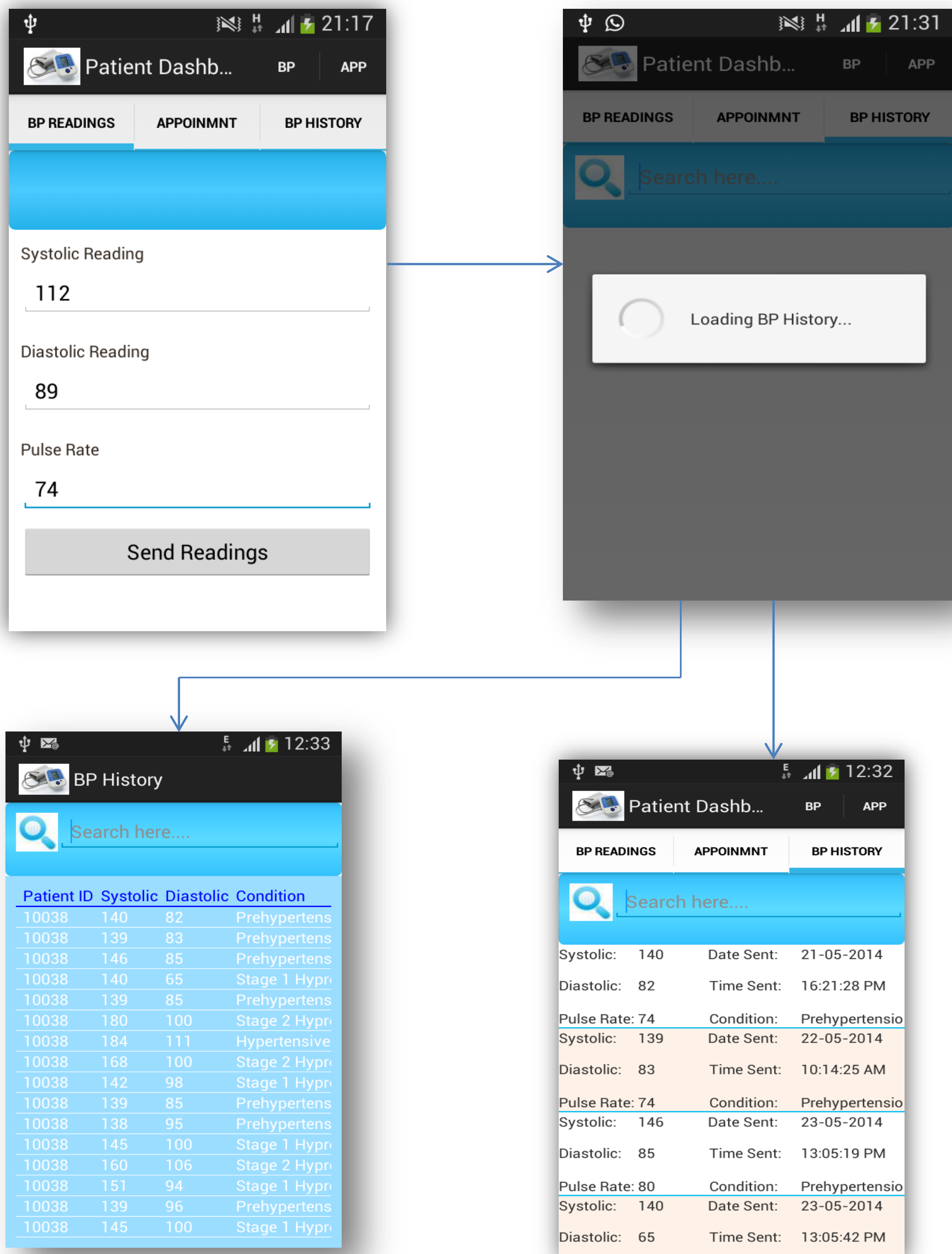

Figure 10: Patient's Data Retrieval Process from Remote Database

ADMINISTRATOR'S MODULE

This module is only accessed by administrator. The administrator has full access to the system. He/she can able register new users especially new doctors and review their details.

Administrator User Registration process

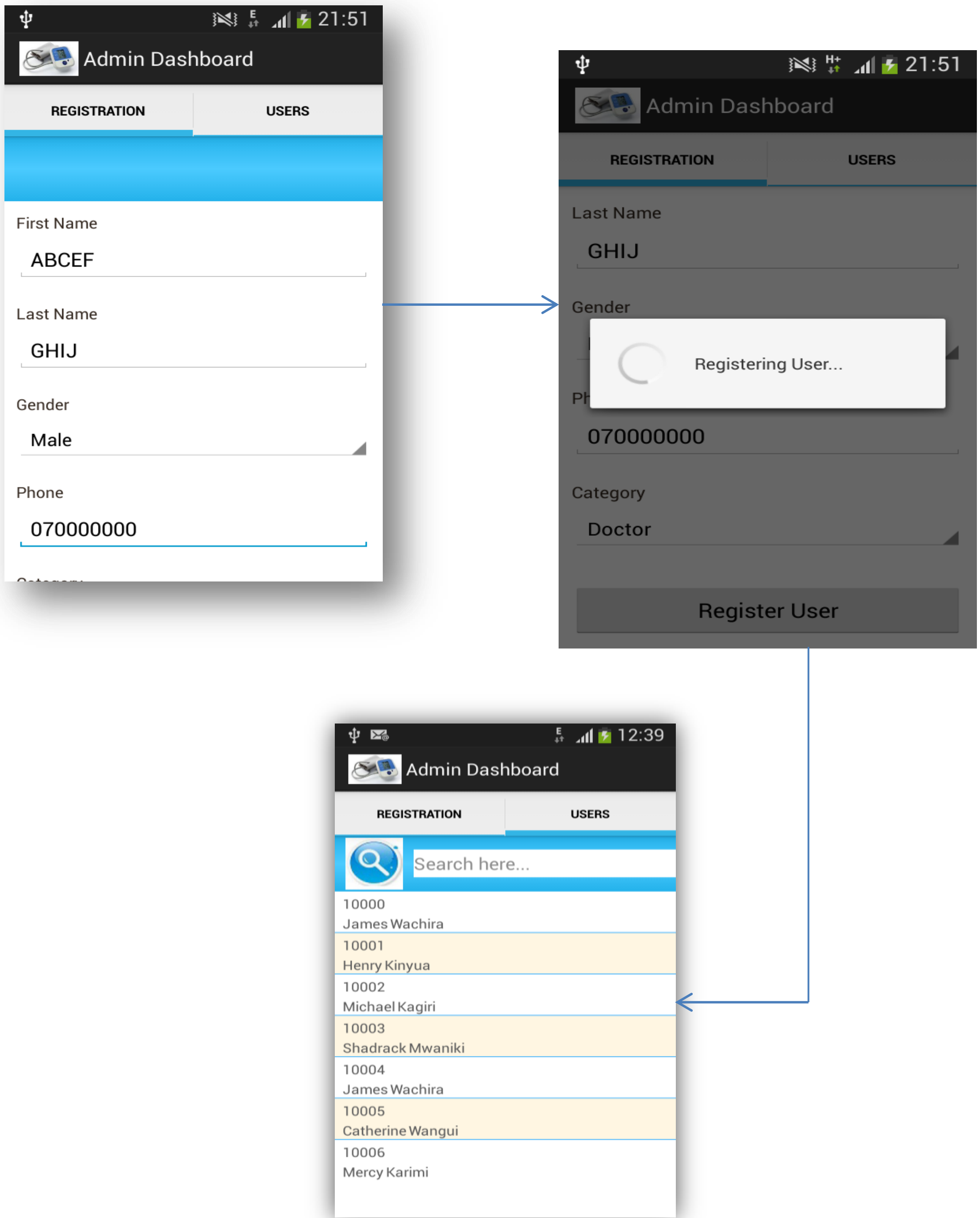

Figure 11: Administrator User Registration process

CHAPTER FIVE: RESULTS AND DISCUSSION

In this chapter the results and discussion of the data analysis are presented. The data were collected and then processed in response to the problems posed in chapter one of this research. Data collection was done in three phases:-

1. The first phase involved interacting with patients and medical specialist in order to identify the parameters required to assist in the design of the proposed system. Also a written consent to participate in this research study by the patients and medical specialist was obtained.
2. The second phase involved actual system design and development and conducting performance testing on the system. Performance metrics such as Uptime, Downtime, MTBF, Reliability, Response Time and Availability were evaluated.
3. The third phase involved collecting user perceptions on the usability and utility of the mobile tele-medicine system in monitoring and managing hypertension.

5.1 PHASE ONE: INTERVIEW WITH DOCTOR AND PATIENTS

27 patients and one medical specialist were interviewed. Patients were very impressed about the idea of using the proposed system in self-managing their BP from their homes. They however stated that some training was required before they could start using the system. In our discussion, most of the patients claimed that they could not afford a Wrist BP monitor. Therefore Wrist BP monitors were to be provided to all patients to enable them take their BP readings.

On the hand, the medical specialist/doctor was also enthusiastic about using the system to monitor BP of patients who were not able to visit the clinic. However he was fearful about the aspect of the patients not visiting the clinic often as this meant he would lose some revenues generated from the consultation fees and patient diagnosis. Moreover the doctor felt that if patients were taking their own BP, it was likely that they would collect wrong readings which could be significantly misleading. He therefore called for adequate training to ensure that patients were proficient in using the BP monitors. In our discussion, the doctor highlighted three important parameters that were to be collected and sent by the patients namely:-systolic, diastolic and pulse rate readings. These parameters formed the design principles of the tele-medicine system.

5.2 PHASE TWO: SYSTEM AND PERFORMANCE TESTING

This phase involved the actual design and development and performance testing of the mobile tele-medicine system. The results of design and development of the system are already discussed in Chapter 4.This phase will therefore discuss results after conducting system and performance testing.

System Testing Results

Table 3: A table showing results of system testing

Test Case ID	Description	Expected outcomes	Pass/Fail
ST1	Installation of system on real android device	The system should install successfully and display login screen	Pass
ST2	Patient/doctor/admin login after putting correct username and password	Patient should access patient's dashboard Doctor should access doctor's dashboard Admin should access admin's dashboard	Pass
ST3	Admin register new doctor	A doctor should be successfully registered and a message shown	Pass
ST4	Admin view all system users	A list of users is displayed on the users tab	Pass
ST5	Doctor register new patients	A new patient should be successfully registered and a message shown	Pass
ST6	Doctor view his/her patients	A list of patients should be shown on patients tab	Pass
ST7	Doctor views each patient BP history.	A list of patients BP history is displayed in the BP history tab	Pass
ST8	Doctor send feedback to patient in form of SMS after	Patient receives feedback message from doctor on his/her	Pass

	reviewing his/her BP history	mobile phone	
ST9	Patient sends BP readings	Doctor receives an SMS after patient sends his/her BP readings	Pass
ST10	Patient views his/her BP condition/status	Patients views his BP condition from BP history tab	Pass

Performance Testing Results

Performance metrics such as Uptime, Downtime, MTBF, Reliability, Response Time, and Availability were evaluated.

Table 4: A table showing results of performance testing

	Day 1	Day 2	Day 3	Day 4	Day 5	Total	Mean
Test Duration (hrs.)	10	10	10	10	10	50	
Operational Time (min)	564	565	568	627	630	2954	
Down time (min)	1	5	2	3	0	11	
Number of failures	1	2	1	1	0	5	
Time to Repair (min)	1	5	2	3	0	11	0.02
Response Time (sec)	508	457	459	506	517	2447	3.94
Number of trials	129	117	117	129	129	621	

$$\text{Uptime} = \frac{2954}{3000} * 100 = 98.46\ \%$$

$$\text{Downtime} = \frac{11}{3000} * 100 = 0.37\ \%$$

$$\text{MTBF} = \frac{\frac{2954}{60}}{5} = 9.847 = 9.85$$

$$\text{Reliability} = \frac{9.847}{(1+9.486)} = 0.9078 = 0.9$$

$$\text{Average Response Time} = \frac{2447}{612} = 3.94 = 4 \text{ seconds}$$

$$\text{Availability} = \frac{9.847}{(9.847 + \frac{11}{621})} * 100 = 99.82\%$$

Performance testing of any system is very important. It is performed to determine how a system performs in terms of responsiveness and stability under a particular workload. It also serves to investigate measure, validate or verify other quality attributes of the system, such as scalability, reliability and resource usage. For mobile applications two performance metrics are important namely: - uptime and responsiveness. From the uptime metric other metrics such as Downtime, MTBF, Reliability and Availability can also be derived. As a result, in this study, six important mobile tele-medicine system performance metrics were evaluated.

In order to ensure that the results are accurate, reliable and reproducible multiple trials were conducted. The independent variable was the testing time while the dependent variables are the response time, time to repair and downtime.

Using the Rules of Thumb, trials were therefore conducted at a time interval of 5 minutes distributed evenly for the 10 hours test duration. This means that on average the number of trials per day was supposed to be 120 and 600 within the 5-days testing period. However due to technicalities in the testing process, some days like Day 2 and Day 3 recorded number of trials below average. Therefore in order compensate for this margin, trials were increased for subsequent days as shown in table 4.

Dependent variables, Time to Repair and Response Time, were measured using a stop-watch. The system was subjected to a series of data transmission and retrieval tests for a total of 50 hours in 5 days i.e. 10 hours in each day. Time to Repair represented the time that the system took to recover from any failure (crash). Response Time represented the time it took for the system to respond to a request made e.g. transmission and retrieval of BP data to and from a remote server. From the testing results, it's clear that the system achieved an Uptime of 98.46%, Downtime of 0.37 %, MTBF of 9.85,Reliability of 0.9, Average Response Time of 4 seconds, and overall availability of 99.82 % during the 5-days testing period.

From the calculations of performance metrics, it is clear that Uptime, Downtime, Time to Repair and MTBF have an overall effect on system reliability and availability, which then have a direct effect on system usability and utility.

Reliability Scores and their Interpretation

Table 5: A table showing reliability scores and their interpretation

	Reliability Score	**Interpretation**
1.	Greater than 0.9	Excellent reliability; at the level of the best standardized system
2.	0.8 to 0.9	Very good for users
3.	0.7 to 0.8	Good; Range for most systems. Few improvements need to be made
4.	0.6 to 0.7	Somewhat low; should be supplemented by other measures. Some improvements are needed.
5.	0.5 to 0.6	Redesign the system if only few changes; Supplement by other measures
6.	Below 0.5	Questionable reliability. The system should not be used at all. Redesign is needed.

As stated above the tele-medicine system achieved an excellent reliability score of 0.91. This means that probability that the system will function as expected without failure(s) within a period of 10 hours is 0.9.In other words, out of 10 hours of operation, a failure will only occur in the ninth hour. We can therefore make conclusion that the excellent reliability score contributed to the good usability and utility of the system.

Availability Interpretation

Availability of a system is typically measured as a factor of its reliability, i.e. Reliability has a direct influence on availability. As reliability increases so does availability, and vice versa. The table below shows availability levels:-

Table 6: A table showing different availability levels

	Service Level	Uptime per Year	Downtime per Year
1.	90% (1-nine)	328.50 days	36.50 days
2.	99% (2-nines)	361.35 days	3.65 days
3.	99.9% (3-nines)	364.64 days	8.76 hours
4.	99.99% (4-nines)	364.96 days	52.56 minutes

5.	99.999% (5-nines)	~365 days	5.26 minutes
6.	99.9999% (6-nines)	~365 days	31.54 seconds

From the results, the tele-medicine system achieved an availability of 99.82 %(2-nines). This translates to an acceptable downtime of 3.65 days per year. This downtime is not substantial to the users and may not affect the usability and utility of the system.

Response Time Interpretation

In his research, John A. H (2000) indicated that lengthy system response times may cause lower satisfaction and poor productivity among users. Consequently, lowered user satisfaction may lead to discontinued use of an application, especially in discretionary applications such as those found on the Internet. His findings showed that user satisfaction will decrease as system response time increases. For three second increase in response time, there is an average of 0.22 drop in average satisfaction. Similarly, Shengqian et al. (2013) stated that poor responsiveness of android software can be very harmful to user perception and adoption success. Nielsen J. (1993), a usability expert, came up with three main time limits, which are determined by human perceptual abilities, to be considered when optimizing web and application performance.

Table 7: A table showing different response time limits and their application

	Time Limit	Application Area
1.	0.1 second	Limit for having the user feel that the system is reacting instantaneously, meaning that no special feedback is necessary except to display the result.
2.	1.0 second	Limit for the user's flow of thought to stay uninterrupted, even though the user will notice the delay. Normally, no special feedback is necessary during delays of more than 0.1 but less than 1.0 second, but the user does lose the feeling of operating directly on the data.
3.	10 seconds	Limit for keeping the user's attention focused on the dialogue. For longer delays, users will want to perform other tasks while waiting for the computer to finish, so they should be given feedback indicating when the computer expects to be done. Feedback during the delay is especially important if the response time is likely to

		be highly variable, since users will then not know what to expect.

The design of the mobile tele-medicine, which is an android mobile application, is characterized by tasks that involve transmission and retrieval of data to and from a remote database. The Android client is connected to the remote server through PHP web services. As a result, it takes time for the remote server to give feedback to the users once a task has been performed. Therefore measures must be taken to ensure that the response time is not too lengthy, as too much delay has been proved to have a negative effect on user's satisfaction and productivity (cause frustrations) .In order to deal with the delay during processing of a user's request, process dialog indicators were used. This therefore means that the acceptable time limit for transmission and retrieval of data to and from a remote database is 10 seconds. From the research findings of this study the average response time for data transmission and retrieval from the remote database was 4 seconds, which is acceptable.

We can therefore conclude that, the short response time contributed to the overall usability and utility of the tele-medicine system. Usability results showed that 17 out of 20 patients were satisfied with using the system, while all patients found the system useful in their process of self-care.

5.3 PHASE THREE: USABILITY AND UTILITY TESTING

This phase will discuss the usability and utility results after the patients and medical specialist used the system in monitoring and managing BP.As stated in the methodology section, 27 patients and one medical specialist were enrolled for the study. Seven patients dropped out of the pilot study for different reasons. Some of them highlighted anxiety as the main cause while taking their BP. During the project execution, it was clear that most of the hypertensive patients could not afford a BP monitoring machine. As a result each of the patients was provided with a Wrist BP monitor to enable them collect their BP readings while at home.

Patients' Characteristics

Table 8: A table showing patient's age characteristics

Gender	**Frequency**	**Age**		
		Lower Limit	Mean	Higher Limit
Male	11	33	37	47
Female	9	35	42	54

Usability Testing

In the attempt to evaluate the usability of the system we administered questionnaire to 20 patients and one medical specialist. SUS questionnaire was used.

ISO 9241-11 suggests that measures of usability should cover:-

1. Effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks)
2. Efficiency (the level of resource consumed in performing tasks)
3. Satisfaction (users' subjective reactions to using the system).

In this research, we focused on the users' satisfaction and effectiveness in using the mobile tele-medicine system to manage their BP.

SUS Questionnaire

The SUS is a commonly used, freely distributed, and reliable questionnaire consisting of 10 items. Scoring the questionnaire yields a usability score in the range of 0–100. Its ease of administration and scoring makes it a popular choice among usability professionals. Recent research (Tullis & Stetson, 2004) has shown the SUS to provide superior assessments of system usability, compared to other questionnaires (for example, QUIS, CSUQ).

The SUS is generally used after the respondent has had an opportunity to use the system being evaluated, but before any debriefing or discussion takes place. Respondents should be asked to record their immediate response to each item, rather than thinking about items for a long time.

All items should be checked. If a respondent feels that they cannot respond to a particular item, they should mark the center point of the scale.

The SUS uses the format shown below:-

Strongly disagree				**Strongly Agree**
☐	☐	☐	☐	☐

Figure 12: SUS questionnaire format

Steps in Scorings SUS

- For odd numbered questions, subtract one from the user's response.
- For even numbered questions, subtract user's response from total score of five
- Add up the converted responses for each user and multiply the total by 2.5. This converts the range of possible values from 0 to 100 instead of from 0 to 40.

SUS Scores Interpretation

Interpretation of SUS scores is considered to be a complex process. Also even though the converted values range from 0 to 100 these are not percentages and should therefore be considered only in terms of their percentile ranking. According to research, a SUS score above 68 is considered to be average. A score below 68 is below average. An average SUS scores in the 90s are exceptional, scores in the 80s are good, scores in the 70s are acceptable, and scores below 70 indicate some usability concerns. The research has showed that SUS is a reliable and valid measure of perceived usability. It performs as well or better than commercial questionnaires and home-grown internal questionnaires. The best way to interpret SUS score has been to convert it to a percentile rank through a process called normalizing.

Initially SUS was only intended to measure perceived ease-of-use but recent research by James and Jeff (2009) has shown that it provides a global measure of system satisfaction and sub-scales of usability and learnability. Usability and Learnability are correlated. Items 4 and 10 provide the learnability dimension and the other 8 items provide the usability dimension. This means you can track and report on both subscales and the global SUS score.

SUS results summary

Using the SUS scale below an adjective rating was assigned to the SUS score for easier interpretation**.**

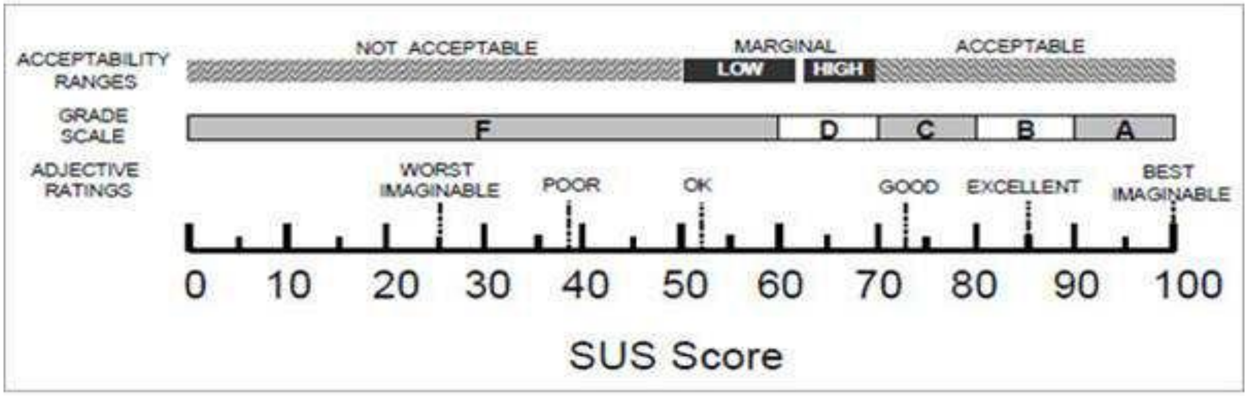

Figure 13: SUS scores adjective ratings scale

Table 9: A table showing frequency of patients with acceptable SUS scores

Acceptability Range	**Frequency (Number of Patients)**	**Percentage (%)**
Acceptable	17	85
Not Acceptable	3	15

Usability of a system is an important aspect to evaluate as it determines its success or failure. A usable system fits the user’s needs, facilitates tasks, reduces stress, is easy to navigate, meets the user’s expectations and is a joy to use. A system that is highly usable is likely to be adopted by the users and vice versa. In this research, usability of tele-medicine system was important because it would determine the probability that the patient and medical specialist would be willing to accept it in BP management. From the usability results, 85 percent of the study participants had usability scores above average which lie within the acceptable range. This therefore means users were satisfied with the system and found it effective in helping them manage their BP.15 percent of the patients did not perceive the system to be usable. Several factors such as inadequate training due to limitation of time, lack of involvement in the design may have contributed to this.

Usefulness/Utility of the System As Compared To Hospital Visits

Perceived usefulness is defined as the extent to which a person believes that using a particular system would enhance his or her job performance. Usefulness cannot be measured in isolation. A system's usefulness can therefore be evaluated by measuring its advantages over alternative solutions based on specific criteria associated with fundamental needs.

In this research study we collected the patients' perceptions about the usefulness of the system in monitoring and managing their BP as compared to hospital visits. A tailor-made questionnaire with ten questions was administered to the patient and medical specialist. The results are as shown below:-

Utility/ Usefulness Results

Table 10: A table showing results of usefulness/utility testing

USEFULNESS METRICS	Frequency/Number of participants										Total		Percentage (%)	
	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree					
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Time Saving	0	0	0	0	0	0	0	0	11	9	11	9	100	100
Improved BP Self care	0	0	0	0	0	0	0	0	11	9	11	9	100	100
Timely and Speedy Transmission of BP data	0	0	0	0	0	0	0	0	11	9	11	9	100	100
Timely and Speedy feedback from doctor	0	0	0	0	0	0	1	1	10	8	11	9	100	100
Better BP Management	0	0	0	0	0	0	0	0	11	9	11	9	100	100
Instant and Easy access to BP History	0	0	0	0	0	0	1	1	10	8	11	9	100	100
Easy Interaction with doctor	0	0	0	0	0	0	0	0	11	9	11	9	100	100

Participants Overall Response on Tele-medicine system versus Hospital visit

Table 11: A table showing overall response of patients

		Telemedicine system		Hospital Visit	
	Questions Asked	M	F	M	F
1.	Would you prefer using the system for BP monitoring or making Hospital visit?	11	9	0	0
		YES		NO	

2.	Would you be willing to participate in another telemedicine BP monitoring exercise?	11	9	0	0

The current practice adopted by these hypertensive patients in managing and monitoring hypertension is making frequent visits to the health center as recommended by the medical specialists. Most of these patients claimed that the frequent visits were tiring and time consuming. The patients' also travelled for long distances to have their BP checked. This practice is therefore impractical especially for critically-ill patients. Consequently, most of these patients had neglected BP check-ups and had therefore focused on medication alone. This put the patient's at risk as uncontrolled BP could lead to devastating consequences.

With the development of the mobile tele-medicine system patients did not have to make hospital visits. Initially, patients were required to travel for long distances to have their BP checked. On average patients used to travel for at least 5 km and hence spent at least 2 hours of time. But with the introduction of tele-medicine system patients were able to monitor and manage their BP from home and this saved them the burden of having to visit the hospital for their BP checkup. From the statistics above, all patients, both male and female, perceived the system to be useful in helping them save time.

On average most patients had their BP checked after 60 days. This is after they made a visit to the hospital. But with the Wrist BP monitors patients were able to take their BP readings at least 3 times a day. This created self-awareness to the patients about their BP levels. It was therefore easy to take preventive measures early enough before the condition deteriorated. The vital parameters measured were transmitted to the doctor immediately. The doctor provided feedback to the patients in form of medication recommendations or general health tips, to help them lower their BP to normal ranges. Through this continuous self-monitoring exercise, patients were there able to take good control of their BP. From the utility results, all patients perceived the system to the useful in helping them take care of their BP.

One important aspect to better BP treatment is ability to examine the trend of the BP data of the patients. This requires quality recording and ease of access of patient records. Initially patients were issued with a hospital card where BP treatment data were recorded. When asked to produce their hospital cards for the previous one month none of patients could manage. This means that if patients were to seek medical service from another hospital, new blind-treatment would be given. This unsystematic BP treatment procedure could lead to more serious consequences. To the doctor he complained of having to keep physical for the patients BP data. He claimed that retrieval of these documents was cumbersome. But with the introduction of this tele-medicine system, data was centrally located. Both the patients and the doctor could access the BP data from their mobile phone faster and on time.

During the 4 weeks of using the system in monitoring BP, some patients reported some improvement in their BP. However, this fact could not be well substantiated as the monitoring time was not adequate enough. Other factors such as, medication compliance, change of dietary habits, frequent physical exercises etc. may have contributed to improvement of BP.

From the patients BP data history, it was clear that most of the patients adhered to the daily measurements that were requested by the medical specialist. This shows how passionate the patients were about the concept of BP self-monitoring. When asked whether they would be willing to continue using the tele-medicine system, all the patients said yes. At the same when asked whether they preferred their old practice of making hospital visits to tele-medicine system, all patient voted for tele-medicine system.

Generally, the tele-medicine system provided great help to remote patients and medical specialist.

5.4 LIMITATIONS

This research study was not without any limitations. First, only patient's with android-enabled phones were enrolled for the study. Patients who were passionate about monitoring their BP but didn't have android-enabled phones were therefore locked out. This problem can be addressed by developing a similar mobile tele-medicine system to accommodate other mobile platforms.

Secondly, some patients felt frustrated especially when the mobile internet connectivity went down or was slow. They complained of not being able to login and send their BP readings quickly. This can be addressed by developing a similar mobile application that does not involve internet usage.

CHAPTER SIX: CONCLUSION

In this research, we have managed to develop a mobile tele-medicine system for hypertension management to help hypertensive patients monitor their condition while at home. Patients were able to collect and transmit their BP readings faster and on time. The doctor was able to provide regular feedback to the patients to enable control their BP.

The tele-monitoring system has proved to be usable and useful to the patients in managing hypertension. It is now clear that the concept of tele-medicine can become a reality in Kenya. If adopted, it is be possible to extend health services to undeserved areas.

The success of this mobile tele-medicine system may therefore be considered as a baseline towards achieving better management of chronic diseases.

With the impressive results from the study, similar tele-medicine systems can also be developed for managing other diseases like diabetes, Tuberculosis etc.

The 4 weeks testing period of this study was not adequate enough to substantially quantify the benefit of drop in BP of the patients. As a result a long-term trial is therefore recommended.

6.1 ANSWERING RESEARCH QUESTIONS

How can hypertensive patients use BP monitors and mobile application to help them regularly monitor and manage their BP condition from the comfort of their homes?

To answer this research question, an android mobile tele-medicine system prototype has been developed and tested with 20 patients. The system has implemented a feature to allow patients send their BP readings using their mobile phones. The system also allows patients to book an appointment as well access and monitor their BP history. Patients also had Wrist BP monitors to assist them take their BP readings from home. Certainly, the system provided help to the patients to interact with a remote medical specialist from their homes. Therefore with the help of BP monitors patients can take their BP readings regularly from their homes and use their mobile application to transmit the BP data to a medical specialist for monitoring. Patients can also receive feedback from a doctor on their mobile phones. This is likely to empower patients to self-manage their BP condition.

How can doctors use their mobile devices to help them continuously monitor BP condition of remote hypertensive patients?

This research question has been answered by developing a mobile application and testing it by involving one medical specialist. The prototype has implemented a doctor's dashboard from where they can be able to access and visualize trending BP data of patients for analysis and decision making purpose. From the usability testing analysis, we can conclude that doctors can use their mobile application to receive notifications for each BP readings sent by the patients. The doctor can also access and visualize the BP history of the patients from the mobile application remotely. The doctor can also provide appropriate feedback to the patients depending on the level of their BP.

What is the usability of using mobile application in helping hypertensive patients monitor and manage their BP condition from home?

From the results of usability testing analysis, we have been able to show that 85 percent of study participants felt the system to be usable and effective. Therefore there is no doubt patients and medical specialist are willing to use mobile tele-medicine system since it provides a continuous, easy, cost-effective and reliable means of BP monitoring.

What is the utility of using mobile application in helping hypertensive patients monitor and manage their BP condition from home?

To answer this research question, a questionnaire was administered to 20 patients. The questionnaire contained questions pertaining to the usefulness of the mobile tele-medicine system in helping patients self-manage their BP from home. From the utility results, it is now clear with the introduction of a tele-medicine system, patients are able to save on time that is consumed when travelling to the hospital. Since the patients are able to monitor their own BP and receive timely feedback from the doctor, this has ultimately contributed to improved self-care.

6.2 FURTHER WORK

The following areas, arising from the research project are proposed for further research:-

1. Data collection in this mobile tele-medicine system was done manually. The patients were provided with Wrist BP Monitors to take their BP readings. The patient would then feed these readings on the mobile application and send them. Further research is required to ensure automatic transmission of the BP readings from the Wrist BP Monitors to the android application via Bluetooth technology.
2. This mobile tele-medicine system was only restricted to users with android enabled mobile devices. Further research is required to develop a similar mobile tele-monitoring system which can run on any other mobile platforms like J2ME or Window phones.
3. In order to ensure sustainability of this mobile tele-medicine system, further work is required to ensure that it is integrated with already existing EHRs.

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APPENDIX SECTION

MOBILE TELE-MEDICINE SYSTEM DEVELOPMENT SOURCE CODES

SAMPLE ANDROID SOURCE CODES

1. **Login Activity.java**

```
package com.example.m_hyper;
import java.util.ArrayList;
import java.util.List;
import org.apache.http.NameValuePair;
import org.apache.http.message.BasicNameValuePair;
import org.json.JSONException;
import org.json.JSONObject;
import com.example.m_hyper.R;
import android.app.Activity;
import android.app.ProgressDialog;
import android.content.Intent;
import android.content.SharedPreferences;
import android.content.SharedPreferences.Editor;
import android.os.AsyncTask;
import android.os.Bundle;
import android.preference.PreferenceManager;
import android.util.Log;
import android.view.View;
import android.view.View.OnClickListener;
import android.widget.Button;
import android.widget.EditText;
import android.widget.RadioButton;
import android.widget.RadioGroup;
import android.widget.Toast;

public class LoginActivity extends Activity implements OnClickListener {

private EditText etUsername, etPassword;
private Button btnLogin;
private RadioGroup rgCategory;
private RadioButton rbCategory;
// Progress Dialog
private ProgressDialog pDialog;

// JSON parser class
JSONParser jsonParser = new JSONParser();

// php login script location:
```

```
// localhost :
// testing on your device
// put your local ip instead, on windows, run CMD > ipconfig
// or in mac's terminal type ifconfig and look for the ip under en0 or en1
// private static final String LOGIN_URL ="http://10.0.2.2/m-hyper/login.php";

// testing on Emulator:
private static final String LOGIN_URL = "http://prestige.site50.net/m-hyper/login.php";
//http://prestige.site50.net/login.php
// testing from a real server:
// private static final String LOGIN_URL =
// "http://www.mybringback.com/webservice/login.php";

// JSON element ids from repsonse of php script:
private static final String TAG_SUCCESS = "success";
private static final String TAG_MESSAGE = "message";

@Override
protected void onCreate(Bundle savedInstanceState) {
// TODO Auto-generated method stub
super.onCreate(savedInstanceState);
setContentView(R.layout.activity_login);

// setup input fields
rgCategory = (RadioGroup)findViewById(R.id.rgCategory);
etUsername = (EditText) findViewById(R.id.etusername);
etPassword = (EditText) findViewById(R.id.etpassword);

// setup buttons
btnLogin = (Button) findViewById(R.id.btnLogin);

// register listeners
btnLogin.setOnClickListener(this);
                    //mRegister.setOnClickListener(this);

}

@Override
public void onClick(View v) {
// TODO Auto-generated method stub
switch (v.getId()) {
case R.id.btnLogin:
new AttemptLogin().execute();
break;
//case R.id.register:
//Intent i = new Intent(this, Register.class);
```

```
//startActivity(i);
//break;

default:
break;
}
}

class AttemptLogin extends AsyncTask<String, String, String> {

@Override
protected void onPreExecute() {
super.onPreExecute();
pDialog = new ProgressDialog(LoginActivity.this);
pDialog.setMessage("Attempting login...");
pDialog.setIndeterminate(false);
pDialog.setCancelable(true);
pDialog.show();
}

@Override
protected String doInBackground(String... args) {
// TODO Auto-generated method stub
// Check for success tag
int success;
int selectedOption = rgCategory.getCheckedRadioButtonId();
rbCategory = (RadioButton) findViewById(selectedOption);
//RadioButton radiovalue =
(RadioButton)this.findViewById(rgCategory.getCheckedRadioButtonId())).getText().toS
tring();

String category = rbCategory.getText().toString();
String username = etUsername.getText().toString();
String password = etPassword.getText().toString();



try {
// Building Parameters
List<NameValuePair> params = new ArrayList<NameValuePair>();
params.add(new BasicNameValuePair("username", username));
params.add(new BasicNameValuePair("password", password));
params.add(new BasicNameValuePair("category", category));

Log.d("request!", "starting");
// getting product details by making HTTP request
```

```
JSONObject json = jsonParser.makeHttpRequest(LOGIN_URL, "POST",params);

// check your log for json response
Log.d("Login attempt", json.toString());

// json success tag
success = json.getInt(TAG_SUCCESS);
if ((success == 1) && ("Patient".equals(category))) {
//Log.d("Login Successful!", json.toString());
// save user data
//SharedPreferences sp =
PreferenceManager.getDefaultSharedPreferences(LoginActivity.this);
//Editor edit = sp.edit();
//edit.putString("username", username);
//edit.commit();

Intent i = new Intent(LoginActivity.this, WelcomeActivity.class);
i.putExtra("username",username);
i.putExtra("category",category);

                                                    //finish();
startActivity(i);
return json.getString(TAG_MESSAGE);
} else if ((success == 1) && ("Doctor".equals(category))) {
//Log.d("Login Successful!", json.toString());

Intent i = new Intent(LoginActivity.this, DoctorMainActivity.class);
i.putExtra("username",username);
i.putExtra("category",category);
//finish();
startActivity(i);
return json.getString(TAG_MESSAGE);
} else if ((success == 1) && ("Admin".equals(category))) {
//Log.d("Login Successful!", json.toString());
// save user data
//SharedPreferences sp =
PreferenceManager.getDefaultSharedPreferences(LoginActivity.this);
//Editor edit = sp.edit();
//edit.putString("username", username);
//edit.commit();

Intent i = new Intent(LoginActivity.this, AdminMainActivity.class);
//i.putExtra("username",username);
i.putExtra("username",username);
i.putExtra("category",category);
//finish();
```

```
startActivity(i);
return json.getString(TAG_MESSAGE);
} else{
Log.d("Login Failure!", json.getString(TAG_MESSAGE));
return json.getString(TAG_MESSAGE);
}
} catch (JSONException e) {
e.printStackTrace();
}

return null;

}

protected void onPostExecute(String file_url) {
// dismiss the dialog once product deleted
pDialog.dismiss();
if (file_url != null) {
Toast.makeText(LoginActivity.this, file_url, Toast.LENGTH_LONG).show();
}

}

}

}
```

SAMPLE PHP SOURCE CODES

1. Login.php

```
<?php

//load and connect to MySQL database stuff

require("config.inc.php");

if (!empty($_POST)) {

//gets user's info based off of a username.

$query = "SELECT id, phone, category FROM user WHERE id = :username and category=:category";

  $query_params = array(

  ':username' => $_POST['username'],

  ':category' => $_POST['category']

);

try {

$stmt   = $db->prepare($query);

$result = $stmt->execute($query_params);

}

catch (PDOException $ex) {

// For testing, you could use a die and message.

//die("Failed to run query: " . $ex->getMessage());

//or just use this use this one to product JSON data:

$response["success"] = 0;

$response["message"] = "Database Error1. Please Try Again!";

die(json_encode($response));


}

//This will be the variable to determine whether or not the user's information is correct.

//we initialize it as false.
```

```
$validated_info = false;
//fetching all the rows from the query
$row = $stmt->fetch();
if ($row) {
//if we encrypted the password, we would unencrypt it here, but in our case we just
//compare the two passwords
if ($_POST['password'] === $row['phone']) {
$login_ok = true;
}
}

// If the user logged in successfully, then we send them to the private members-only page
// Otherwise, we display a login failed message and show the login form again
if ($login_ok) {
$response["success"] = 1;
$response["message"] = "Login successful!";
die(json_encode($response));
} else {
$response["success"] = 0;
$response["message"] = "Invalid Credentials!";
die(json_encode($response));
}
} else {
?>
<h1>Login</h1>
<form action="login.php" method="post">
Username:<br />
```

```
<input type="text" name="username" placeholder="username" />
<br /><br />
Password:<br />
<input type="password" name="password" placeholder="password" value="" />
<br /><br />
<input type="submit" value="Login" />
</form>
<a href="register.php">Register</a>
<?php
}
?>
```

SYSTEM USABILITY SCALE (SUS) QUESTIONNAIRE

Participant ID:		Category:	Patient	Doctor	Date:	

Instructions: For each of the following statements, mark one box that best describes your reactions to the mobile application in managing high blood pressure

1. I think that I would like to use this mobile application frequently.

Strongly disagree				**Strongly Agree**
☐	☐	☐	☐	☐

2. I found this mobile application unnecessarily complex

Strongly disagree				**Strongly Agree**
☐	☐	☐	☐	☐

3. I thought this mobile application was easy to use

Strongly disagree				**Strongly Agree**
☐	☐	☐	☐	☐

4. I think that I would need assistance to be able to use this mobile application.

Strongly disagree				**Strongly Agree**
☐	☐	☐	☐	☐

5. I found the various functions in this mobile application were well integrated.

Strongly disagree				**Strongly Agree**
☐	☐	☐	☐	☐

6. I thought there was too much inconsistency in this mobile application

Strongly disagree				Strongly Agree
☐	☐	☐	☐	☐

7. I would imagine that most people would learn to use this mobile application very quickly.

Strongly disagree				Strongly Agree
☐	☐	☐	☐	☐

8. I found the mobile application very cumbersome to use.

Strongly disagree				Strongly Agree
☐	☐	☐	☐	☐

9. I felt very confident using the mobile application.

Strongly disagree				Strongly Agree
☐	☐	☐	☐	☐

10. I needed to learn a lot of things before I could get going with this mobile application.

Strongly disagree				Strongly Agree
☐	☐	☐	☐	☐

Please provide any comments about this mobile application:

SYSTEM UTILITY QUESTIONNAIRE

Participant ID:		**Category:**	Patient	Doctor	**Date:**	

Instructions: For each of the following statements, mark one box that best describes your reactions to the usefulness of using the system in managing high blood pressure from home

1. Have you ever been involved in a telemedicine BP self-management exercise before?
   Yes ☐ No ☐
2. Using tele-medicine system saved me time as compared to face-to-face consultations?

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

3. Using system helped me improve self-care of my BP as opposed to visiting the hospital in-person?

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

4. Using system provided timely and speedy transmission of BP data to the doctor for review compared to hospital visits?

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

5. Using system helped me receive timely and speedy feedback from the doctor on how to control my BP?

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

6. What is the frequency of BP checkup? After ☐ days/months. Using the system I was able to manage my BP regularly?

Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
☐	☐	☐	☐	☐

7. Can you recall your BP history for the last one month? Yes ☐ No ☐ Using the system provide instant and easy access to my BP history?

Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
☐	☐	☐	☐	☐

8. Using the system I was able to interact with the doctor easily as compared to hospital visit.

Strongly disagree				**Strongly Agree**
☐	☐	☐	☐	☐

9. Would you prefer using the system for BP monitoring ☐ or Physician on site ☐

10. Would you be willing to participate in another telemedicine BP monitoring? Yes ☐ No ☐