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Wireless Blood Pressure Device Integration with Electronic Medical Records:

Case Study of University of Nairobi Health Services

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DECLARATION

I, Benard Nzyoka Mutisya, do hereby state that this Masters research is my original work and where there's work or contributions of other individuals, it has been acknowledged. To the best of my knowledge, this research project has not been previously presented to any other academic institution or forum.

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I, Dr. Stephen Mburu Ng'ang'a, do hereby certify that this Masters research has been presented for the award of Master of Science in Applied Computing with my approval as the University of Nairobi Supervisor.

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DEDICATION

To my late Dad John Timothy Mutisya Mbwikoh; though the cruel Jaws of death met you while I was pursuing my master's studies, your strong love for education will forever remain my source of inspiration.

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ABSTRACT

Medical devices offer invaluable information to clinicians on a patient's illness, making them a crucial component in the provision of safe, effective and efficient patient care. However, the entry of the most output data from various associated medical gadgets into Electronic Medical Records (EMR) remains manual. These outputs are often presented and kept in the form of paper reports. It means, therefore, that when clinicians and patients have a need to access the information at any given time, it is only possible by looking at the paper files which is a process that is tedious, error-prone, inefficient and not accessible remotely.

In this study, we describe a demonstration in which available Electronic Medical Records system (EMR) was successfully integrated with a wireless Blood Pressure Monitor (BPM). This was implemented by adopting the use of RESTful Application Programming Interface (API) technologies and commonly established standards designed for medical devices interoperability.

We have implemented a solution named BP-Easy to capture data from the device and synchronize seamlessly we used with a local database. Before deploying the prototype, we conducted pilot tests at the University nursing station to get feedback on the time spent using the conventional blood pressure data capture methods and the newly integrated application. Clinical data from the device was exchanged adhering to the HL7/XML standard communication protocol. Data stored can be retrieved and shared between clinicians and the patients to aid in making clinical decisions.

We used quantitative data collecting methods and the data were analyzed using the SPSS software and Microsoft Excel 2010. According to the data observed for the period blood pressure data was gathered, there was a measurement differential in time for both before pre and after the device integration was found. Suffice to say, the duration the blood pressure cuff was on the patient was an average of 58 seconds before the integration of the device, and 38 seconds after. Additionally, there was an observable substantial reduction in the average time that the medical assistant spent at the intake section from 326 seconds before the medical device was integrated and an average of 204 seconds after the integration. The Findings indicate that a positive outcome was availed on the time taken for the Blood Pressure readings, time spent by the patient at the nursing station, as well as the data accuracy fed in the EHR system.

Key Words: EMR, BPM, Interoperability, RESTful, API, Integration, SPSS, HL7/XML

LIST OF ABBREVIATIONS

API…………………………...Application Programming Interface

BPM……………………….Blood Pressure Monitor

EMR…………………….…Electronic Medical Records

SPSS……………………….Statistical Package for the Social Sciences

XML…………………….…Extensible Markup Language

HL7………………………..Health Level Seven

HIE……………………..….Health Information Exchange

RESTful……………………Representational State Transfer

HIMSS…………………….….Healthcare Information and Management Systems Society

PCD ……………………..…Patient Care Device

CDSS…………………….. .Clinical-Decision Support System

IT…………………………..Information Technology

WHO……………………....World Health Organization

IHI ………………………...Individual Health Identifier

HIPAA…………………….Health Insurance Portability and Accountability Act

PHR………………………...Personal Health Record

FHIR……………………….Fast Healthcare Interoperability Resources

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GLOSSARY OF TERMS

1. Deployment: Information systems deployment involves all the processes involved in making the software operational including installation, configuration, running, testing and systems customization.

2. Clinical Information Systems (CIS): this is a technology-based systems used at the point of care. The system is used to support the information process as well as providing processing capabilities and storage

3. Medical Device Integration (MDI): is the formation and preservation of a connection through which data is transmitted between a medical device, such as a patient monitor, and an information system. The word is used interchangeably with biomedical device integration or biomedical device connectivity.

4. Health IT: it is an area in IT that involves designing, developing, creation, usage and preservation of information systems within the healthcare industry.

5. Interoperability: this is defined as an electronic exchange of data between different IT systems that are incorporated into each other.

6. mHealth: mHealth (mobile health) is a general term for the use of mobile phones and other wireless technology in medical care. The most common application of mHealth is the use of mobile phones and communication devices to educate consumers about preventive health care service.

7. Medical Device Gateway (MDG); is a model that delivers the capability to access and retrieve data from the devices through the use of a dedicated network using a standards-based messaging model

CHAPTER 1

Introduction

1.1 Background

In the last few years, healthcare providers all over the world have been concentrating on putting in place Electronic Medical Record (EMR) systems as well as refining the workflows and the system functionalities with the aim of meeting the end-user needs. The adoption and implementation of the EMR system has been successfully undertaken in a number of countries across the globe. Hospitals have been tasked to do more with less, while at the same time they are expected to keep up with the emerging technology and the increasing patient expectations. The clinical staff often spends a lot of time working on documents, when ideally they should be attending to patients.

A question could be asked as to what advantage there is in having expensive isolated medical devices and at the same time have health care providers noting down patient vitals on paper then later manually keying the parameters in the electronic record? Having a coordinated and enhanced care needs complete, accurate, and technologically supported data gathering methods. Healthcare technology connectivity and interoperability have rapidly become a high priority in healthcare contexts due to the plentiful benefits it provides within the care continuum. Ensuring that there is a well-planned strategy for device connectivity can help healthcare institutions to put in place clinical alarms anchored on the established response systems, early warning scores, emergency alert, electronic charting, as well as intensive care units (ICUs), medical device management, patient surveillance, and monitoring.

Despite the significant progress towards the enhancement of technologies in medical devices, several obstacles that impede the potentiality of the adoption of health information technologies including the absence of medical device integration which is a significant limitation (Stefan Fischer& David Gregorczyk, 2016). Medical device Integration can be described as the ability for the exchange of information between the devices and with the patient data repositories including the electronic health records (Cheolgi Kim, 2013). Such integration enables clinical medical equipment to establish a consistent, reliable, and predictable exchange of clinical data with EHRs seamlessly. Limited availability and use of integrated medical systems lead to diagnostic errors, failures to detect deteriorating patients, communication errors and inefficient workflows (Simon C. Mathews et al, 2011)..

1.2 Health IT

Health Information Technology (Health IT or HIT) is an area in IT that involves designing, developing, creation, usage and preservation of information systems in the healthcare industry. Health IT is considered a key component in enabling innovative care delivery and health care reform initiatives. Broadly defined, health IT refers to hardware and software, including electronic information systems, used to create, store, transmit, receive and analyze health information. Health IT generally consists of the three components: health information exchange, (HIE) electronic health records (EHRs), and tele-health. Widespread application of health IT can help to significantly enhance the quality of patient care, reduction of medical errors, and achieve cost savings through greater efficiency. The integration of technology within the primary care embraces an assortment of electronic techniques applicable in the management of information regarding people's health and healthcare. Health IT creates the possibility for healthcare professionals to efficiently deliver care services through the application and share patients' healthcare information.

1.3 Medical Device Networking and Connectivity

The compounded annual growth rate in the market for medical device connectivity is anticipated to reach 38% through 2019, from $3.4 billion worldwide in 2012 (Transparency Market Research, 2012). The successful adoption of medical device connectivity has the power to provide significant savings for the entire healthcare ecosystem, simultaneously improving quality of care. As the trend towards biomedical device integration gains momentum, medical device manufacturers find themselves in the need to innovate their products, capitalizing on the uptake of computerized medical technology.

Communication among interconnected healthcare devices as well as the medical information systems (MIS), especially such devices as multi-parameter patient monitoring and smart infusion pumps has been found to mitigate possible adverse events. It, therefore, means that an integrated system incorporating a central medical dashboard enabled with focus on patients can help healthcare providers through the prioritization of those patients that are in need of higher levels of care.

1.4 Medical device integration

Integration explains the degree to which isolated devices and systems are able to exchange and understand shared data. Two systems are considered to be interoperable if they are capable of exchanging data and consequently present that data in a format that can be comprehended by a user (WHO, 2011). Medical device integration also known as interoperability denotes info sharing between one medical device and another or amongst the medical devices and Electronic Health Records (EHRs). Successful interoperability ensures the efficient communication between the connected medical devices in a predictable, consistent, efficient, and reliable manner. This makes health systems more reliable and safer and can be used to address transcription and administrative errors in health care delivery. Medical device interoperability provides tangible improvements in safety and efficiency of medical processes in a clinical process. Such enormous benefits can be measured in savings in the provision of health care, yet, regardless of the significant paybacks, there is a scanty use of medical device interoperability.

1.5 The State of Medical Device Integration

According to HIMSS Analytics recent report, over 90% of the health facilities surveyed each facility has at least six types of medical devices that are have the capability to integrate with EHRs. These devices include ventilators, vital signs monitors, electrocardiographs, defibrillators, as well as infusion pumps. HIMSS also reported that only about a third of the healthcare institutions have integrated medical devices today.

Moreover, organizations wishing to invest in interoperability often incorporate fewer than three devices which is way below the six devices likely to be found in the facility (Andrew King et al, 2015). Due to this gap where devices are not integrated often, there are unavoidable avenues risks to the patient safety due to incomplete information that the clinicians depend on in the decision making process.

Currently, companies that manufacture the medical device lack the authority to enable interoperability among the devices they produce because a majority of the healthcare providers cater for these costs. Many healthcare providers operate without interoperability because in most instances, the value propositions are not satisfactorily quantified. Given the effectiveness and associated quality assurance tools offered by the medical device interoperability, there is a great need for healthcare stakeholders to invest immensely in interoperability of health systems.

1.6 Challenges of Medical Device Integration

Medical device integration with EHRs is a formidable and complex process which requires work at various levels, from developing software to actually building a network of bridges and gateways for the medical devices and the data collecting devices. Below are some of the challenges associated with medical devices integration with EHRs:

i. **Need for custom interfaces:** Custom intuitive interfaces must be built, providing a link between the medical devices to the EHR. Designing and building these interfaces requires highly skilled technical personnel and dedicated resources which many health care providers often lack.

ii. **Cross-vendor Integrations:** Traditionally, most manufacturers of medical devices have developed devices in isolation in order to protect their own interests. Data obtained from various medical devices lack unified global standards and often may not comply with emerging cross-vendor standards.

iii. **Challenge's learned:** currently, there are few well-defined user cases which can demonstrate the challenges and achievements associated with medical devices integration. In the absence of such cases, the institution that wishes to move in this direction has to basically start from the beginning in obtaining the essential information and making a determination on the best practices that would guide the project implementation and management of device integration.

iv. **Staff compliance:** It is necessary to have the necessary staff compliance that would guarantee adherence to a consistent workflow of data entry into the correct EHR data centers since most y patient encounter presents a significant challenge. In numerous situations, there is inadequate clinical staff, which makes the transfer of knowledge on the optimized application of EHRs and essential medical devices a significant challenge.

So far it is apparent that the problem of medical device integration is a hard procedure for two major reasons. First, it is the fact that medical device connectivity becomes a complex process since there is no "one model" solution for the establishing connection among all medical devices and secondly, the local databases of the hospitals also vary from one place to another.

1.7 Gains of medical devices integration

The increasing use of Information Technologies in the healthcare industry has made it necessary to have the integration of medical devices for the hospitals and clinics to keep the complete patient records on a central Electronic Medical Record (EMR) system. It is beneficial in collecting any patient data from various devices at one location so that a neutral medical solution provider can use it for rendering appropriate treatment to patients on the basis of the information available on EMRs.

i. **Efficient integrated workflow**: By integrating medical devices hospitals receive an efficient, easy and a well-organized workflow. All the sections of the hospital are connected and due to the web-based system, they can be easily controlled.
ii. **Reduced errors:** There is no need of collecting the data manually since the software for integration is able to collect, synchronize and analyze the data automatically. Consequently, the medical personnel receive clear and processed information, probably even collated and summarized. So in the process, errors resulting from manual human data entry are eliminated.
iii. **Remote access:** Now doctors can monitor the health status of each patient even if they aren't at the hospital. And what is more, patients are also able to check the information about their health without actually going to the hospital and share the same with doctors or family members remotely.
iv. **Cloud storage:** The data received from all the medical devices will be managed, stored and secured online. The stored data can be filtered using various criteria, reducing the effort required to locate patient data from the devices. Moreover, the collection and transmission of data to the online storage portal are automatic as devices send the data directly.

1.8 Problem Statement

Although there has been a worldwide push for the adoption and implementation of integrated information technology across the healthcare environment driven by the innovation that underlie the development of medical devices, there are numerous barriers that significantly impede the adoption of the essential health care technology (WHO, 2015). The lack of functional medical device integration has been found to be one of the most significant impediments to effective and efficient health care delivery. Traditionally, most of the available medical devices operate on the proprietary protocols as defined or described by the manufacturer as well as the different ways of connecting to the computer (USB, Bluetooth etc.) (Barbara Franz, 2013). During the treatment process, it is essential for the clinicians to use various medical devices repeatedly in order to gather the necessary data. Currently, the medical devices output data are often manually posted into the information system, a practice that often results in serious mismatches between the diagnostic reports and manually entered patients results. For the small healthcare organizations whose information construction is often weak, the data produced by the electronic devices is still delivered in paper reports format. It means, therefore, that when the health care providers or the patients need to access the data at any given time, they have to search the paper-based. It, therefore, means that the data integration has been a significant problem for the health care providers largely because the information produced by the technological devices often lacks the requisite standards and have recognizable outstanding heterogeneity of the essential medical devices. With the emergence of IT construction within the medical institutions, medical or health care information systems are bound to revolve in the direction of mobile applications as well as intelligent analysis and interconnectedness as well as interworking. The present limitation of non-standardized medical devices connectivity as well as the lack of device integration impedes the effective and efficient workflow aimed at improving patient healthcare and wellbeing.

1.9 the Aim of the Study

The aim of this research is to develop a mHealth application that interfaces Blood Pressure Monitors (BPM) and electronic records in a separate database. The artefact implores the use on Nokia BPM device and Nokia's Application Development Interface (API) for integration.

1.9.1 Research Objectives

The objectives of the study are to:

i. Develop a prototype that will interface between Blood Pressure monitor and an electronic medical records system.

ii. Test and validate the prototype using the test data collected using the integrated interface.

1.9.2 Research Questions

To achieve the stated objectives, the study seeks to answer the following questions:

i. Which factors significantly influences the integration of Blood Pressure monitor and existing health information systems?

ii. How can mHealth application are used to ensure correct capture of data from the BPM device and existing health information system?

iii. How can such model are validated in terms of practical utility and usability of system?

1.10 Study Justification and setting

mHealth and applications are extensively used by healthcare providers and patients in the day-to-day practice. These offerings help health care givers in processes of diagnosing, monitoring, consulting, and treating common diseases. As mHealth applications allow doctors to look up patient information from the patient's bedside, they are able to save time and it enables them to deliver optimum treatment to the patient. Since the apps are readily accessible on Smartphone's and tablets, doctors can ride on the increasingly flexible access to medical information (Breen & Matusitz 2010). They can effortlessly access resources of good quality and make important judgments on the patient's clinical care. However, there is a need to integrate the existing medical devices in order to ensure there are seamless patients data exchange to minimize the potential data transcription errors, improve efficiency and enhance informed clinical decision support. To demonstrate the concept, The University of Nairobi Health Services senior clinic staff was chosen and all necessary approvals were sought.

University of Nairobi Health Services

The study was conducted at the University of Nairobi, Health Services (UHS) main staff clinic located along statehouse road in the main campus. The hospital provides in-patient and out-patient services for a population of approximately 85,000 people made up of both students and staff. The clinic has an In-House developed Health Information System named University Health Management Information System (UHMIS). This system has various modules including, Pharmacy, Triage, Records, Prescription and Administration. Patients who visit the facility go through the Nursing section, where vitals like blood pressure, height, weight and body temperature vitals are recorded. At the nursing station, we have a few medical devices such as; a standalone Philips VM6 Vital sign Monitor, A digital Weighing scale with a height meter scale and digital thermometers. However, none of these devices is connected to the University Health Management Information system. Patient's clinical vital readings data measured by the devices electronically are read by a clinician, written on a small piece of paper or Blood pressure log paper cards. These paper-based logs are stored in the patients' physical files which clinicians refer to during consultation and treatment of the patients.

1.11 Scope of the Study

Many hospitals provide patient's blood pressure screening services as health vitals for all the patients before treatment. The proposed prototype uses a Nokia BPM device and the Nokia Health API. However, due to financial and time constraints, we only implemented BPM data exchange prototype interface named BP-Easy at the University of Nairobi, senior staff clinic.

CHAPTER 2

Literature Review

2.1 Introduction

The emergence of information computer technologies to manage patient info has deeply altered the workflow of the health care providers with many hospitals increasingly embracing the use of Clinical Information Systems (CIS). Equally, Mobile health technologies also known as mHealth have the potential to greatly influence health care, and health outcomes (Andreas Schuler & Oliver Krauss, 2016). CIS has several advantageous effects, such as minimized archiving costs, facilitated organizational tasks, improved access to patient data, patients data sharing, structured evidence, improved patient protection through decision support and enhanced access to information. However, many healthcare establishments are confronted with increasing data gathering and reporting necessities from a wide range of medical devices to assist in making clinical decisions (Moore, 2013). Healthcare data has a tendency to reside in many places and devices; diverse source systems, like HR or EMRs software, to diverse departments, like triage, radiology and pharmacy. There is a dire need to aggregate this data into one, central system, such as an enterprise database which makes the data available and actionable (Valarie Gay, 2017). In this chapter, we start by understanding health basics and some of the issues that hinder successful medical device integration. Later we conclude by discussing Health APIS and how such technology can be harnessed to achieve medical device integrating in order to enhance safety, efficiency, and quality of healthcare.

2.2 Introduction to Clinical Health Records

Health records are viewed as the main databases of healthcare management of patient care. Constant recording by clinical staff as well as other non-clinical staff is an indication of appropriate monitoring and management of the health, treatment and planning (Ljubljana & Slovenia, 2015). The first health records were meant for describing individual processes. In the present day, health records have taken up a broader model than in the past for the reason that in the older days, only the doctor who documented the patients' data. Health documents and records are the heart for the realization of patients' rights, for the purpose of civil and legal relations, together with the exercise of liberties linking to privacy and the retrograde defining the health status.

2.3 Electronic Health Records

Electronic Health Records (EHR's), which is also referred to as the Electronic Medical Records (EMR's), although many people apply both terms interchangeably (Torrey, 2011). The EHR can be defined as an electronic form of an individual's health information that is historically created and stored in a paper chart. The individual's EHR is often created and managed by the medical institution (Roman, 2009). As such, only the medical professionals involved in the patient's care are supposed to have access and use the information contained in the electronic health record (Roman, 2009). On the other hand, the Personal Health Record (PHR) is a health care record that is controlled by the patient (Roman, 2009). In the United States of America, EHR's are protected by law under the Health Insurance Portability and Accountability Act (HIPAA); however, the Personal Health Records do not have any protection under HIPAA (Roman, 2011).

The Electronic Health Record (EHR) is largely viewed as an electronic record of an individual health data that is generated by the encounters in any healthcare delivery institution (Huffman, 2009). The medical records Include information on, progress notes, diagnosis, medications,, past medical history, laboratory data, and immunizations, The EHR has the capability of generating complete records of all patients clinical encounters. It also supports other care-related activities which may be direct or indirect via interfaces that may include an evidence-based decision-making process, quality management, as well as other outcome's reporting.

2.4 History of Electronic Health Records

The practice of maintaining health care records have existed since the advent of healthcare practice. Initially, the healthcare records were used to document the patients' ailment and its probable cause (National Institutes of Health, 2006). The 1960's, however, saw the advent of a rapidly changing environment in patient care which was marked by the introduction of Medicare in the USA (Hufford, 1999). At the same time, other third-party players entered the healthcare industry additionally, healthcare related litigations began to emerge, and as a consequence, the quality of healthcare became important with governments passing stringent laws in an effort to regulate the industry (Hufford, 1999). Consequently, medical records began to be viewed as a necessity in the management of is giving rise to the first electronic medical record. However, the utilization of the electronic records was slow. It was estimated by healthcare specialists and researchers that in 2009 not more than 8% of medical institutions had adopted any health recording system (Ford, Menachemi, Huerta, Yu, 2010). The major reasons attributed to the slow uptake are associated with the immense costs, lack of global standards, as well as patient privacy considerations (Morissette, 2011). The USA Congress enacted the American Recovery and Investment Act In 2009. Through the Act, the United State government offered some significant incentives to the established medical institutions to adopt and implement the Electronic Health Records (EHR) system. Under this Act, healthcare institutions and physicians got monetary incentive through the Medicare and Medicaid if they adopted the health information technology by 2014 (AHA News, 2010).

Nowadays, it is the practice to keep health records of individuals from when they are birth till death. The individual health history may also incorporate medical information of other family members. Health records are often made up of various data that is collected and entered by health care professionals largely in either paper or digital formats and may include electronic images, photos, computerized tests, and other necessary health information. In practice, however, medical records are supposed to be handled and stored by health institution administrators and nurses. An individual's health records, even within a single health care organization, are created by various experts. It can, however, be observed that the managing, storing, provision of accessibility are not clearly legally defined, a situation that allows for excessive availability and the possibility of disposal of or destruction of patients' documents or records entirely.

2.5 Medical Device Integration with Electronic Health Records

Healthcare providers across the globe are adopting the application of the electronic medical records (EMR) systems in the concerted effort to enhance patient care. In this regard, the Integration of medical devices enables healthcare services providers to directly send or access point of care patient data, such as temperature and blood pressure directly to an individual's medical record, and thereby significantly reducing the transcription errors and at the same time ensuring the timely transfer or sharing of important clinical data (Venkatraman et al., 2008). It can, therefore, be argued that Medical devices can play a significant and integral role in the provision of healthcare by delivering crucial healthcare data essential to guiding life-saving procedures (Jitterbit, 2014). Nevertheless, many medical devices are not being maximized to attain their full potential. In many health care institutions, there are far too many devices that sit unused or are not yet connected to the EMR systems that drive patient care.

Although integration of medical devices with EMR systems is possible, a lot has been written on the benefits of its benefits but little discussed are requisite strategies for ensuring the success of the integration. Additionally, The technology that is involved can be, to a large extent, deceptively simple, and in the scheme of the implementation of an ambitious EMR the healthcare device portion is often regarded as relatively unimportant, yet its benefits are huge in the management of patient care (Lau et al., 2012).

2.6 Medical Device Integration standards

The establishment of standards for the medical device interoperability exists to enable medical information systems to engage across organizational, system, as well as across regional and global boundaries (Barbara Franz, 2015). By establishing the requisite standards, the potentiality for sharing important healthcare information can be significantly enhanced as well as supporting national eHealth initiatives, for example, the implementation of the Individual Health Identifier (IHI) or EHR. As such, In order to support and facilitate the complex layers of interoperability, it is important to establish a number of standards (Bob Brackney, 2015). There some organizations that have initiated adoptable standards to support the device interoperability, many of these standards operate in tandem to facilitate functional as well as the semantic interoperability of healthcare devices and EMRs. Below are some of the commonly used standards for data exchange.

i. **Messaging standards**; are used to define the content, data and structures requirements that appertain to electronic messages in order to enable and support the effectiveness and accuracy of the shared information. Some of the available examples include HL7 v2.x used for health care administrative data. Another example is the Digital Imaging and Communications in Medicine (DICOM) for radiology images.

ii. **Application standards;** these standards determine the adoption of business rules and regulations for the application of software systems in their interaction. For instance, the standards can permit one user to have access to different information systems within a given environment which allows for efficient access to the essential and applicable health data.

iii. **Architecture standards;** these are the standards are used to define and apply, for instance, a generic model for medical information systems. These standards enable the possible integration of medical information systems through the provision of guidance to help in designing and planning of systems as well as enabling the integration of existing healthcare systems. The integration is achieved through the deification of common data elements coupled with the established business logic that exist across systems. For instance, the CEN standard ENV12967 (Healthcare Information Systems Architecture or HISA) offers what is described as an open architecture which is largely independent of complex, and sometimes confusing technical specifications

2.7 Medical Device Gateways

Apart from the provision of device-level communication, most producers of networked devices, for example, the vital sign monitors or infusion pumps, use internal networks which provide isolated conduits for the integrated communication among several devices with a central service point, which is commonly known as Gateways. In such a scenario, Medical Device Gateway (MDG) can be viewed as a model that delivers the capability to access and retrieve data from the devices through the use of a dedicated network using a standards-based messaging model (John Zaleski, 2013).

2.8 EMR Integration Challenges of Connecting Medical Devices

Many Healthcare organizations still view EHR interoperability as a significantly elusive goal as they pursue the quest to change their health IT infrastructure to a streamlined and integrated system that is able to merge clinical data with financial management interests (Jennifer Bresnick 2015). In this regard, the focus of medical technology developers should be to offer seamless data integration to help the healthcare organizations meet their future demands in the dynamic healthcare landscape and environment (Doug Brown, 2016). In the view of many industry players, the bigger issues with interoperability in the promotion of health outcomes and quality of care reporting. These are very critical issues in the application and success of essential technological health initiatives (Brown, 2013).

As the sharing of data risks increases, the same is the case with the demand for sharing of information between healthcare providers regardless of what type of the model of EMRs employed. It means, therefore, that there is a need for simplified interfaces for interoperability among the health care services stakeholders, the available healthcare devices, as well as the existing health information systems.

2.9 Open APIs, Driving Medical Device Interoperability

APIs are often used to enable the emerging technologies in the consumers' everyday lives. Why then has healthcare APIs yet to benefit patients? It can be argued that the Application programming interfaces (APIs) can avail the means for a given s program to communicate with another (Barbara Franz, 2015). In the world of information technology, analogies abound that can be used to explain the working of APIs; however, one analogy that is particularly compelling and clearly offers a good illustration, is the wall socket example. In this scenario, instead of hardwiring an appliance to the identified the source of power all that is required is to plug in to draw electricity (John Zaleski, 2015). The person using the device does not need to have any understanding regarding the concept of electricity or it's delivery, all that is needed is just that fits correctly the plug in the socket. The electricity that is accessed through the socket can be viewed as representing the information that could be contained in software; as such, the API acts like the socket and enables and supports a request either to be received or answered.

In view of the medical care industry's association with the health systems and desperate data stores, many industry innovators continue to investigate and explore the potentiality of the application of the widespread API in the medical environments in order to enable possible health or patients care data interoperability.

2.9 Description of Open Medical APIs

Innovation and use of the Open APIs is not restricted to new opportunities or applications. There is still a need to provide real interoperability between existing healthcare systems such as EMR systems and Health Information Exchanges (HIEs). To streamline the provider's clinical workflow, these systems need to interoperate at the discrete data level meaning that Document based exchange needs to give way to standards based discrete data exchange (such as FHIR). Below is a list of some of APIs from Programmable Web's API directory.

Table 1: Open Medical APIs

API Name	**API Description**
MyHealthAccount API	MyHealthAccount is a patient centric medical record service from the Swedish company Infogosoft. Clinics use myHealthAccount modules to send medical records and images to patient's accounts and patients can use myHealthAccount to gather their medical records, vaccinations, and drug lists all in one place. The myHealthAccount REST API allows developers to write applications that access myHealthAccount services. API methods exist for folders, vaccines, and documents. Most responses are in JSON format. An API key is required
BMI API	The BMI Calculator API aims to offer developers a calculator to determine BMIs in software applications. The API is written in CURL, Java Ruby, PHP, Python, Node, Objective- C, and .NET. Body mass index (BMI) is a measure of body fat based on height and weight that applies to adult men and women.
HaVOC API	HaVoc Health Vocabulary API is a REST based API which offers access to every medical terminology registered in the UMLS (Unified Medical Language System), and is used to implement health and biomedical vocabularies to health applications. This API features class based queries, autosuggestions for disease names or symptoms, synonyms, and abbreviations. JSON is used for data exchange, and API Keys are required for authentication. Applied Informatics is a New York based firm that provides holistic technology solutions and services.

iHealth API	iHealth provides wireless scales, blood pressure monitors, and other mobile monitoring devices, along with an app that allows patients to track their own health data, including weight, BMI, bone mass, heart rate, blood pressure, diet, and physical activity. The iHealth API allows third party applications and services to interact with an iHealth user's health data, after user authorization. Responses are given in JSON and XML.
eHealthMe API	The eHealthMe API offers aggregated FDA adverse drug outcome reports available as a public service. The API is comprised of GET calls with JSON formatted responses. There is a limit of 1 request per second, and a total of 100 requests per hour per public IP address. Information is available by gender, age, duration, and more.

2.10 Advantages of Health APIs

In many healthcare markets where the use of APIs is commonplace, many patients often can have access to their data, a possibility that can help them understand and digest and their health issues and arrive at informed decisions (Robert Huckman, 2015). Below are some benefits of health Application Programmable Interfaces.

i. Health APIs can be empowered and promoted by the exploitation of innovative interfaces and creative analytics platforms that generally support the health care provision decision-making process.

ii. Beyond the immediate effects, there is a secondary benefit associated with healthcare API application which would open up IT innovation to those without a little history of health care.

iii. The easy access to clinical information can also lead to the emergence of new healthcare technology innovators who do not necessarily have expertise in medical care but when access to medical data is availed from the healthcare industry, they can design instruments of significant value. These benefits have the potential of significantly allowing the health care market to capture the true potential of the existing data resources (Uppaluru, 2015).

2.11 Challenges of medical devices integration

Medical device integration with EHRs is a daunting and complex process which requires work at various levels, from developing a software to actually building a network of bridges and gateways for the medical devices and the data collecting devices. This last issue is still happening due to the fact that many medical devices might have different specs they were given by the manufacturer. So there is no “single size” that will fit all the existing devices.

Moreover, there is no single electronic healthcare record system as such. Most commonly various EHR has different functions, interfaces, and operational systems. Therefore, a software for integrating EHR with medical devices should be flexible and match various types of medical network and their inner network.

So, it’s not only the problem of integration. It is a hard procedure for two reasons. First, it is the fact that medical device connectivity becomes a complex process since there is no "one model” solution for the establishing connection among all medical devices. And second, the local databases of the hospitals also vary from one place to another. However, let's take a closer look at the medical devices integration services. What are their functions and why is it important to rearrange all medical devices into one system

2.12 Privacy, Security Concerns of Healthcare APIs

There are some industry players who have expressed fears that application of APIs may open new security risks, particularly with apps that are able to access patient personal and medical data 'for evil' purposes, and often without getting the appropriate or proper patient authorization. It has been argued that APIs could provide what has been described as the 'firehose' of data. In contrast to the 'one sip at a time' kind of access that a health care organization web site or email interface may provide. Regardless, the API task force found these issues and concerns to be unfounded particularly when based on the ability of the APIs to deliver high level security compared to the popular ad-hoc interfaces (Michele Luglio et al, 2010). While the access to medical data through the APIs requires additional regulatory compliance and considerations it is believed by many industry experts that existing standards are, for now, adequate safeguards through the use of APIs today. Suffice to say, Healthcare information security and the inherent risks normally associated with API application, nevertheless, still require active and robust oversight by government agencies.

2.13 Extant and Emergent Healthcare APIs

It is largely accepted that APIs have the potential to address the many barriers associated with the sharing of patient's health care information particularly between providers, patients, and others but these innovations are relatively new to healthcare industry (Eric Schneider, 2013). While the Fast Healthcare Interoperability Resources (FHIR) specifications and API are getting accolades in the current discussion regarding healthcare API application point to other APIs which are in operation in enabling medical data communication. For instance, among the operational APIs, they are those that are currently being used by the Blue Button toolkit. The Toolkit includes the regulatory recommended technical standards for sharing data particularly with patients in an organized and structured manner, as well as the associated marketing materials to help the organizations communicate the value of technological access to health records.

The RESTful API can be viewed as one such example that is used to largely support the sharing of information in JSON (JavaScript Object Notation) and XML (Extensible Markup Language) formats while leveraging the security standards OAuth and SAML which are used to confirm that delivery of the information and the requisite authorization to view the information. However, in the recent past the Blue Button toolkit, which is used to allow users to view, download and transmit sensitive health information, has particularly taken to FHIR. The software was initially developed by an organization called the Health Level Seven International (HL7), FHIR potentiality can significantly -change the delivery of care.

2.14 Examples of medical devices integration

Medical device integration can make the work of the entire hospital much faster and even safer. By connecting devices, which are important for vital health data monitoring, medical personnel is receiving the full picture of the patient's health status without the need to be present in front of the monitors and checking the information through a bunch of devices, like vital signs monitor, ventilations pumps, etc.

With the software integration, it is possible to receive an entire health report with not just collected but analyzed data from all the monitors and devices. It is beneficial in a matter of time, and also provides common medical devices with modern functions. For instance, usually, all the information obtained by the medical devices, such as EKG machines or vital signs monitors, was “locked” inside the device. It slowed all the processes down, making simple things complicated. In such a way all the documentation was done manually, then transformed into paper reports, including all the indexes, and only after that it was possible to have a full picture of the patient’s data.

However, patient care device integration inside the hospital network would allow the staff to skip the routine and useless procedure and replace them with the automatized connectivity of the devices. It not only allows collecting all the data from the machines but also might work as alarm triggers if anything goes wrong with the patient’s records. For example, there can be alarms for tracking the heart rate of the patient. Other examples can include such integrated devices as defibrillators, electrocardiographs, vital signs monitors, ventilators and infusion pumps.

2.15 Systems Design: User Centered Approach to Design (UCD)

The typical design of the everyday objects cannot be viewed as always intuitive because at times it often leaves the user frustrated and, most significantly, unable to complete a simple task. As such, the User-centered design’ (UCD) has been viewed as a broad term in the description of design processes where the end-users have the ability to influence how a specific design takes shape (Chadia Abras, et al, 2004). In this regard, the User experience can be taken as a holistic term used to describe the general experience a user faces when using a system. It can then be observed that the user experience research largely lays focus on the interactions between people and products/services, as well as the experience arising from the interaction thereof (Juhani Viitaniemi, 2010). The experience of even of a given simple artefacts does not necessarily have to exist in a vacuum but, rather, in the established and growing dynamic relationship with other people, places and objects (Buchenau et al. 2000). A Deification of the user experience sometimes can extend to various concerns in respect to all aspects of experiencing the products and services, including physical, cognitive, aesthetic, and emotional relationships (Kuniavsky 2003). It can, therefore, be concluded that the User experience has the capacity to strengthen the role of time, context, meaning, and emotions in the 7utilizationn of products or services as well as In the same breath Also shared experiences (Battarbee, 2005) and social interactions are later taken into the discussion (Leikas et al. 2006).

2.16 UCD life Cycle

The User Centered Design work cannot be taken as a one-time activity where the user interface often fixed before the release and promotion of a product, but it has to viewed as a set of activities that are geared at the throughout life-cycle of the given product's development.

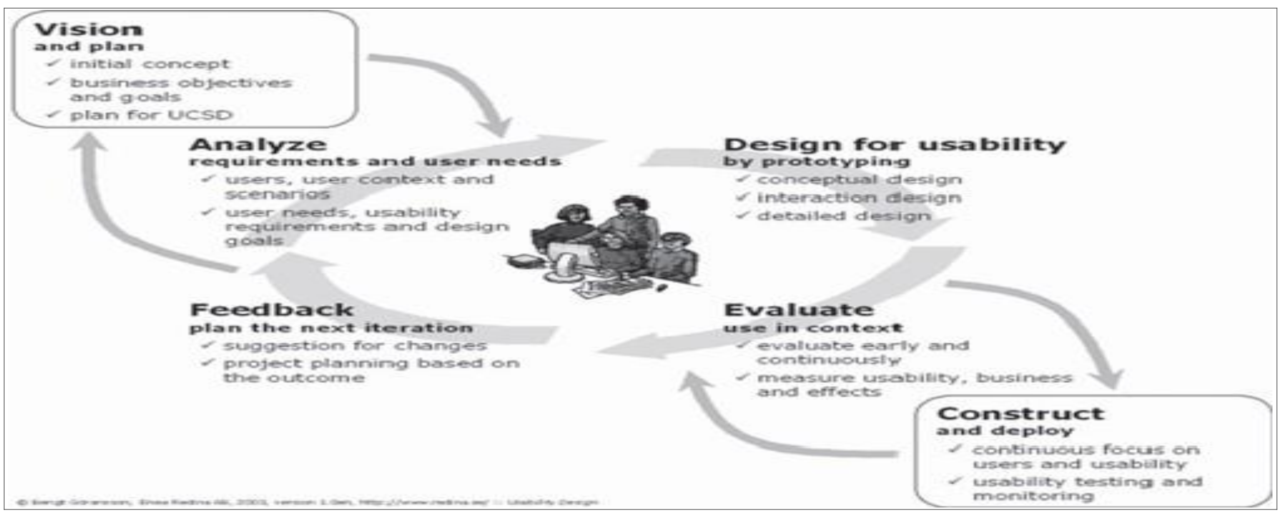

Figure 1: UCD system life cycle (Gulliksen et al., 2003).

As such, there is an obtaining need for multiple levels of the application of UCD that supplement other phases of the project. In this regard, Usability cannot be viewed in isolation from the broader corporate product development context. Regularly Usability efforts may produce even greater returns on investment in the foreseeable future as new technologies evolve in the product family. (Nielsen, 1993).

2.18 Conceptual architectural model design

The diagram below in figure one shows the relationship between different actors in the conceptualized architectural model. The variables such as integration, analysis, tracking and platform independent will be built into service-oriented monitoring prototype.

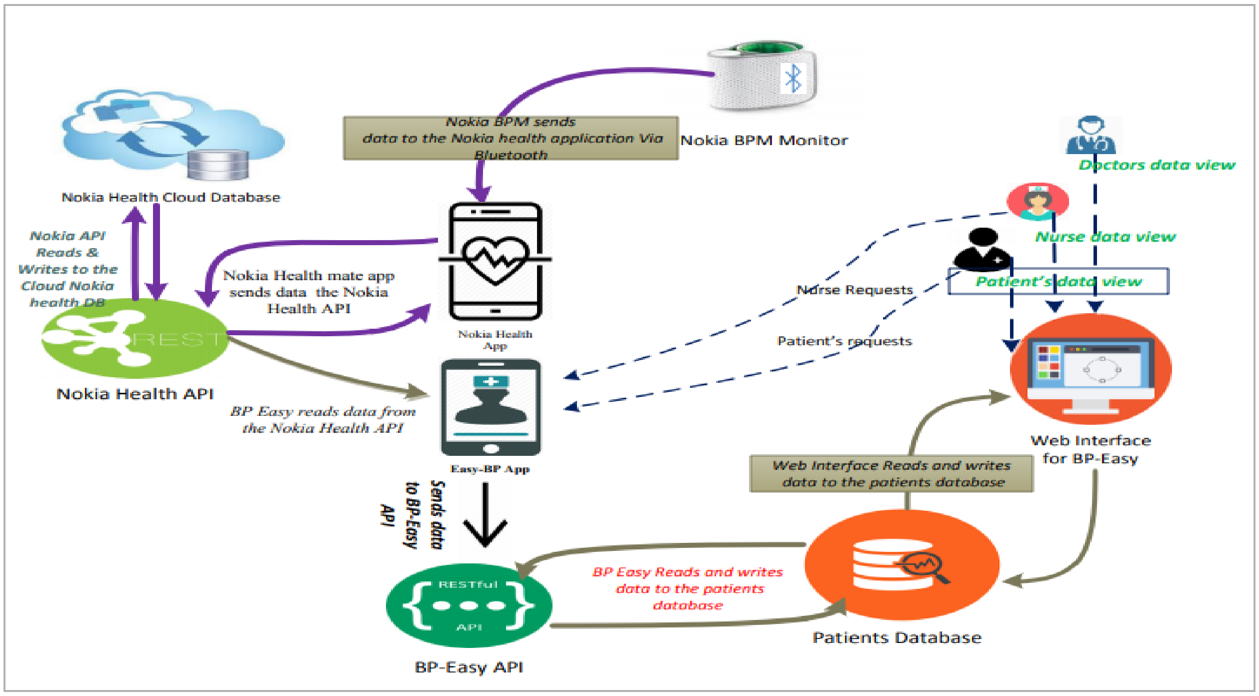

Figure 2: Bp-Easy High level diagram

The Nokia BPM device sends data requests to the Nokia Health Mate Application via Bluetooth. Nokia Health Mate App writes the BP reading obtained from the BPM device to the Nokia Health API. The Blood Pressure readings data exchanged at the API is stored at the Nokia Health Cloud for retrieval when required. The BP-Easy application reads BP readings data from the Nokia API and sends the patient readings to the custom BP-Easy API which subsequently stores the data into the patient's database. The web interface reads and writes into the patient's database providing customized views of data for patients, doctors and Nurses. Data is represented in different visualizations in form of graphs and well-tabulated reports.

CHAPTER 3

Methodology

3.1 Introduction

Research methodology is often described as a systematic way of looking for solutions. It's a scientific way of conducting an investigation that is aimed at arriving at some findings (Kothari, 2004; Rajasekar et al., 2013). In the same breath, Research design can be viewed "as the arrangement of specific conditions for the collection, collating, and analysis of the available data in a manner that is aimed at combining the relevance with the research purpose and economy in procedure. It is essentially the conceptual structure within which a scientific investigation is conducted. The research design constitutes what can be considered as the blueprint for the collection, measurement, and analysis of data (Kothari, 2004).

The main objective of this research is to demonstrate that a Blood Pressure Monitor device can be integrated into an existing Electronic Medical records. The study seeks to discuss the various technical interoperability challenges that are often encountered while organizations seek to integrate health data into a central database. Through the limitation of the negative effects of health data silos, such technological engagement as mobile apps can offer an enhanced and holistic view of health data and allow for more control over the data while enabling sharing of medical information with the clinicians.

The research will endeavor at designing and developing a web-based prototype which will integrate the Blood Pressure Monitor with the University of Nairobi Health Database. Data Captured from the BPM will be stored in a separate database and also text messages will be sent as feedback.

3.2 Software prototype development approach

This research used an agile methodology which promotes empirical processes over prescriptive processes, (Larman, 2003). These processes are decomposed into what can be described as self-contained mini-projects (sprints) and releases (Sliger & Broderick, 2008). Suffice to say; agile projects often run multiple sprints before the actual software is released at the same time, the project can be layered into multiple releases that have their schedule and scope. In order to convert the blueprints into a practical software development process, we used the Agile Unified

Process (AUP) (Koch, Kraus & Hennicker 2007). The rationale was to use an approach that adheres to ISO 9241- 210:2010 (2010) standard on user-centred design. A release can sometimes be internal or external (deployed to production). However, not all sprints may produce a release. In this instance, the software release was designed in such a manner that it is releasable after each one. Although the agile process is iterative substantially incremental the project, nevertheless, still tangentially transitions through different phases of the system's life-cycle (Leffingwell & Widrig, 2003). Agile phases include inception, elaboration, construction and transition.

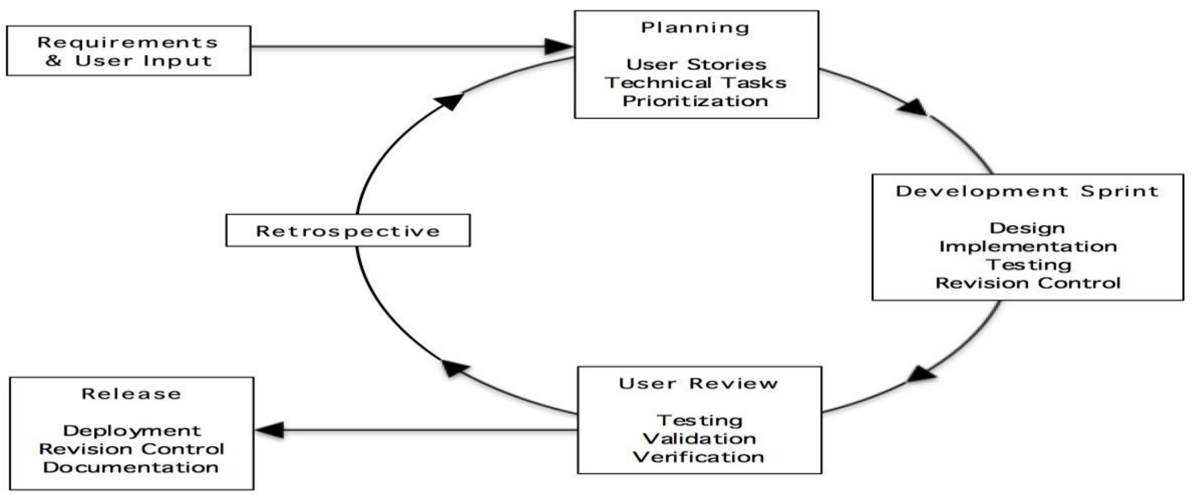

Figure 3: Agile software development methodology

i. **Inception Phase:** In this phase, more emphasis is on **conceptualization** to identify stakeholders' needs through business modeling and requirement elicitation.
ii. **Elaboration phase:** Detailed analysis of requirements using UML-based system models.
iii. **Construction phase**: Design and implementation of system artefacts suitable for the stakeholders' needs.
iv. **Transition phase:** Deals with deployment of the system, training of users and system maintenance.

3.3 Planning Phase/Inception

This is the initial step towards the achievement of our proposed solution. The main purpose of the inception phase is to appreciate and comprehend the domain context and pinpoint the project stakeholder's wants and expectations. In our context, stakeholders refer to subjects of care mainly patients, doctors and nurses. A feasibility study was conducted at the UHS, to seek to understand the user environment and how Blood Pressure data vitals are captured, recorded and stored. During this process, we identified the existing processes and how they are currently achieved using the existing systems. Important also was to understand the business environment and being a hospital necessary approvals are necessary because of dealing with the patient's data.

3.3.1 User Requirements modeling

The tasks undertaken here involved the analysis of business needs and requirements in measurable goals, review the existing technology landscape, conceptualize the needs of the user and map it to the proposed system. Some of the methods used during the conceptualization stage include brainstorming, storyboards, mock-ups and low-fidelity prototypes.

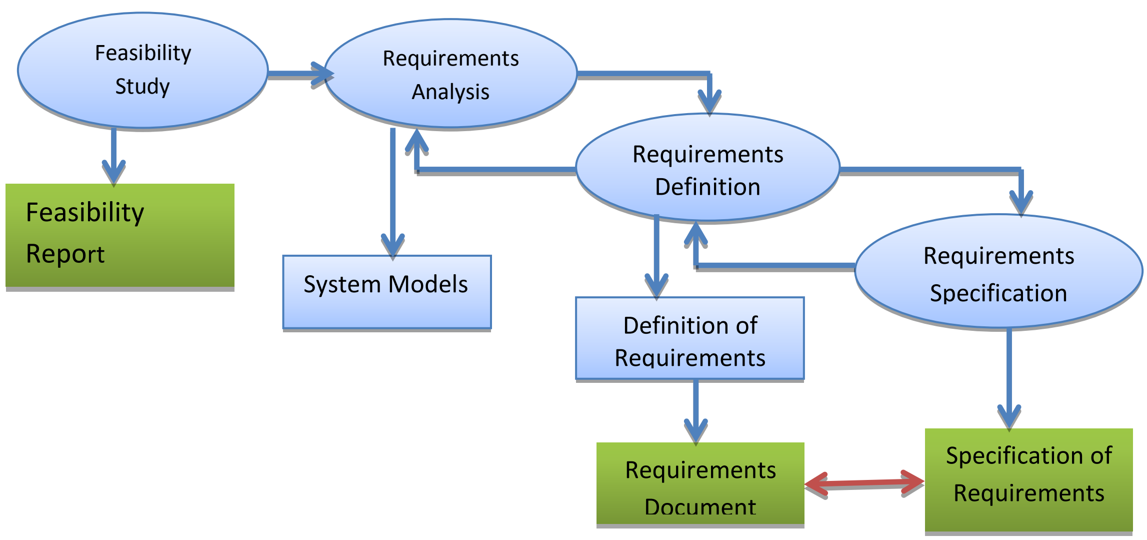

Figure 4: Requirements discovery Model

At the nursing station, there were connected computers and the staff had good understand on computers. At the nursing station we had, one Dell 780 desktop machine connected to the internet, a standalone Phillips MV6 Machine and a digital weighing scale. The process of data capture was simple with the readings from the BPM device being recorded in the paper file and the blood pressure log card. Also, there was a hardcover book to record the time taken by the patient during conduction the entire process of taking blood pressure reading.

3.3.2 Functional Requirements

After identifying the problem a functional requirement document was developed to define the functionality of a system and its subsystems. Users here, proposed below functionalities to ensure the proposed system meets their expectations.

i. The application system should retrieve data from the device and store it in a separate database
ii. The application should allow user registration and capture of patient's demographic data associated with blood pressure.
iii. The system should generate a variety of periodic and on-demand tabular and graphical reports useful for clinical intervention and High blood pressure condition.
iv. The proposed system should allow only administrators to view all blood pressure vitals for all the patients.
v. The system should allow the clients to view their own data receive SMS text messages.

3.3.3Non Functional requirements:

i. The proposed system should be useful, usable and efficient
ii. The proposed system should ensure data transfer is safe and secure.
iii. Since application uses Bluetooth technology it should be able to store offline data

3.3.4 Operational feasibility

Operational feasibility answers the question that, does the proposed system meet the intended expectation and functionality of interfacing the device with the existing database? Also mapping of the requirements with the research objectives was evaluated to act as a guide to remain focused on the user needs.

3.3.5 Technical feasibility

The available technology and infrastructure was accessed to ensure it supports development and implementations of the proposed system. The preliminary study shows that the project is technically viable due to availability of Core i3 Desktop machine connected to fast internet bandwidth, availability of Wireless BPM devices, goodwill of the UHS nurses and Doctors and availability of Open RESTful API for the Nokia Health integration devices.

3.3.6 Economic feasibility

The cost of the BPM monitor with wireless technologies was $99.9 making it affordable. A budget has been prepared and will be met in this research. Upon full implementations of the proposed system, the cost analysis will be evaluated.

3.3.7 Project schedule feasibility

This research was carried out in a set of three milestones and deadlines will strictly be adhered to. A project schedule has been prepared and time allocation for each milestone allocated appropriately. This is an academic project and shall be completed within the specified time frame though we experienced semester delays due to unforeseen circumstances.

3.3.8 Ethical clinical feasibility

The issues of research ethics, confidentiality of information gathered, privacy of personal information and rights of participants will be well protected throughout the research. Data collection approval was granted by the chief medical officer.

3.4 Analysis and Design Phase

At this phase, we thorough investigations on the requirements of the proposed system were carried out and transformed into system models. Research goals and objectives were reviewed to act a guide that will drive the development of the proposed system medical device Integrations and generate a working prototype. Meetings with the UHS staff were conducted to examine if there is any existing applications portfolio at the senior staff clinic and also understand the services, policies, procedures and processes in clinic. During design phase, conceptualized processes and services and analyzed requirements were transformed into set of related models and platform interfaces. The artifact designed was iteratively tested conform to design principles such as service coupling and cohesion that guarantee that the services which will be developed in the proposed system will be useful, usable and effective.

3.4.1 User-Centered Design

The design phase is actualized by the following important elements specification of user centered design approach (Johnstone, 2005).

- ✓ **Task analysis:** Task analysis often takes the user's research a step further through the discovery and analyzes of specific tasks the system users perform with the specific application in order to arrive at the desired goals. The gathered data can then be used to design either new systems or to improve the existing workflows to work in tandem with the users' needs. Flowcharts, Diagrams, Sitemaps, User scenarios and Use cases diagrams will be used in analyzing the user tasks.

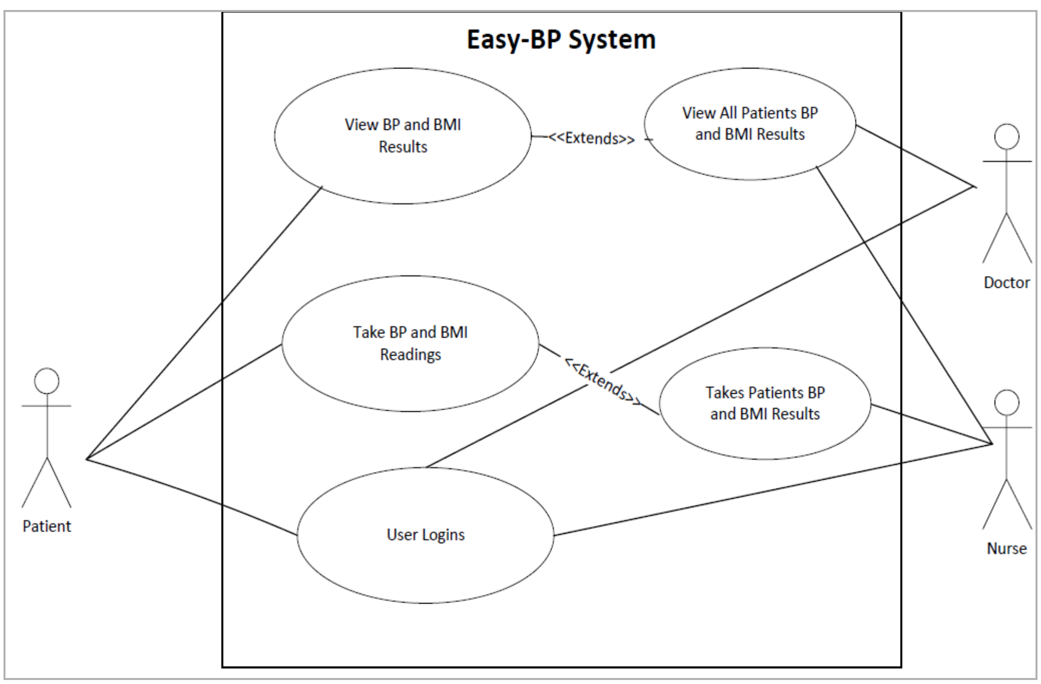

Figure 5: Use case Diagram

- ✓ **Concept design: most** Designs at the conceptual level normally includes aspects such as the information architecture of the given system, possible user workflows, and the required low-fidelity wireframes in order to model the users interface at relatively low level of details. Concept design may, nevertheless, include possible redesign and structuring of whole business strategies, services, and processes. A Dataflow diagram was developed to model data exchange from the Nokia BPM device to the central database.

- ✓ **Database Schema:** Relation database management systems (RDBMS) are still the mostly widely available both commercially and as open source. Therefore, the approach used involves the use and defining the object states as attributes while the operations were implemented in application layer using server-side PHP web development language. Mysql Database will be used in database modeling. Bp-Easy Modeling Entity Relationship Diagram; all entities were linked and database normalization done to ensure data consistency and integrity.

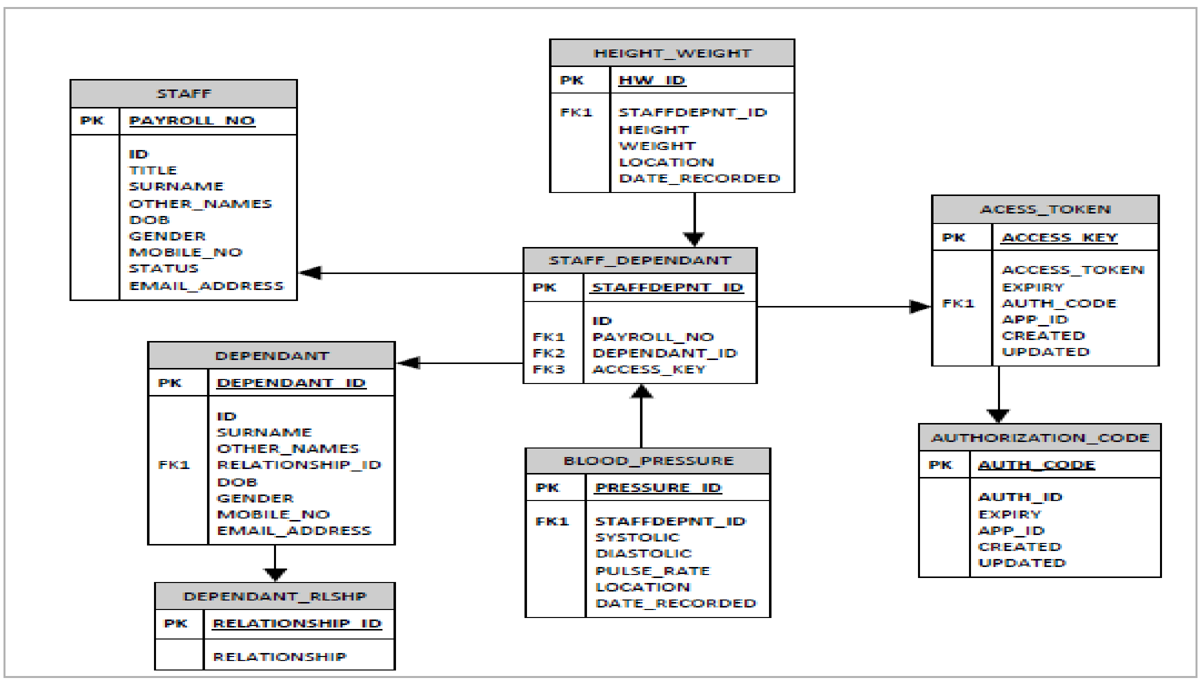

Figure 6: BP-Easy Modeling Entity Relationship Diagram

University staff was linked with dependents to ensure only authorized patients are supposed to access the services. Patient's vitals data tables were linked with the access token table which stores access authorization calls for data from the Nokias API.

- ✓ **UI Design**: Emerging trends in web engineering is responsive design of web applications that dynamically adjusts to different multiple platforms and device profiles. For example, when a user switches from a desktop to mobile phone, the website dynamically scales to fit into screen size, orientation and device resolution. A user responsive interface was provided both the front end and the back end. User friendly home screens, forms and screens and dynamic menus will be developed.

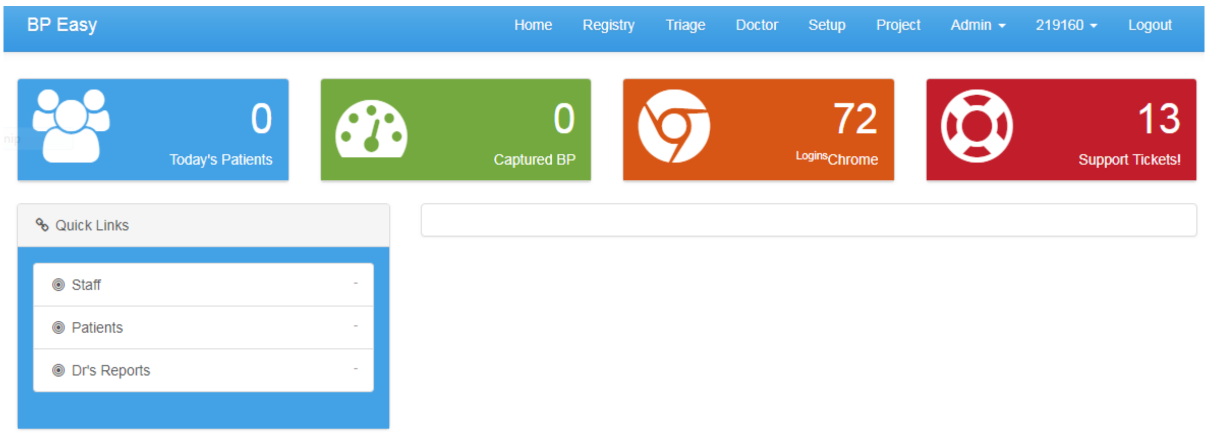

Figure 7: Bp-Easy Dashboard

Responsive UI design was done to ensure the system responds well both in web and on mobile browser.

3.5 Construction Phase

This phase entails the conversion of the system models into a working prototype for deployment. At this point, emphasis shifted from modeling to implementing or acquiring an artefact that satisfies stakeholders' needs. Early releases of the system may be deployed to obtain users' feedback and iteratively requirements were addressed until the user was completely satisfied.

i. Nokia Blood pressure Monitor BPM7 which has wireless Bluetooth capability. Also will use private Nokia Health API

ii. SMS Server: TSOBU SMS gateway will be used to send text messages to the patients

iii. Nodejs, HTML5, CSS3 and JavaScript(jQuery and Ajax will be used for scripting and validation

iv. WAMMP 3.0.6: WampServer has been designed as a Windows web development environment. It allows the user to create the essential web applications with Apache2, PHP and a MySQL database. Alongside, *Php MyAdmin* which allows the user to easily manage the database.

3.5.1 Client side implementation

Client side implementation mobile application interface used by the nurse at the triage will be implemented using Apache Cordova framework.

Why Apache Codeover Framework?

Apache Cordova can be described as an open-source mobile framework. The app allows the user to exploit the standard web technologies such as HTML5, CSS3, and JavaScript for the necessary cross-platform development. The Applications is designed to operate within wrappers which are often targeted to each platform, and mostly rely on the regulated standards-compliant API bindings to access the various gadgets capabilities including sensors, network status, data, and so forth. Apache Codeover is a rapid application development (RAD) tool for mobile applications.

Architecture

There are several components to a Cordova application. The following diagram shows a high-level view of the Cordova application architecture.

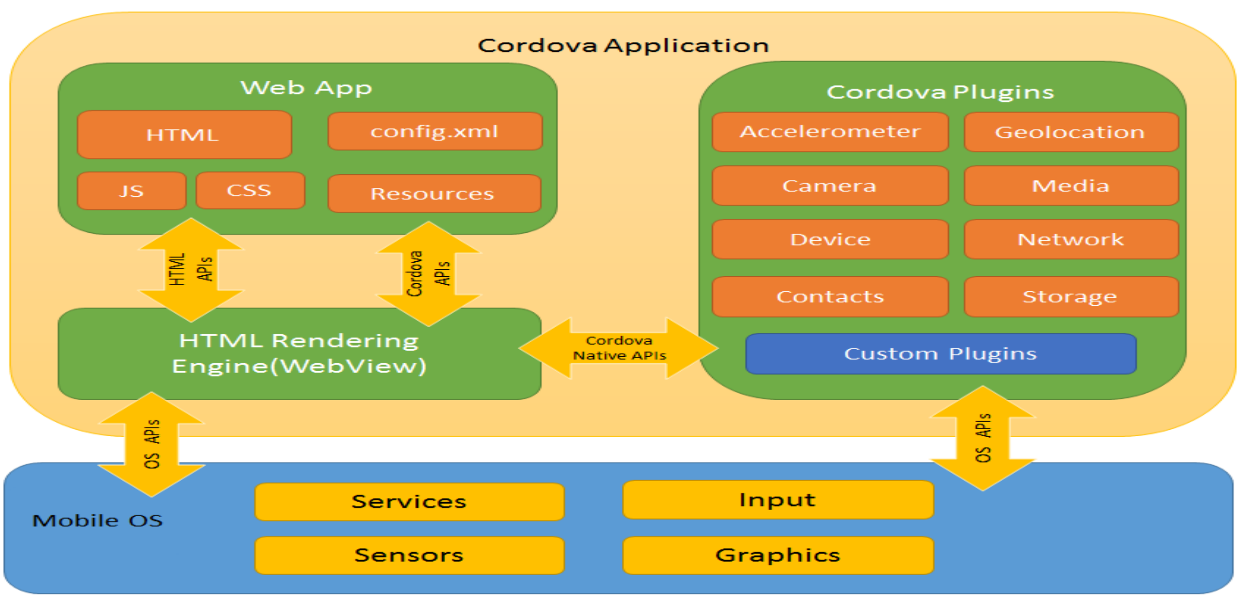

Figure 8: Codeover RAD architecture

Apache Cordova applications

- *Is often used to extend an application activity across several platforms, without necessarily having to re-implement it with every platform's language and tool set.*
- *The application is also used in the deployment of a web app that may be packaged for distribution in a variety of app store portals.*
- ***Apache Cordova applications** Are largely interested in mixing native or original application components with a WebView (special browser window) that has the capacity to access device-level APIs, or if the user desires to develop or include a plug-in interface between the original or native and WebView components*

Apache Cordova is enabled to create a single screen within the original application; the screen normally contains only a single WebView that often occupies most of the available space on the medical device screen.

Bp-Easy Mobile application

At the client side of the application, we have an android application which provides an easy to use interface to register and take the patients' blood pressure vitals. This interface captures patient's demographic data as well as the patient's blood pressure readings.

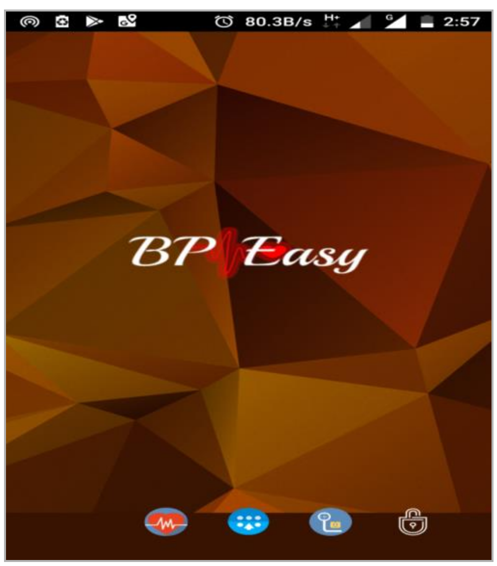

Figure 9: Home screen for BP-Easy solution mobile application

BP-Easy mobile interface provides capturing and synchronizing interface for the data recorded from the Nokia BPM device. Also the mobile application provides tabulated results on form of graphs. Also at client side, the application connects to the patient's records and provides a search mechanism to ensure the patient taking readings is retrieved from the database. Other vital information about a patient, including height, Weight and smoking history can be captured using this interface. This information is very useful towards patients' wellbeing because it can be used to provide insights for further diagnosis and treatment.

3.5.2 Server-side Implementation

Yii 2.0 framework was used to implement the server-side interactions and validations. Yii has been designed as a high performance component-based PHP framework that is enabled to provide for the rapidly developing modern Web applications. Yii framework uses Model View Controllers (MVC) approach which provides am modular approach in design of web based applications.

System Dashboard: BP-Easy solution has an interface which provides at glace important information about patients to the clinicians. The dashboard comprises of various nuggets with each having dynamic information e.g. at glance you can tell the numbers of patients at any given time, total number of the readings captured and total number of log ins to the system. Also the system dashboard provides quick links to staff, patients and doctors reports.

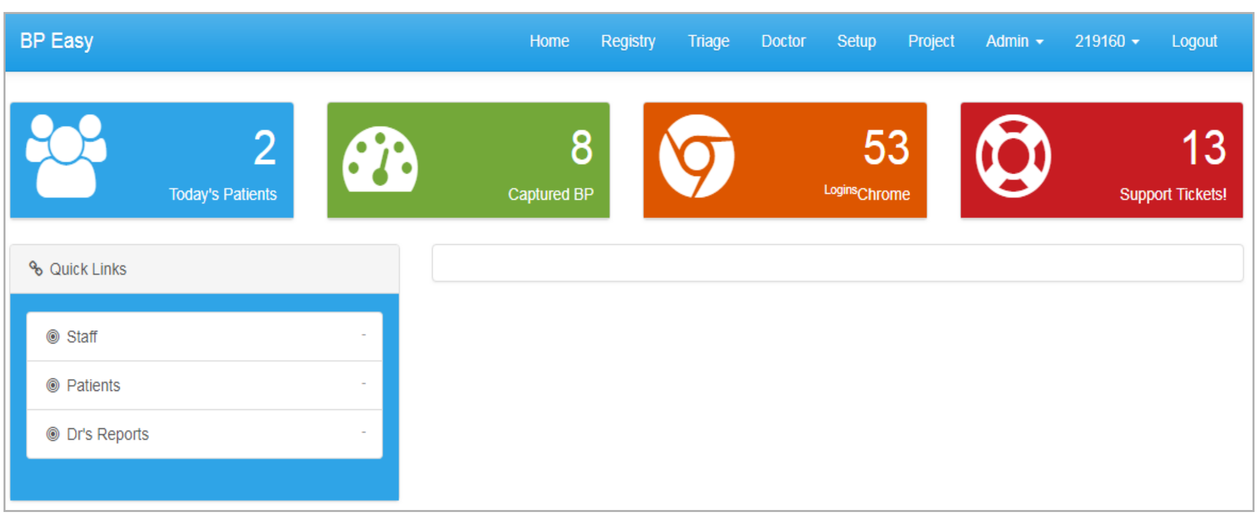

Figure 10: BP-Easy System dashboard

At the top of this interface we have the different system modules including registry, triage, doctor, setup and Admin.

Registry keeps data of all University staff and dependants. New staff and dependants can be added. Only active staff and dependants can access the triage services. At the triage, this is where the nurses at the nursing station interact with the system to capture and synchronize the blood pressure readings. Data reordered is represented in form of line graphs and tabular format.

The system starts by loading all active staff and dependants. You start by selecting the patient you want to capture the BP readings the start your mobile application. Ensure the Bluetooth is on. When you finish click the button capture readings to synchronize the readings captured.

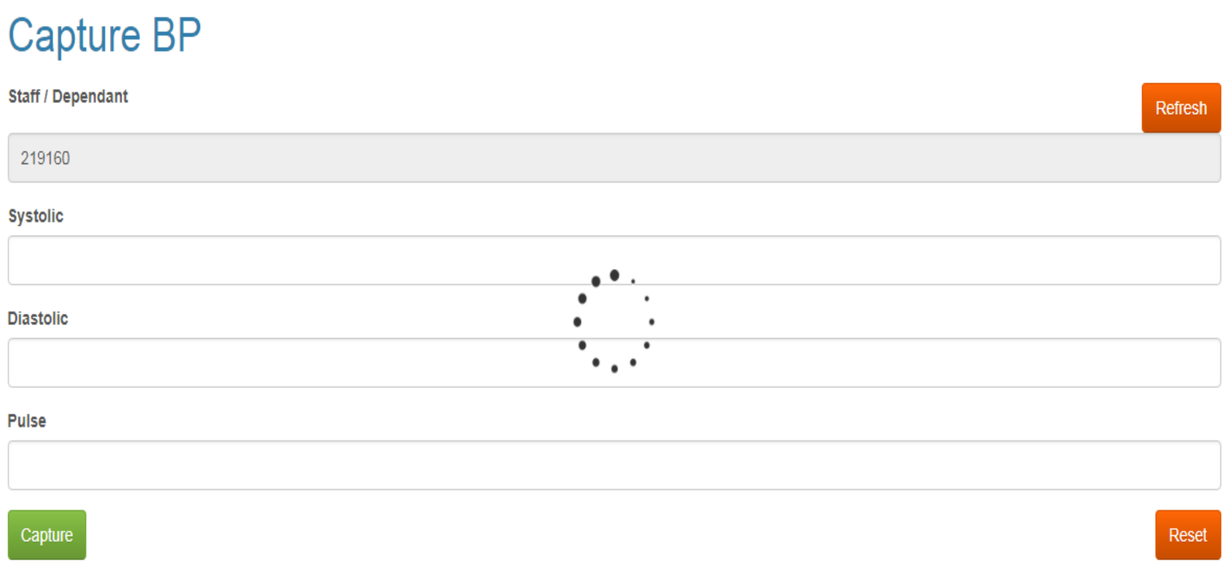

Figure 11: User data capture interface

At the Doctors tab, there are two main items namely; patients and reports. Once patient's blood pressure readings are captured, the doctors can view the readings at a glance by clicking the link with patients. Patients are sorted, the most current on top of the list to make it easy in identification. No more use of manual files where traditionally readings were recorded. Clinicians now can make informed decisions since patient's information is easily available. The graphs here are highlighted and at a glance the clinicians can monitor the trends of patient's readings.

Blood Pressure (BP) | Body Mass Index (BMI)

BP Readings

View Chart

	Recorded	Sys/Dia	Pulse	State
1	2018-04-24 10:28:30	142.00/87.00	68	Isolated, High Blood Pressure Stage 1
2	2018-04-24 10:25:27	141.00/89.00	67	Isolated, High Blood Pressure Stage 1
3	2018-04-24 10:24:33	141.00/89.00	67	Isolated, High Blood Pressure Stage 1
4	2018-04-24 10:23:30	134.00/84.00	65	Isolated, High-Normal
5	2018-04-24 02:38:32	129.00/82.00	72	Isolated, High-Normal
6	2018-04-07 15:59:41	120.00/80.00	70	Isolated, Normal
7	2018-04-07 11:38:46	152.00/102.00	61	Isolated, High Blood Pressure Stage 2
8	2018-04-07 11:37:23	134.00/93.00	72	Isolated, High Blood Pressure Stage 1
9	2018-04-07 10:53:01	133.00/92.00	75	Isolated, High Blood Pressure Stage 1
10	2018-04-07 10:51:33	143.00/89.00	63	Isolated, High Blood Pressure Stage 1

Showing 1 to 10 of 10 entries

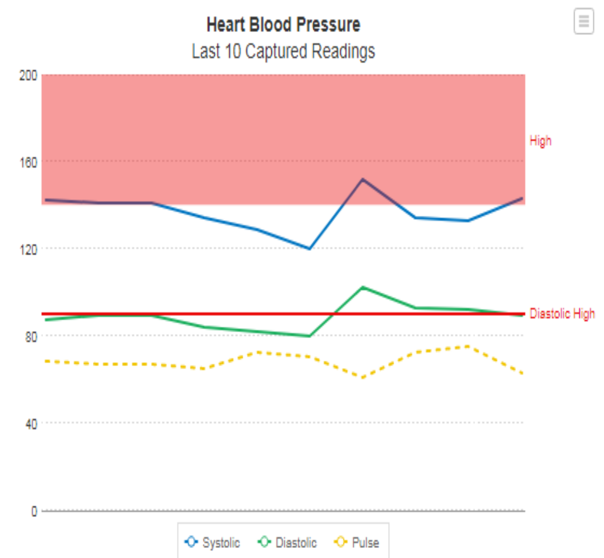

Figure 12: Doctors interface

BP-Easy Settings Interface

Setup menu plays a very important role in keeping the API configuration details. This makes it easy when making new setups for data exchange between the Nokia BPM device and the application.

New API Config

Showing **1-9** of **9** items.

#	Identifier	Value	Last Updated	
1	key	ebd68e06fe6d44db65739dd159b24e260fbe271c03c0ecb49d70850ff47	2018-03-26 18:46:59	
2	consumer_secret	4c8cd0941ec330430e23705c59619f28d4b2248661eb71de9dbe7c858e3d6	2018-03-26 18:46:59	
3	nonce	4de5cd53fac4b12ea965fedf27454eff	2017-11-02 17:17:05	
4	oauth_token	715702608211cb2b10033bd278643094deb849001b8117760f636302d8237	2018-03-26 18:46:59	
5	oauth_token_secret	6bc44b93104e7b3607283bebec2683195b259bbf4fb4f404182995c7284bf3	2018-03-26 18:46:59	
6	oauth_version	1.0	2017-11-02 17:21:49	
7	user_id	14541965	2018-03-26 18:46:59	
8	url	http://api.health.nokia.com/measure	2018-03-06 12:20:54	
9	bpq	action=getmeas	2018-03-06 12:20:54	

Figure 13: Nokia API settings

The Admin menu has several sub items including, users, user roles, permissions, permission groups and a visit log. User roles are defined and different users are given permissions to access certain specific functionalities. E.g. Nurses at the triage cannot access doctor’s interface. This enhances systems security.

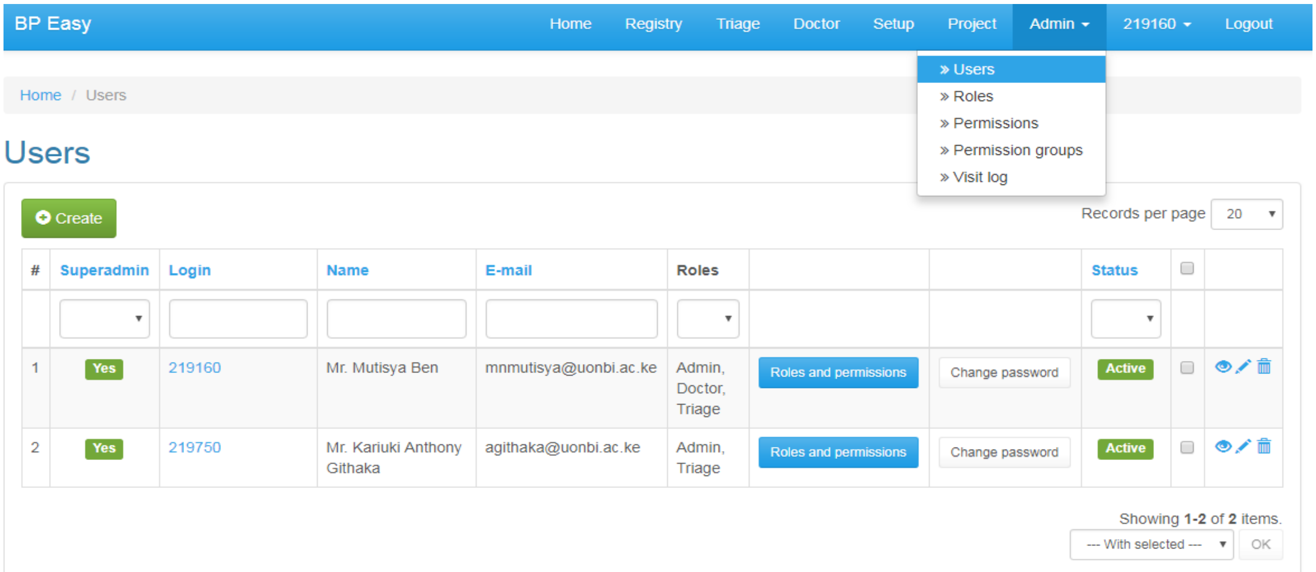

Figure 14: Setting Users

3.6 Security and Privacy

BP-Easy has implemented systems security both at the Database and the application components of the system. As a measure of ensuring confidentiality, security, and privacy of the patient's data several data protection mechanisms were implored. Such mechanisms included user passwords, database rights and system module permissions. User roles are enforced by use of user rights.

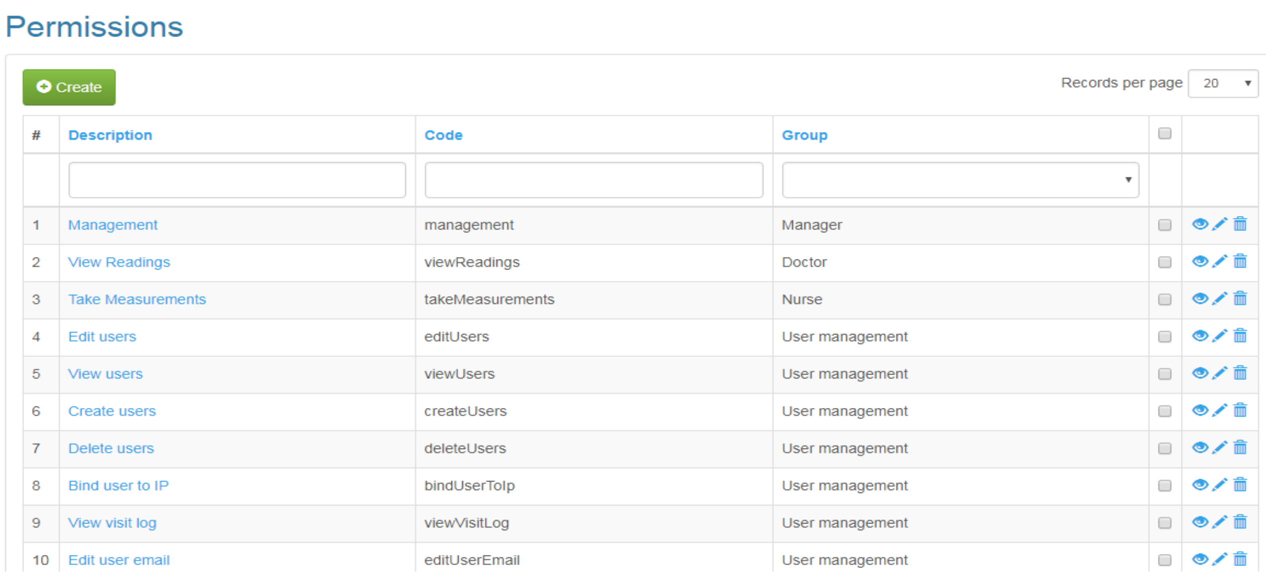

Figure 15: User Permissions

3.6.1 Confidentiality

Confidentiality in the medical industry often viewed as the obligation of industry players who may gains regular access to patients' medical information to confidentially hold that private information. (AHIMA, 2011). The patients' health data shall be kept confidential through encryption. BP-Easy solution was developed adhering to HL7 standards.

3.6.2 Privacy

Privacy, when viewed as distinct from patient confidentiality, can be described as the right of the patient to be allowed to make decisions regarding how their personal information should be shared (Brodnik, 2012). Each user was provided with a secrete user name and password to access the system.

3.7 Prototype Testing

This phase provides needed feedbacks that will help to improve expected users' needs in reporting, notifications and accessing to monitoring of service delivery in proposed system. In the proposed system following testing mechanisms were used (Shelly & Rosenblatt, 2012).

a) **Unit testing** – Each individual program or module was tested for completeness iterative manner to ensure expected standards are meets. The main objective was to identify and eliminate execution errors causing program termination abnormally and any logic errors. This ensured correct data input and output in each system module.

b) **Integration testing -** It's testing where modules depend on each other's. This was done to ensure smooth integrated modules and in iteratively manner in the proposed system. Nokia Health API and the BP-Easy APIs were tested to ensure there is seamless data transfer. Also we checked whether the system interfaces links has integrate well with web interface and ensured data sharing was seamless.

c) **System testing** – The entire system was tested and all users involved. BP-Easy system integration involved ensuring that system meets all specifications and required features have been included has intended by users and other stakeholders. In this testing users and other stakeholders will have entered data including available actual samples, perform queries, and at the same time generate the necessary reports to show real operations conditions.

3.8 Deployment Phase

In this phase it refers to rolling out the proposed application to UHS and other stakeholders including patients. The Bp-Easy application was installed and tested at the user. A server was provided where the system resides.

3.9 Monitoring Phase

This phase is concerned with the health care service level monitoring and measurement which will be a continuum and closed-loop method of monitoring, measuring, reporting, and improving the quality of service of systems and applications. Monitoring will be done through user's feedbacks and caregivers recommendations.

3.9 Training and Awareness

Users were sensitized and trained on the Bp-Easy application. Training sessions were held at the nursing station where blood pressure readings are normally taken. User manuals were also provided during training. The Chief Medical officer recommended for the gadgets to be purchased and adopt the technology.

3.10 User Acceptance Testing

Before deployment of the *Bp-easy solution*, the system was first tested by the patients, Nurses administrators and Doctors. Iteratively all issues raised by the users were addressed.

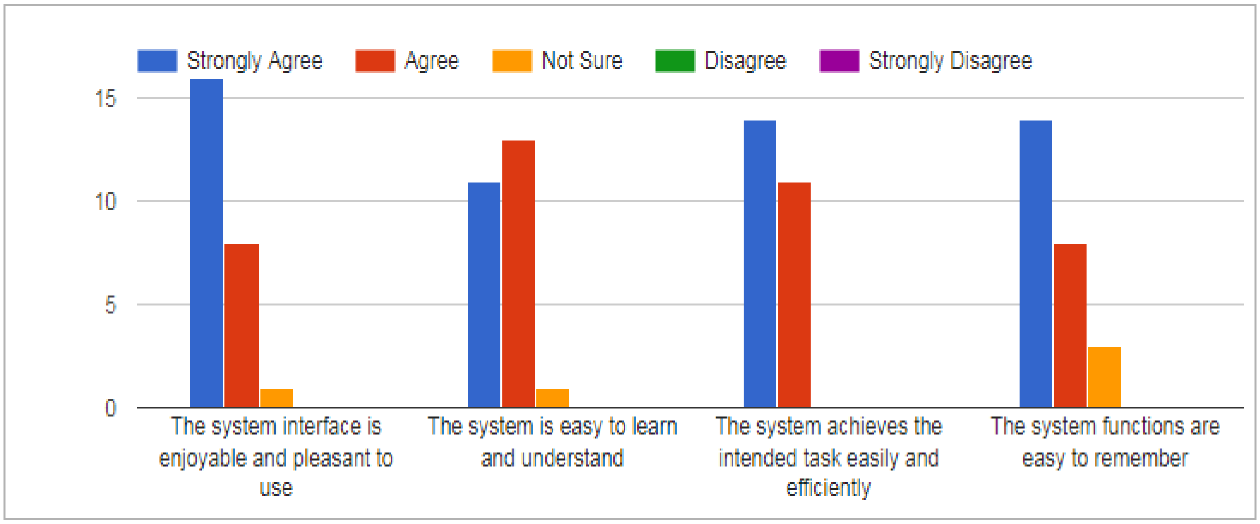

Figure 16: Usability testing survey

CHAPTER 4

4.0 Survey

4.1. Population and Sample Size

A research study Population is often defined as the group of individuals or objects they have a common and distinctly observable characteristic (Mugenda & Mugenda, 2003). In this research a population has being chosen which university of Nairobi as a case study. In order to capture user requirements correctly a total 33 examples was considered. This includes clinicians and patients who are active employees of the University of Nairobi.

4.2 Data collection tools

The system needs and design concerns were gathered through Face to face interviews, observations and Questionnaires with stakeholders.

4.2.1 Questionnaires

Questionnaires are very popular means of data collection and were chosen because they are cheaper compared to other data collecting method. Closed questionnaires were used in requirements gathering and user satisfaction survey. Online questionnaires were issued and data analyzed.

Advantages:

- ✓ The responses gathered are standardized, which makes the questionnaires more objective than interviews.
- ✓ Generally it is relatively easy to administer and the results can be easily quantified.
- ✓ Can be scientifically analyzed.

4.2.2 Face-to-face interviews

We conducted structured and unstructured face-to-face interviews with patients and caregivers in order to investigate their needs, expectations and suitability of using the integrated Blood pressure monitor.

Advantages

- ✓ **Accuracy:** The Face-to-face interviews often give accurate screening. The interviewees do not have the opportunity to falsify information regarding gender, age, or race.

- ✓ **It also allows keeping focus. In this scenario,** The interviewer maintains control over the proceedings of the interview and generally keeps the interviewee on track to completion
- ✓ **Capture emotions and behaviors.** Face-to-face interviews capture an interviewee's emotions and behaviors

4.3 Data presentation, analysis and presentation

This is the collection and arrangement of pertinent measures together with the searching for relationship obtaining among data groups. Hence, in the process, the relationship of competing interests with new hypotheses should be subjected to robust statistical tests to determine with what validity the data can be said to provide any meaningful conclusions (Kothari, 2004). In this study we used quantitative methods of data analysis. Questionnaires from the pretest and post-test observations were checked and those found incomplete or incorrectly filled eliminated. Codebook was used to code responses to numerical values for analysis using Microsoft Excel and (SPSS). After coding the responses on the questionnaire, the numeric values were keyed into Microsoft Excel and SPSS for further processing.

4.4 Ethical issues

The research was conducted in strict conformity to clinical ethics and rules. Patient's privacy of data will be ensured. The data was considered confidential and only used for this study. It will involve briefing the participants about the research objective and their roles in this research. Written consent was sought on information that is protected and abiding to all procedures. Approval for data collection was granted by the Chief Medical Officer.

CHAPTER 5

Results and Discussion

5.1 RESULTS

According to observational blood pressure data collection, the study found a measurement differential in times before and after device integration. It means that, on average, the duration that the blood pressure device was on the patient's arm was 58 seconds prior to the integration, and 38 seconds after. Additionally, it was observed that there was a significant reduction in the time taken by the nurse in the intake room from approximately 326 seconds before integration and 204 seconds after (Table 2 below).

Table 2: Time spent taking vitals, pre and post device assessment

Time	**BP Cuff Time**		**Total Time Spent in the nursing room**	
	Conventional	***Integrated***	***Conventional***	***integrated***
Average (Seconds)	58	38	236	204
Median (seconds)	41	36	265	180
Range (seconds)	18-120	12-93	113-290	60-960

CHAPTER 6

Conclusion and Recommendations

6.1Conclution and future research

Despite most Medical device technologies being developed in isolation, the integration of commercial medical devices with existing EHR system has been adopted by some hospitals. Medical staff acceptance was found to be high after an adjustment. The clinicians indicated that they prefer using the integrated system to the old manual way of collecting and recording the Blood Pressure readings. The initial findings indicate that a positive impact obtains during the taking of the Blood Pressure and rooming the patient. In this demonstration project, however, the sample size was small and not repetitive, as such; there is a need for further studies to find out whether the results are replicable in a bigger scale. Given the rising acceptance of the adoption of the emerging technology, EHR integration with medical devices is critical for efficient, effective, and safe care. Successful interoperability ensures the efficient communication between the connected medical devices in a predictable, consistent, efficient, and reliable manner.

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APPENDICES

Appendix 1: Bp-Easy Care givers questionnaire

Time____________ Date_________________________

INSTRUCTIONS

i) Do not indicate your Name on the guide

ii) This questionnaire comprises of six sections

iii) Attempt all questions in each section

1.0 Personal Information

1. What is your Occupation?

☐ Nurse ☐ Clinical Officer ☐ Doctor ☐ Pharmacist

2. What is your Gender?

☐ Male ☐ Female

2.0 Health system availability and use

2.1 Do you have any Electronic Medical Records (EMR) system in place?

☐ Yes ☐ No

2.2 If Yes, Is the system currently being used?

☐ Yes ☐ No ☐ Not Applicable

3.0 Blood Pressure monitoring station

3.1 Do you have a nursing station where patients' blood pressure readings are taken?

☐ Yes ☐ No

3.2 Is it mandatory to take all your patients' Blood pressure readings at the monitoring station?

☐ Yes ☐ No ☐ Not Applicable

3.3 How do you record the patients' blood pressure readings?

☐ Patients file ☐ Use of manual card ☐ Electronically ☐ Not recording

3.4 Does the Blood pressure monitor have network connectivity?

☐ Yes ☐ No ☐ Not Sure

3.5 Is the blood pressure monitor integrated with any other health system in the clinic?

☐ Yes ☐ No

4.0 User feedback on the current system

4.1 How do you rate the current system for Capturing, storing and retrieving patients’ blood pressure readings?

☐ Very Efficient ☐ Efficient ☐ Slightly Efficient ☐ Not fficient ☐ Not Sure

4.2 What is your experience in managing patients’ blood pressure data especially for those with hypertension using the current?

☐ Very Easy ☐ Easy ☐ Difficult ☐ Very Difficult ☐ Not Sure

5.0 Proposed Integrated blood pressure system

5.1 Do you think the use of computer technology will improve the process and maintenance of patients’ blood pressure records?

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

5.2 Which technologies would be suitable for sending blood pressure readings feedback to the patients?

☐ Mobile Application ☐ Web application ☐ SMS ☐ All above

5.3 How helpful would an integrated blood pressure monitor if fully implemented?

☐ Very helpful ☐ Helpful ☐ Not sure ☐ Not Helpful

Appendix 2

Bp-Easy Prototype User satisfaction questionnaire

Time_____________ Date___________________________

INSTRUCTIONS

i) Do not indicate your Name on the guide

ii) This questionnaire comprises of six sections

iii) Attempt all questions in each section

1.0 Personal Information

1. What is your Occupation? ____

2. Please indicate your Age

- ☐ 18 – 25 Years
- ☐ 26 - 30 Years
- ☐ 31 - 35 Years
- ☐ 36 - 40 Years
- ☐ Above 41 Years

3. What is your Gender?

☐ Male ☐ Female

2.0 Ease of Use and User friendliness

To what extent do you agree with the following regarding Ease of Use and user-friendliness of the system?

2.1 The system interface is enjoyable and pleasant to use

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

2.2 The system is easy to learn and understand

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

2.3 The system achieves the intended task easily and efficiently

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

2.4 The system functions are easy to remember

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

---

3.0 System Accuracy, precision and completeness

To what extent do you agree with the following as far as the accuracy of the data generated by the system?

3.1 The system provides accurate and precise readings

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

3.2 The system tabulates the readings accurately according to the known standards?

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

3.4 Are you satisfied the information stored is complete and accurate?

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

3.5 The system captures data accurately from the device

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

---

4.0 Timeliness and usefulness

To what extent do you agree with the following regarding system timeliness and Usefulness?

4.1 The system provides reports and information needed in a timely manner

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

4.2 The system provides up-to-date information

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

4.3 The system is important and useful for the intended purpose

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

---

5.0 System content and Output Format

To what extent do you agree with the following regarding system data reports and data forms?

The systems reports have the correct visualizations

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

The reports and data forms are clear and readable

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

The system provides precise information for decision making

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

The system reports and forms are presented in easy and pleasant format

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

The system provide all reports that seems to be exactly what I need for reporting

☐ Strongly Agree ☐ Agree ☐ Not Sure ☐ Disagree, ☐ Strongly Disagree

---

6.0 General comments on the system____

Appendix 3

Integrated blood pressures monitor solution clients

Time____________ Date_________________________

INSTRUCTIONS

i) Do not indicate your Name on the guide

ii) This questionnaire comprises of five sections

iii) Attempt all questions in each section

1.0 Personal Information

1. What is your Occupation? _______________________________________

2. Please indicate your Age

☐ 18 – 25 Years

☐ 26 - 30 Years

☐ 31 - 35 Years

☐ 36 - 40 Years

☐ Above 41 Years

3. What is your Gender?

☐ Male ☐ Female

2.0 Patients and blood pressure information

2.1 How often do you take your blood pressure readings and Body weight?

☐ Daily ☐ Weekly ☐ Monthly ☐ Annually ☐ Health Facility Visit

2.2 Do you have your own blood pressure monitor?

☐ Yes ☐ No

2.3 If yes, do you understand how do use the device?

☐ Yes ☐ No ☐ Not Applicable

3.0 Blood pressure readings capture at the nursing station

3.1 During health services visit do you take blood pressure readings and body weight and height?

☐ Yes ☐ No

3.2 If yes, do you have a blood pressure card where you record the readings every time you visit the clinic?

☐ Yes ☐ No ☐ Not Applicable

3.3 Are you aware of your current blood pressure status?

☐ Yes ☐ No ☐ Not Sure

3.4 Are you able to interpret the blood pressure readings correctly?

☐ Yes ☐ No

4.0 Patients and Mobile phone Devices

4.1 Do you have a mobile phone?

☐ Yes ☐ No

4.2 If yes, do you have a smart phone or a feature phone (Mulika Mwizi)?

☐ Smart phone ☐ Feature phone ☐ Both

4.3 Would you prefer receiving text notifications regarding your blood pressure readings?

☐ Yes ☐ No

5.0 Patients data Privacy

5.1 Do you share your phone with family members or close friends?

☐ Yes ☐ No

5.2 Are you comfortable sharing your blood pressure readings with authorized medical personnel?

☐ Yes ☐ No

Appendix 4

Code for the View of Capturing and Retrieving BP Readings

```
<?php

use yii\helpers\Html;
use timurmelnikov\widgets\LoadingOverlayAsset;

/* @var $this yii\web\View */
/* @var $model app\modules\triage\models\Bp */
LoadingOverlayAsset::register($this);
$this->title = 'Capture BP';
$this->params['breadcrumbs'][] = $this->title;
?>
<div class="bp-create">

    <h1><?= Html::encode($this->title) ?></h1>

    <?= $this->render('_form', [
        'model' => $model,
        'fid' => $fid,
    ]) ?>

</div>
<?php
// JavaScript code (heredoc-syntax)
$gtBP = \yii\helpers\Url::to(['fetch-bp']);
$script  =  <<<JS

// Settings (cannot be used, then - all by default)
$.LoadingOverlaySetup({
    color: "rgba (102, 255, 204, 0.2)",
    maxSize: "80px",
    minSize: "20px",
    resizeInterval: 0,
    size: "50%"
});

// Overlay jQuery LoadingOverlay on an element with ID # p0, when sending an AJAX request
$(document).ajaxSend(function (event, jqxhr, settings) {
    $("form").LoadingOverlay("show");
}) ;

// Hide jQuery LoadingOverlay to an element with ID # p0, after running the AJAX request
$ (document).ajaxComplete (function (event, jqxhr, settings) {
    $("form").LoadingOverlay("hide");
});

$(document).on('click','button.refresh',function(){
    window.location.reload(true);
})

$(document).on('click','button.reset',function(){
    $(document).find('form .jeget').each(function(){
        $(this).prop('readonly',false);
    });
})

$.ajax({
    method: "GET",
    url: '$gtBP',
    dataType: "json",
    success: function(response) {
        $(document).find('form .jeget').each(function(){
            $(this).prop('readonly',false);
        });
```

```
        if(response.error){
            alert('Could not retrieve BP Readings.' +
             'Kindly capture the readings on the Form Presented');
        }else{
            $(document).find('form .jeget').each(function(){
                $(this).prop('readonly',true);
            });
            $('.sync_sys').val(response.data.sys);
            $('.sync_dia').val(response.data.dia);
            $('.sync_bpm').val(response.data.bpm);
        }
    },
    error: function (jqXHR, exception) {
        alert('Could not retrieve BP Readings.' +
             'Kindly capture the readings on the Form Presented');
    },
});

JS;
// Connecting the script in the
$this->registerJs( $script, yii\web\View::POS_END) ;
?>
```

Code for the BP Controller

```
<?php

namespace app\modules\triage\controllers;

use app\modules\triage\models\PatDetailsView;
use Yii;
use app\modules\triage\models\Bp;
use app\modules\triage\models\BpSearch;
use yii\web\Controller;
use yii\web\NotFoundHttpException;
use yii\filters\VerbFilter;
use linslin\yii2\curl\Curl;
use app\modules\triage\models\NokiaConfig;

/**
 * BpController implements the CRUD actions for Bp model.
 */
class BpController extends Controller
{
    /**
     * @inheritdoc
     */
    public function behaviors()
    {
        return [
            'verbs' => [
                'class' => VerbFilter::className(),
                'actions' => [
                    'delete' => ['POST'],
                ],
            ],
            'ghost-access'=> [
                'class' => 'webvimark\modules\UserManagement\components\GhostAccessControl',
            ],
        ];
    }

    /**
     * Lists all Bp models.
     * @return mixed
     */
    public function actionIndex()
    {
```

```php
        $searchModel = new BpSearch();
        $dataProvider = $searchModel->search(Yii::$app->request->queryParams);

        return $this->render('index', [
            'searchModel' => $searchModel,
            'dataProvider' => $dataProvider,
        ]);
    }

    /**
     * Displays a single Bp model.
     * @param integer $id
     * @return mixed
     * @throws NotFoundHttpException
     */
    public function actionView($id)
    {
        return $this->render('view', [
            'model' => $this->findModel($id),
        ]);
    }
    /**
     * Creates a new Bp model.
     * If creation is successful, the browser will be redirected to the 'view' page.
     * @return mixed
     */
    public function actionCreate()
    {
        $model = new Bp();

        if ($model->load(Yii::$app->request->post()) && $model->save()) {
            return $this->redirect(['view', 'id' => $model->id]);
        } else {
            return $this->render('create', [
                'model' => $model,
            ]);
        }
    }

    /**
     * Creates a new Bp model.
     * If creation is successful, the browser will be redirected to the 'view' page.
     * @return mixed
     */
    public function actionCapture($id)
    {
        $model = new Bp();

        if ($model->load(Yii::$app->request->post()) && $model->save()) {

            $sd = PatDetailsView::find()
                ->select('sid,type')
                ->where('id='.$model->fid)
                ->asArray()->one();
            return $this-
>redirect(['/triage/default/details','id'=>$sd['sid'],'type'=>$sd['type']]);

        } else {
            return $this->render('capture', [
                'model' => $model,
                'fid' => $id,
            ]);
        }

    }

    /**
     * Updates an existing Bp model.
     * If update is successful, the browser will be redirected to the 'view' page.
```

```php
     * @param integer $id
     * @return mixed
     * @throws NotFoundHttpException
     */
    public function actionUpdate($id)
    {
        $model = $this->findModel($id);

        if ($model->load(Yii::$app->request->post()) && $model->save()) {
            return $this->redirect(['view', 'id' => $model->id]);
        } else {
            return $this->render('update', [
                'model' => $model,
            ]);
        }
    }

    /**
     * Finds the Bp model based on its primary key value.
     * If the model is not found, a 404 HTTP exception will be thrown.
     * @param integer $id
     * @return Bp the loaded model
     * @throws NotFoundHttpException if the model cannot be found
     */
    protected function findModel($id)
    {
        if (($model = Bp::findOne($id)) !== null) {
            return $model;
        } else {
            throw new NotFoundHttpException('The requested page does not exist.');
        }
    }

    /**
     * Fetch BP Readings
     */
    public function actionFetchBp()
    {
        $tstamp = time()-Yii::$app->params['nokia_rest_diff']; // nokia timestamp has a
difference
        $curl = new Curl();
        $nokiaRQ = $curl->get(Bp::generate_url($tstamp));

        if(!empty($nokiaRQ) && json_decode($nokiaRQ)){
            $nokiaRQ = json_decode($nokiaRQ,true);

            if(!empty($nokiaRQ['body']['measuregrps'])){
                $units = $nokiaRQ['body']['measuregrps'][0]['measures'];
                // reading post params
                $systolic = 0;
                $diastolic = 0;
                $pulse = 0;

                foreach($units as $r){
                    if($r['type']==9)
                        $diastolic = $r['value'];
                    if($r['type']==10)
                        $systolic = $r['value'];
                    if($r['type']==11)
                        $pulse = $r['value'];
                }
                $data = array('dia'=>$diastolic,'sys'=>$systolic,'bpm'=>$pulse);
                $info['message'] = "Blood pressure entry captured successfully";
                Yii::$app->api->sendSuccessResponse($data, $info);
            }else{
                $info = "No results found from Nokia BP!";
                Yii::$app->api->sendFailedResponse($info);
            }
        }else{
```

```
            $info = "The request could not be handled! try again!";
            Yii::$app->api->sendFailedResponse($info);
        }
    }
}
```

Code for the BP Model

```php
<?php

namespace app\modules\triage\models;

use Yii;

/**
 * This is the model class for table "bp".
 *
 * @property integer $id
 * @property integer $fid
 * @property double $systolic
 * @property double $diastolic
 * @property integer $pulse
 * @property string $location
 * @property string $recorded
 */
class Bp extends \yii\db\ActiveRecord
{
    /**
     * @inheritdoc
     */
    public static function tableName()
    {
        return 'bp';
    }

    /**
     * @inheritdoc
     */
    public function rules()
    {
        return [
            [['fid', 'systolic', 'diastolic', 'pulse'], 'required'],
            [['fid', 'pulse'], 'integer'],
            [['systolic', 'diastolic'], 'number'],
            [['location'], 'string'],
            [['recorded'], 'safe'],
        ];
    }

    /**
     * @inheritdoc
     */
    public function attributeLabels()
    {
        return [
            'id' => 'ID',
            'fid' => 'Staff / Dependant',
            'systolic' => 'Systolic',
            'diastolic' => 'Diastolic',
            'pulse' => 'Pulse',
            'location' => 'GPS Lat Long',
            'recorded' => 'Recorded',
        ];
    }

    /**
     * @param $id
```

```php
     * @return array
     * @throws \yii\db\Exception
     */
    public static function GetBP($id)
    {
        $db = Yii::$app->getDb();
        $model = $db->createCommand("
            select fid,systolic,diastolic,pulse,location,
            case cnt when 2 then concat(\"Isolated, \",verdict) else verdict end as
verdict,recorded
            from
            (
            select
            count(t.id) as cnt,t.*, lv.verdict
            from bp t
            RIGHT JOIN
            bp_levels lv ON (( lv.sys_min <= t.systolic AND lv.sys_max >= t.systolic  ) OR (
lv.dia_min <= t.diastolic AND lv.dia_max >= t.diastolic))
            WHERE t.fid = $id
            GROUP BY id
            ) jn
            ORDER BY recorded DESC
            LIMIT 10
      ");
        $data = $model->queryAll();

        return $data;
    }

    public static function generate_signature($time,$latest='')
    {
        $method = 'GET';
        $token = NokiaConfig::findOne('oauth_token')->value;
        $query = NokiaConfig::findOne('bpq')->value;
        $url = NokiaConfig::findOne('url')->value;
        $token_secret = NokiaConfig::findOne('oauth_token_secret')->value;
        $consumer_secret = NokiaConfig::findOne('consumer_secret')->value;
        $version = NokiaConfig::findOne('oauth_version')->value;
        $key = NokiaConfig::findOne('key')->value;
        $user_id = NokiaConfig::findOne('user_id')->value;

        $base = $method.'&'.rawurlencode($url).'&'
            .rawurlencode(''
                .$query
                .(empty($latest)?'':'&lastupdate='.$latest)
                .'&oauth_consumer_key='.rawurlencode($key)
                .'&oauth_nonce='.rawurlencode('4732f478388cbc5d3558033537a0748e')
                .'&oauth_signature_method='.rawurlencode('HMAC-SHA1')
                .'&oauth_timestamp='.rawurlencode($time)
                .'&oauth_token='.rawurlencode($token)
                .'&oauth_version='.rawurlencode($version)
                .'&userid='.rawurlencode($user_id)
            );

        $k = rawurlencode($consumer_secret).'&'.rawurlencode($token_secret);

        $signature = base64_encode(hash_hmac("sha1", $base, $k, true));

        return $signature;

    }

    public static function generate_url($latest='')
    {
        $token = NokiaConfig::findOne('oauth_token')->value;
        $query = NokiaConfig::findOne('bpq')->value;
        $url = NokiaConfig::findOne('url')->value;
        $version = NokiaConfig::findOne('oauth_version')->value;
        $key = NokiaConfig::findOne('key')->value;
```

```php
        $user_id = NokiaConfig::findOne('user_id')->value;
        $time = time();
        $signature = Bp::generate_signature($time,$latest);

        $base_url = $url . '?'
            .'oauth_consumer_key='.rawurlencode($key)
            .'&oauth_nonce='.rawurlencode('4732f478388cbc5d3558033537a0748e')
            .'&oauth_signature='.rawurlencode($signature)
            .'&oauth_signature_method='.rawurlencode('HMAC-SHA1')
            .'&oauth_timestamp='.rawurlencode($time)
            .'&oauth_token='.rawurlencode($token)
            .'&oauth_version='.rawurlencode($version)
            .'&userid='.rawurlencode($user_id)
            .'&'.$query
            .(empty($latest)?'':'&lastupdate='.$latest);
        return $base_url;
    }
}
```

Code for the Nokia Config (JSON)


```json
[
  {
    "id": "key",
    "value": "260fbe271c03c0ecb49d70850ff47ebd68e06fe6d44db65739dd159b24e"
  }, {
    "id": "oauth_token",
    "value": "715702608760f636302d8237211cb2b10033bd278643094deb849001b8117"
  }, {
    "id": "oauth_token_secret",
    "value": "b93104e7b3606bc44bf4fb4f404182995c7284bf37283bebec2683195b259b"
  }, {
    "id": "consumer_secret",
    "value": "0e23761eb71de9dbe7c858e3d605c59619f28d4b24c8cd0941ec330432486"
  }, {
    "id": "oauth_version",
    "value": "1.0"
  }, {
    "id": "user_id",
    "value": "87541236"
  }, {
    "id": "url",
    "value": "http://api.health.nokia.com/measure"
  }, {
    "id": "bpq",
    "value": "action=getmeas"
  }
]
```


Sample Code for the REST API (OAuth v1)

```php
<?php
namespace app\modules\api\behaviours;
use Yii;
use yii\filters\auth\AuthMethod;
use common\models\HaikuApps;
class Apiauth extends AuthMethod
{
    /**
     * @var string the parameter name for passing the access token
     */
    public $tokenParam = 'access-token';
    public $exclude = [];
    public $callback = [];

    /**
     * @inheritdoc
```

```php
     */
    public function authenticate($user, $request, $response)
    {
        $user->identityClass = Yii::$app->restUser->identityClass;
        $headers = Yii::$app->getRequest()->getHeaders();

        $accessToken=NULL;
        if(isset($_GET['access_token'])){
            $accessToken=$_GET['access_token'];
        }else {
            $accessToken = $headers->get('x-access_token');
        }

        if(empty($accessToken)){

            if(isset($_GET['access-token'])){
                $accessToken=$_GET['access-token'];
            }else {
                $accessToken = $headers->get('x-access-token');
            }
        }

        if (is_string($accessToken)) {
            $identity = $user->loginByAccessToken($accessToken, get_class($this));
            if ($identity !== null) {
                return $identity;
            }
        }
        if ($accessToken !== null) {
            Yii::$app->api->sendFailedResponse('Invalid Access token');
        }
        return null;
    }
    public function beforeAction($action)
    {
        if (in_array($action->id, $this->exclude)&&
            !isset($_GET['access-token']))
        {
            return true;
        }
        if (in_array($action->id, $this->callback)&&
            !isset($_GET['access-token']))
        {
            return true;
        }
        $response = $this->response ?: Yii::$app->getResponse();

        $identity = $this->authenticate(
            $this->user ?: Yii::$app->getUser(),
            $this->request ?: Yii::$app->getRequest(),
            $response
        );

        if ($identity !== null) {
            return true;
        } else {
            $this->challenge($response);
            $this->handleFailure($response);
            Yii::$app->api->sendFailedResponse('Invalid Request');
        }
    }

    */
    public function handleFailure($response)
    {
        Yii::$app->api->sendFailedResponse('Invalid Access token');
```