A SECURE PATIENT MONITORING AND TRACKING SYSTEM USING RFID AND INTERNET OF THINGS FOR THE UNIVERSITY TEACHING HOSPITAL

By

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DECLARATION

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CERTIFICATE OF APPROVAL

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ABSTRACT

In the present era, quality and affordable patient health care is now the main concern for hospitals in Zambia. Hospitals have to accept the obligation of the patient safety and the patient's well-being. However, due to the congested and understaffed hospitals in Zambia with intricate work procedure patterns, the healthcare system has seen a rise of different types of medical errors. With the advance in medical technology, medical care errors such as wrong medication, miss-placement of medical files and patient miss-identification can be radically reduced. Internet of Things (IoT) has improved the advancement of conventional medical model towards healthcare by the introduction of remote health monitoring using sensors (wearable, environmental and implanted) with the purpose of monitoring the user's health within or outside the hospital. Hence the supply of valuable set of data, in real time mode significant to the stakeholders (patient and medical staff) using electronic form (technology) is called E-health. Radio frequency identification (RFID) is a technology that is used as a physical layer of IoT system for remote tracking and monitoring because of its minimal efforts and affordable sensors. It's also known for providing unique ID numbers. A monitoring and tracking system was developed using passive RFID tags, temperature and heart beat sensors integrated on Arduino controller boards. The software component of the system was enhanced by Gecko and Arduino open source applications. The patient was provided with unique RFID number and details regarding the patient and treatment were stored in a centralized database which was retrieved by the server. The proposed system was designed to monitor and track patients online. The adopted communication technologies in this study were 4G internet and Wi-Fi. The proposed application can be used to identify and monitor the patients inside a closed environment.

Key words: Internet of Things (IoT), RFID, Tag, Monitoring, E-health, Tracking

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ACRONYMS

E-Health	Electronic Health
EHrs	Electronic Health Record
RFID	Radio Frequency Identification
HIE	Health Information Exchange
IoT	Internet of Things
ICD	International Classification of Diseases
IT	Information Technology
ISO	International Organization for standardization
IPv6	Internet Protocol Version 6
IEC	International Electro Technical Commission
JCAHO	Joint Commission on Accreditation of Healthcare Organisations
NFC	Near-field communication
MEMs	Micro-Electro-Mechanical Systems
WHO	World Health Organization
PCs	Personal Computers
ROI	Return on Investment
TC	Transmission Control
PDA	Personal Digital Assistant
UTH	University Teaching Hospital
Wi-Fi	Wireless Fidelity

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter gives a background to internet of things and RFID technologies. The problem statement and objectives are stated in this chapter. Furthermore, the research outline and limitations/scope are outlined.

1.1 Background to Study

The rise in life expectancy and the consequent progressive aging of the population, with a prevalence of chronic diseases, prompt a watchful intuition on the role and modes of providing care to people in order to ensure a decent quality of life, without imposing traumatic changes of habits and domestic environment.

I. Miscommunication

II. Physician order Transcription errors

III. Incomplete Patient Medical Records

IV. Overcrowding

With the recent advances in what is known as medical technology, the world health organisation has estimated that if hospitals worldwide were to implement technology, medical related errors would be reduced [1] [2].This will help to avoid fatal mistakes in most government hospitals by at least 40% as stated by the WHO report on medical errors [3][4].

Overcrowding has been one of many problems in the health sector in Zambia. According to a report by Paul Shalala [5], there is a shortage of 3000 doctors and over 6000 nurses. According to the World Health Organisation, the normal doctor-patient ratio is 1 doctor per 5,000 patients but Zambia has one of the most abnormal doctor-patient ratio, which now stands at 1 doctor per 12,000 patients [5]. A survey carried out at the two major hospitals in Zambia (University Teaching Hospital and Levy Mwanawasa) showed that the hospitals are overcrowded, with patient’s medical records sometimes missing or incorrect information being recorded. Furthermore, patients being admitted are identified by wristbands or just a paper attached on the beds.

The remote monitoring and support thus become strategic implements to execute social strategies over the long haul [6]. In this sense, the capacity to unavoidably, watchfully, and for the most part uncooperatively measure the wellbeing conditions and the human associations with nature is the initial step to give all the data required to adjust effectively settled medicinal services conventions to new needs [6].The developing worldview of Internet of Things (IoT) [7] and a wide assortment of cheap sensors (wearable, embedded, and natural) can possibly set up individual Smart-Health systems facilitating new interconnections between the common territory of the individual, his body, and the Internet at the purpose to produce and manage "participatory" medical knowledge [8]. By displacing wireless sensors inside the home, on clothes and personal items, it becomes possible to monitor, in a way that preserves the privacy, the macroscopic behaviour of the person as well as to compile statistics, to identify signs of perilous behavioural anomalies, and conclusively to activate alarms or prompt for remote actions by appropriate assistance procedures [9]. Among the various technologies that potentially converge to this development, RF identification (RFID) systems may represent a strategic enabling component thanks to the energy autonomy of battery-less tags [10].

With the development of the technology, barcode systems are now widely used for patient identification, monitoring and tracking. In 2006, it was estimated that 70 percent of all medication containers had bar codes [11]. Bar codes can also be used for identifying patients and staff [11]. However according to Colucci [12], due to the non-uniqueness and non-multiple reading properties of barcode system, medical care errors have still arisen in the understaffed and high population flow healthcare industry.

Radio frequency identification (RFID) is one kind of burgeoning technology and its applications ranges from supply chain management, production inventory management and physical asset [13].
RFID is now being used for tracking of moving of physical assets, monitoring of critical and mentally ill patients and for remote patient monitoring [14]. The RFID technology has also improved the admission process in the healthy sector as patients and doctors can now easily access medical and personal records of patients [14].

However, few studies addressed the integration of RFID devices with other technologies such as mobile and sensor devices and mobile messaging services to improve understaffed and high population flow healthcare environment and enhance patient safety [15].

In healthcare industry, Internet of Things (IoT) provides an opportunity of discovering healthcare information about a tagged patient or medical object by browsing an Internet address or database entry that corresponds to a particular Radio-Frequency Identification (RFID) tag [13][16]. Now, it is extended to the general idea of medical things, especially healthcare everyday objects, those are readable, recognizable, locatable, addressable, and/or controllable. These objects may be equipped with devices such as sensors, actuators, and RFID tags, in order to allow patients, doctors, equipment and other healthcare actors to be connected anytime and anywhere with anything and anyone.

According to Javdani and Hooman [17], medical field has remained one of the major applications of the internet. The collaboration of internet and medical formed a sub-field e-health. An application of Internet and other related technologies in healthcare industry seek to improve the access, efficiency, effectiveness, quality of clinical and business processes utilized by healthcare organizations, practitioners, and patients in an effort to improve the health status of patients. Along with many other services, online appointment services in particular are the most common e-health services [15].

E-health is one of small component of IoT based healthcare management system, in which an online interaction of a patient to a doctor is made possible and easy along with easy access to online healthcare record checking for the patients. Whereas IoT based healthcare system consists all this plus identification and tracking of patients and doctor’s locations, tracking of patient’s health records and tracking locations of hospital equipment etc. IoT have also enabled intelligent behaviour of some equipment which alarm automatically when near to expiry or auto informing a relevant doctor if concerned patient is brought to Intensive Care Unit. “Patients and medical objects tracking, tracing and monitoring are demanded by world-wide healthcare institutions, governments and other organizations, the universal expectation of all healthcare organizations wants state-of-the-art patients tracking system, has put endorse superior requirements” [18].

The idea of the Internet of Things initially wound up noticeably prevalent in 1999. On the off chance that all articles and individuals in day by day life were provided with identifiers, personal computers (PCs) could oversee and stock them. The Internet of Things (IoT) is the system of physical articles gadgets, vehicles, structures and different things installed with hardware, programming, sensors, and organize availability — that empowers these items to gather and trade data.[19] The internet of Things enables items to be detected and controlled remotely crosswise over existing system foundation,[16] making open doors for more straightforward incorporation of the physical world into PC based frameworks, and bringing about enhanced proficiency, precision and monetary advantage. At the point when IoT is increased with sensors and actuators, the innovation turns into an occasion of the broader class of digital physical frameworks, which moreover includes advances, for example, keen networks, shrewd homes, canny transportation and brilliant urban areas. Each thing is exceptionally identifiable through its implanted processing framework however can interoperate inside existing Internet foundation. Specialists assess that the IoT will comprise of just about 50 billion protests by 2020 [20].

1.2 Problem Statement

Overcrowding in government hospitals and health centres has been one of many problems in the health sector in Zambia. This is mainly due to lack of adequate health workers and medical facilities especially in the rural areas. The University Teaching Hospital is Zambia’s largest referral hospital, with an average of 500 patients being admitted per day and about 10% of the 500 patients are admitted under the Mother and Child Hospital (formerly maternity ward).

With the influx of hundreds of patients coming to the hospital on a daily basis, it has negatively affected the service delivery at the hospital. The hospital personnel are overwhelmed with large number of patients they need to attend to and the resources (medical equipment and facilities) are limited. Furthermore, the Hospital lacks the resources to properly handle patients’ medical records especially that most of it is paper based. Retrieving and tracking of records is another challenge the hospital is facing, hence making it difficult for doctors to follow up on their patients’ medical history as well as progress. This can sometimes lead to patients being misdiagnosed and given the wrong medications, thus developing complications and in some instances death.

With the current system at the hospital, monitoring of patients can only be done within the Hospital and once the patient leaves the hospital it's difficult to track or monitor their progress. For cases like high blood pressure in pregnant women which is considered to be dangerous it's immediate admission (under observation) which can even last for more than 6 months. This is due to the lack of proper systems that can allow a patient to be monitored remotely. Furthermore, over admission of patients sometimes leads to overcrowded bed spaces which are limited at the maternity ward. Due to limited resources at the Hospital especially the maternity ward, patients sometimes have to endure long queues for them to be attended to by doctors.

Though the adoption of technology in the Zambian medical sector has been gradual, the introduction of the e-health policy will change the landscape of the health sector in Zambia. The utilization of IoT and RFID technologies in the health sector provides a solution to the challenges mentioned above.

The implementation of a remote tracking and monitoring system in the hospital will improve quality service delivery at the Hospital and will increase efficiency of the health personnel at the Hospital. Proper management of patients' medical records can also be achieved with the use of RFID technologies.

1.3 Aim of the Study

To establish the challenges, the Hospital faces by assessing the current file opening, processing, retrieval and storage of patient's information and develop an RFID Monitoring and Tracking system using internet of things (IoT) to address the challenges.

1.4 Objective

The main objective of the research was to design an online Patient Monitoring and Tracking system by integrating a probable patient information system with the use of Radio Frequency identification and Internet of Things technology.

1.4.1 Specific Objectives

i. To investigate the challenges faced by University Teaching Hospital with the current records management system

ii. To investigate the methods used to store, track and access patients' medical records at the Hospital.
iii. To study the current patient monitoring and tracking systems available on the market.
iv. To present a running system prototype that uses RFID and IoT technologies which perform patient monitoring and tracking.

1.4.2 Research Questions

The questions emanating from the objectives were;

(i) What challenges are the University Teaching Hospital facing with the current manual registration and records management system?
(ii) What systems are the Hospitals currently using for management of patients' medical records?
(iii) What current health systems monitoring systems are available on the market?
(iv) Is it possible to present a running system that uses both IoT and RFID that will be able to track and monitor patient?

1.5 Significance of Study

This study will help improve the delivery of quality services at the Hospital and enhance efficiency in the health sector. The improved system will ensure that not only will the patients 'information be easily accessed by the right personnel the system will also enhance security to the medical records of the patient, hence only authorised individuals will be allowed to access the information. This will also bring accountability in case of any Irregularities' that might arise during and after the patient's visit to the hospital.

1.6 Limitations

Due to limited resources an open source health management system (gecko platform) was used for online health monitoring. The developed database was not able to migrate and integrate results from the RFID module to the IoT platform. This was due to different system applications that RFID and IoT use. The IoT gecko application is an open source development platform that has restrictions hence it was challenging to link the two modules. For remote monitoring, android smart phones will be adopted because they are readily available and easy to use. Low frequency (125 kHz) passive tags were adopted for this research, hence reading tag distance was limited to less than 10cm.

1.7 Scope

The project will mainly focus on developing a system that will track and monitor patients immediately they arrive at the hospital. The project will be localised at the University Teaching Hospital, at the maternity department. The proposed system will focus on tracking patients as they arrive at the hospital by using a RFID sensor and tag. The patient’s information will be captured and stored in the database using an RFID reader.

1.8 Dissertation Roadmap

I. Chapter 2 presents literature review of past research works on radio frequency identification and its use in the health sector.
II. Chapter 3 presents detailed procedure for the methods used to design the monitoring and tracking system.
III. Chapter 4 gives detailed analysis and discussion of the results.
IV. Chapter 5 gives the Conclusion and recommendations.

1.9 Summary

The contents of this chapter focused on understanding the problems faced by health sector and common medical errors. It narrows down to the challenges faced by Zambia’s biggest teaching hospital, UTH and the impact of technology in the health sector. It outlines the importance of technology in the health sector and the strides that have being made globally to improve the delivery of health service in the last decades. The use of RFID in records management and patient tracking has being outlined, furthermore, the introduction of IoT and its uses in the medical field is also discussed. The main aim, objectives and research questions are also outlined in this chapter

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature on RFID and IoT technologies and their applications in different industries particularly the health sector. The chapter gives an overview of the improvement of the RFID technologies over the past decades and its integration with the Internet of Things. The importance of technology in the health sector is reviewed and challenges faced by health institutions regarding file management are discussed. An overview of the health sector and the emerging of E-health in Zambia is reviewed. Different security features that exist in wireless and wired systems are discussed and models of the RFID technology are discussed in this chapter.

2.1 Understanding Remote Tracking and Monitoring

Remote tracking and monitoring is a healthcare delivery practice that uses the latest developments in information technology to collect patient data outside the normal healthcare setup [21]. Most effective remote patient monitoring systems are basic systems that use devices that are tech consumer –friendly. The technologies used in most of the health monitoring systems are made in such a way that the patients using them are comfortable. Figure 2.1 shows an example of remote and tracking system for a medical centre that seamless tracked patient's biomedical vitals online without human interactions [17]. The comfort helps to increase patient's confidence and engagement in the systems hence improving quality of health. Not only does the system make the patients have some level of involvement in their health, it also helps the clinicians to be better equipped to manage their patients' health. Randy Swanson [22], CEO of Care Innovations points out that "remote tracking helps clinicians to be alert and identify alarming conditions early in patients".

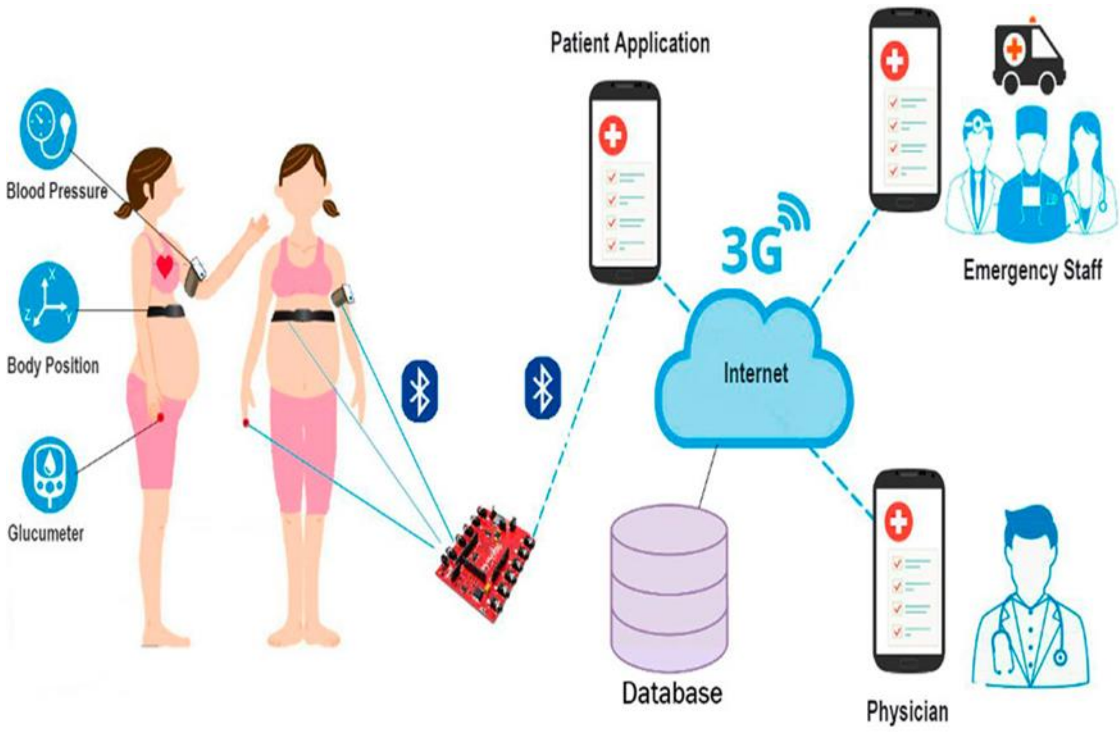

Figure 2.1: Example of Remote Health monitoring [17].

2.1.1 Technological components of remote monitoring and tracking

There are several variants of remote tracking monitoring systems on the market each built from variations of technology architecture. Despite the several variants, most technologies are designed from a general architecture that comprises of four components [17] [21] [23];

I. Sensory devices (temperature, pressure, humidity, blood pressure) that are enabled by wireless communication various parameters.
II. Local database
III. Centralized database to store data from local database or various monitoring applications
IV. System application developed to be an interface between the users and the system hardware.

2.2 Health Care and Technology

Health is the fundamental capability humans require to perceive, feel, and act efficaciously, and as such, it represents a primary element in the development of the individual, but withal of the environment humans belongs. World Health Organization (WHO) describes health, as "Condition of finish physical, mental, and social prosperity, and not simply the nonappearance of illness or infirmity [24]. As characterized by World Health Organization (WHO), health is a dynamic condition coming about because of a body's steady change and adjustment in light of stresses and changes in the earth for keeping up an inward balance called homeostasis [24].

Health care or healthcare is the upkeep or improvement of fitness with the aid of the diagnosis, treatment, and prevention of disease, illness, injury, and other bodily and intellectual impairments in human beings [25]. It includes the work achieved in presenting main care, secondary care, and tertiary care, as well as in public health. That is why it is fundamental to furnish enough approaches and betokens to verify the opportune healthcare distribution predicated on parameters monitoring and direct imparting of the scientific assistance.

Worldwide, all sectors are embracing Information and Communication Technologies to enhance provider transport and enlarge competitiveness [26]. Health care is no exception. ICTs can seriously change how health care is delivered and how health structures are run. The use of Information and Communication Technologies in fitness care provider delivery is termed eHealth. The World Health Organisation defines eHealth as "the combined use in the health zone of digital verbal exchange and information science for clinical, schooling and administrative purposes, each at the local site and at a distance." [27]. In greater practical terms, eHealth is the capability of making sure that the proper fitness statistics is supplied to the proper man or woman at the proper area and time in a secure, electronic structure for the reason of optimizing the satisfactory and effectively of fitness care delivery, research, training and knowledge.

This definition of E-health covers a vast domain, including [19] [20] [22] [27]:

i. Electronic Health Records (enabling sharing of patient records between points of care),
ii. Routine fitness administration statistics (e.g. web-based surveillance systems, electronic disorder registers, digital district health records systems),
iii. Vital Registration (the use of computerised systems for registration of loss of life or births),
iv. Consumer Health Informatics (access to records on health by using healthy folks or patients),

v. Health Knowledge Management (e.g. high-quality exercise tips managed and accessed electronically),
vi. mHealth (e.g. use of cell units such as cell-phones to share information or to acquire combination or affected person data),
vii. Telemedicine (e.g. use of ICTs to supply care at a distance),
viii. Virtual Healthcare (e.g. teams of gurus working together with the aid of ICTs), and
ix. Health Research (e.g. use of excessive performance computing to cope with large volumes of data).

Technology is viewed to be the driving force behind enhancements in healthcare and visually analysing the charge of change and latest innovations, many discover it difficult not to accede with that observation [21][22]. Technology is influencing many aspects of our lives as breakthroughs in data accumulation, research and treatments allow medical providers to utilize incipient new tools and find fresh and innovative ways to practice medicine into the future. Data and information are essential aspects of a healthy, robust health care infrastructure. Services, treatment, and care rely on various components of the health care system delivered at different levels.

This ubiquity of technology is beginning to extend into the medical field. Advances in medical technology are changing medicine by giving physicians more information — as well as better, more specific data. Topol had this to say about the changing landscape of medical technology: "*This is a new era of medicine, in which each person can be near fully defined at the individual level, instead of how we (have previously) practiced medicine at a population level. We are each unique human beings, but until now there was no way to determine a relevant metric like blood pressure around the clock while a person is sleeping, or at work, or in the midst of an emotional upheaval. This represents the next frontier of the digital revolution, finally getting to the most important but heretofore insulated domain: preserving our health*." [28].

A number of industry analysts have observed that increased accessibility of treatment is one of the most tangible ways that technology has changed healthcare. Ritesh Mehta [21][23][24]in his research indicated that Health IT opens up many more avenues of exploration and research, which allows experts to make healthcare more driven and effective than it has ever been.

Another key area that has grown and continues to do so is patient care. The use of information technology has made patient care safer and more reliable in most applications. The fact that nurses and doctors who are working on the frontline are now routinely using hand-held computers to record important real-time patient data and then sharing it instantly within their updated medical history is an excellent illustration of the benefits of health IT [25][26][27].

Being able to accumulate lab results, records of vital signs and other critical patient data into one centralized area has transformed the level of care and efficiency a patient can expect to receive when they enter the healthcare system. An increased level of efficiency in data collection means that a vast online resource of patient history is available to scientists, who are finding new ways to study trends and make medical breakthroughs at a faster rate.

With widespread innovations like these affecting patient care practices, it is not surprising that the way medical records and information are stored and shared is changing as well. These technological advancements are cost-effective and improve the ability of medical professionals to diagnose and treat health issues of all kinds.

Three of the main changes that are revolutionizing the future of healthcare are electronic medical records, health information exchange and ICD – 10 [29].

2.3 Features of an E-Health System

2.3.1 Electronic Health Records (EHR)

Over the past few decades, both medical billing and coding have switched from being paper-based to a computerized format. Electronic medical records offer a wide variety of benefits to the medical field. As Milt Freudenheim, a New York Times contributor, points out, "*They can make healthcare more efficient and less expensive, and improve the quality of care by making patients' medical history easily accessible to all who treat them."* [30].

2.3.2 Health Information Exchange (HIE)

HIE gives health care professionals and patients the information access they need. It allows for the secure sharing of patient medical history between physicians of all specialties, while also allowing patients to access data about their own health. Because health information exchange creates improved communication and care quality, it provides “safer, more effective care” based on the needs of each specific patient [31]. According to HealthIT.gov, “new payment approaches that stress care coordination and federal financial incentives are all driving the interest and demand for health information exchange [32].

2.3.4 ICD-10 and Medical Billing

The International Statistical Classification of Diseases, or ICD-10, is the latest innovation when it comes to diagnostic tools. It is essentially an enhanced medical coding system that includes over 14,000 different codes globally, as well as additional subcategories [33][34]. This means that patients and insurance companies can be billed for services and procedures in a highly specific way. And in the United States, ICD-10 classification is even more extensive it includes additional codes that push the total to 76,000 ways that medical procedure claims can be processed and paid [35][36][37]. This beneficial tool allows countries to retrieve and store all diagnostic information in a streamlined, efficient way [38].

2.4 Zambia and Development of the E- Health System

Zambia has a high disease rate problem, which is primarily characterised by high occurrence and effect of communicable diseases, mostly, malaria, HIV, AIDS, STIs, and TB [39]. Others include high maternal, neonatal, child morbidities and mortalities. The country has a challenge with a rapidly growing problem of non-communicable diseases, including mental health, diabetes, cardiovascular diseases and violence. Developing from a severely constrained health system, are opportunities for eHealth in Zambia [40] [41]

In order to enhance the use of technology in the health sector, the Ministry of Health developed an eHealth strategy [41]. The eHealth strategy is a product of collaboration with stakeholders within the ministry of Health, cooperating partners and end users of eHealth [41] [42].The government believe effective and efficient use of ICTs will not only translate into better and efficient service delivery but will also improve training of health personnel and research in the health sector[42][43].The eHealth strategy is a benchmark for the provision of guidelines that will drive growth and transformation though effective use of ICTs.

As stated in the report [40] [44] the strategy will give broad operational guidelines on how to make the various eHealth system efficient and interoperable. The priority focus area from 2017 to 2021 include: Service Delivery, Research and eLearning. Furthermore, the strategy has been designed to provide everyone within the health sector with new opportunities for collaboration, skills development, and access to important information for research and decision-making. The strategy also leverages potential to expand and build on the current eLearning training programs for pre-service and in-service personnel. In order to harness and provide adequate protection to the ICT resources, various components of the strategy ensure that ICT is well developed, maintained and utilised.

Some of the solutions that were noted to be provided by the eHealth for the health sector include [41] [42] [43]

i. Computerised point of care services: resource wastage can be avoided if electronic medical record systems are used to facilitate real-time referral services and improve quality of care
ii. Telehealth services: can facilitate cost effective provision of specialist services to communities, without need to travel long distances.
iii. Electronic surveillance systems: can deliver decision makers with the power to formulate
iv. suitable involvements, and provide services relevant to the target population
v. Electronic performance reporting and analytical systems: can be used to leverage financial and health service output data to monitor program performance, identify potential inefficiencies [45].
vi. augment the use of resources invested in responding to health needs of the population

2.5 Records Management System and Challenges in Zambia

Record management has been a challenge in most government hospitals and health centers. Patient’s record management in most public hospitals and health centers is manual and paper based though recently the government introduced a pilot smart care program at the University Teaching hospital that will enhance record management at the Hospital. The patient record is the primary source for information about a patient's health care. The record file used by Ministry of Health has the patient particulars, address, next of keen, previous illnesses, date of birth etc. It affects, in some way, virtually everyone associated with providing, receiving, or reimbursing health care services.

Even with the many technological advances in health care over the past few decades, the typical patient record of today is remarkably similar to the patient record of 50 years ago [46]. The failure of patient records to evolve as technology is advancing is creating additional stress in the health sector [47]. A study by Ellwood indicated that the records system in the U.S is not meeting the needs of its stakeholders [48] .The failed patient records system is creating additional stress within the already burdened health care system as the information needs of needs of practitioners, patients, administrators, third-party payers, researchers, and policymakers often go unmet.

As described by Ellwood [48], a patient record system is a collection of components forming mechanism by which patient records are created, retrieved, used and stored. In most cases, the patient record system is located within a health care provider locale. It is a combination of people, data, rules and procedures, processing and storage devices, and communication and support facilities [48] [49]. A type of clinical information system which is dedicated to collecting, storing, manipulating, and making available clinical information important to the delivery of patient care is also known as a patient record system [50] [51]. Mostly the principal focus of these systems is clinical information and not financial or billing information [52]. These systems are sometimes limited in their range to a single area of clinical information or they may be inclusive and cover virtually every aspect of clinical information pertinent to patient care (e.g., computer-based patient record systems) [53] [54].

The major challenges faced by the government hospitals are storage space and accessibility of the records at the University Teaching Hospital. Figure 2.2 and 2.3 shows the status of the records room at the biggest Hospital in Zambia.

Government hospitals are well on their way towards developing new electronic approaches to patient records. This development has been plausible because of progresses in computer technology and successful research on the application of such technology to medicine [55] [56]. These advances include, but are not limited to, hand-held computers; picture archiving and communications systems that permit electronic storage, transmission, and display of medical images; disk drives that offer mean time between failures of 60,000 or more hours; and high-speed telecommunications networks that can carry 1.7 billion characters per second over a 100-kilometer link [57][58] . Innovations and applications can enhance the nature of patient consideration, advance the logical premise of prescription, direct the expenses of medicinal services administrations, and improve the training of human services experts.

Figure 2.2: Records room at the University Teaching Hospital

Figure 2.3: Patient’s records storage at the registry office (University Teaching Hospital)

2.5 Technologies commonly used in the Healthcare Industry

Healthcare industry has continuously been on the forefront in the implementation and deployment of information and communication technologies (ICT) for the proficient administration as well as patient treatment. Modern developments in ICT and the emergence of Internet of Things (IoT) have unlocked up new avenues for research and exploration in the all fields including medical and healthcare industry [57] [58]. Hospitals have started using the mobile devices for communication intent and for this intent internet of things (IoT) [59] has been used and fused with Wi-Fi sensor node reminiscent of RFID, NFC tag and small sensor nodes[60][61].The usage of a cellular agent in healthcare technique underneath Wi-Fi community environment gives a chance to suggest improved services for patients and staffs reminiscent of medical professionals and nurses given that of its mobility

Advancements in Internet of Things (IoT) are mostly used for connecting the different devices like as sensors, appliances, vehicles and other objects. All these devices may equip with radio-frequency identification (RFID) tag, sensors, actuators, mobile phones and many other [62]. By using IoT all these devices are connected to establish the communication between them and efficiently access the information. The main support of IoT is to swell the profit of Internet with remote control talent, data sharing, eternal connectivity and many more. The healthcare servers keep electronic medical records of registered users and provide different services to patients, medical consultants and informal caregivers. The patient's consultant can access the data from office via internet and examine the patients' history, current symptoms and patient's response to a given treatment as shown in figure 2.4.

Figure 2.4: Using IoT for remote monitoring [1]

The current evolution of the traditional medical model toward the participatory medicine has been boosted by the Internet of Things (IoT) paradigm involving sensors (environmental, wearable and implanted) spread inside domestic environments with the purpose to monitor the user’s health and activate remote assistance [63][64]. Radio Frequency Identification (RFID) technology has matured to provide part of the IoT physical layer for the personal healthcare in smart environments through low-cost, energy-autonomous and disposable sensors. It is here presented a survey on the state of the art of RFID for application to body centric systems and for gathering information (temperature, humidity and other gases) about the user’s living environment. Many available options are described up to the application level with some examples of RFID systems able to collect and process multi-channel data about the human behaviour in compliance with the power exposure and sanitary regulations.

2.5.1 Radio Frequency Identification (RFID) Technology

Radio Frequency Identification (RFID) is a communication technology which allows for defining some unique characteristics of an object or a living being [65] [66]. Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects [67] [68]. RFID belongs to a broad category of technologies called automatic identification technologies (auto-id) [69] [70]. According to Wyld and Budden [71], auto-id technologies provide rapid and reliable object identification and tracking capabilities. Auto-id systems attach an identifier to a physical object by some means that may be automatically read. The auto-id may be represented optically, electromagnetically, or even chemically [72]. Other technologies that fall under the auto-id classification include bar codes, magnetic links, optical character recognition, voice recognition, touch memory, smart cards and biometrics [73] [74].

A Scottish physicist, Alexander Watson-Watt, discovered how to use radio waves to detect objects [74]. This discovery directed to the invention of radars in 1935. Through World War II, radars were heavily used to detect inbound plane. The ground base station would send out pulses of radio energy and if it hits an object, the pulses would echo back indicating it detects something. The one main problem with this was that the base could not tell if the plane was an ally or an enemy. The first active RFID method used was when the Germans discovered that by having the planes spiral towards the base, the pulses hit the spiralling plane a different signal would reflect back [75] [76].

RFID offers a communication infrastructure at the radio frequencies between a special tag and reader device that can detect the tag, and allows for inaugurating communication between devices within the system without any physical contact, or even without seeing each other [75]. Passive tags collect energy from a nearby RFID reader's interrogating radio waves. Active tags have a local power source such as a battery and may operate at hundreds of meters from the RFID reader [77].

According to Stefan [78], RFID device serves the same purpose as a bar code or a magnetic strip on the back of a credit card or ATM card; it provides a unique identifier for that object. In addition, just as a bar code or magnetic strip must be scanned to get the information, the RFID device must be scanned to retrieve the identifying information [79]. In this regard, communication comfort can be provided with RFID technologies in environments where technologies, which require that the devices must exactly see each other, like the case in barcode systems, cannot be used.

RFID tags have many applications in industries, for example, an RFID tag attached to an automobile during production can be used to track its progress through the assembly line; RFID-tagged pharmaceuticals can be tracked through warehouses; and implanting RFID microchips in livestock and pets allows positive identification of animals [80].

2.5.1.1 RFID System Components

Radio Frequency Identification (RFID) is an automatic wireless-based identification method that evolved from radio technology [80] [81]. The components of a typical RFID system include an RFID tag, an RFID reader, an RFID middleware and the backend system as shown in figure 2.5. The tags contain electronically stored information while the Interrogator (RFID Reader) transmits and receives the signal from the tag attached to the object [69]. RFID middleware is used to process the transmission of information between the reader and other applications after receiving the information [67] [68]. The software that facilitates communication between the system and RFID devices is middleware.

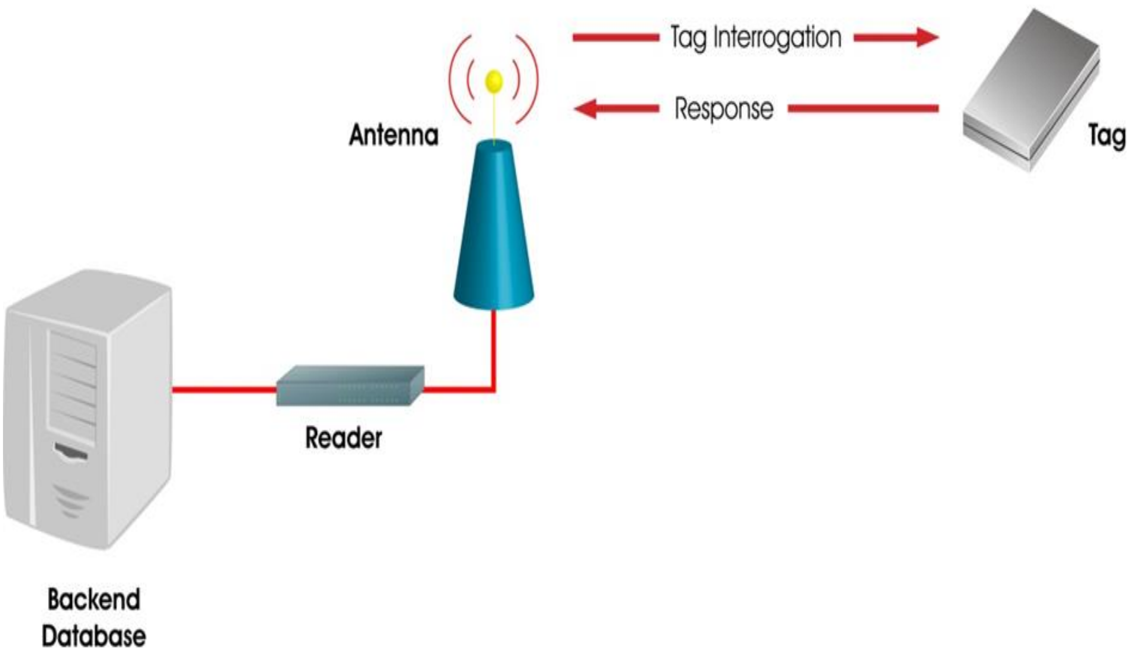

Figure 2.5: Basic components of RFID system [80]

2.5.1.2 Radio Frequency Tags

RFID tags are wireless computer chips that can be employed as a label, or attached or embedded to anything, such as a product or wireless keys [82] .The RFID tag is composed of 3 components, a coil, a silicon chip and material onto which the coil and chip are implanted as shown in figure 2.6. The coil acts as an antenna. The silicon chip includes a processor that contains all the information about the product as well as the radio transceiver. The chip can hold as much as 2 kilobytes of data. In order to retrieve the information from the RFID tag, an RFID reader must be used.

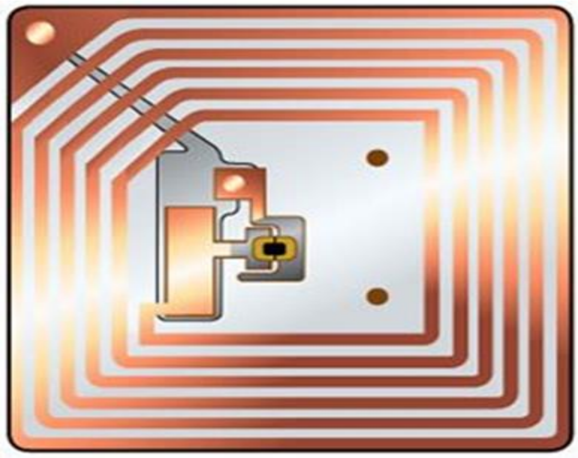

Figure 2.6: RFID Tag [82]

The reader generates a radio frequency field around it and when the tags are within the range of the reader, depending on the type of reader, it will be able to capture and transmit the data. The frequency field emits and receives radio waves from and to the tags. The RFID reader is attached to a network that receives the information to a central computer.

2.5.1.3 Classification of Tags

There are two types of RFID tags, active and passive [83]. Active tags have an on-board power source that makes the tags bigger and more expensive. It can deliver its own signals over long distance to the reader. The range can be anywhere from 60 feet to 300 feet.

There are two types of active tags, transponders and beacons [84]. Transponders are tags that would be awaken when a signal from the receiver is sent to it. This type of tag would conserve energy because it is active only when the signal sent by the receiver is within range of the reader. Beacon tags are more real-time and emit a unique identity signal at certain intervals which could be every few seconds or once a day.

The reader would pick up the signal sent by the beacon tag. Active tags are more expensive depending on amount of memory, battery life and other features such as on-board temperature sensor. Passive tags do not require a battery source because they use the RFID readers' own magnetic field to power the microchip's circuits and antenna which enables the chip to transmit information. This also means that the distance of the range between the reader and the RFID tag must be shorter. These tags are very inexpensive and the life of the tag does not expire [85]. Table 2.1 shows the categories of RFID Tags.

Table 2.1: Categories of RFID Tags [86]

	Active tag	Passive tag	Battery-Assisted Passive (BAP)
Tag Power source	Internal to tag	Energy transfer from the reader	Tag uses internal power source to power on and energy transferred from the reader to RF to backscatter.
Tag Battery	yes	no	no
Availability of Tag Power	Continuous	Only within field of range	Only within field of reader
Required signal strength from reader to tag	High	Very low	moderate
Cost	Very expensive	cheap	Expensive
Life validity	Between 5 and 10 years	Up to 20years	Up to 10 years
Storage	128 Kilobytes per read	128 bytes	128 kilo bytes per read
Communication range	Long range (100m or more)	Short range (up to 10m)	Moderate Range (up to 100m)
Senior capability	Ability to monitor and record sensor input .	Ability to read and transfer values only when tag is powered by reader	Able to read and transfe values only when tag Receives RF signal from reader.

2.5.2 RFID Readers

RFID readers are gadgets that play out the interrogation of RFID transponders [87] [88]. Figure 2.7 shows the circuit diagram of 125 kHz RFID tag reader. In a passive RFID framework, the RFID reader supplies the tag with basic power with the end goal for it to perform regulation of the reader's cross-examination flag. Hence, the reader and transponders are in a master-slave relationship where the reader goes about as an ace (master) and the transponders as slaves. A software application, also called middleware, processes data from the RFID reader, acts as the master unit and sends commands to the reader.

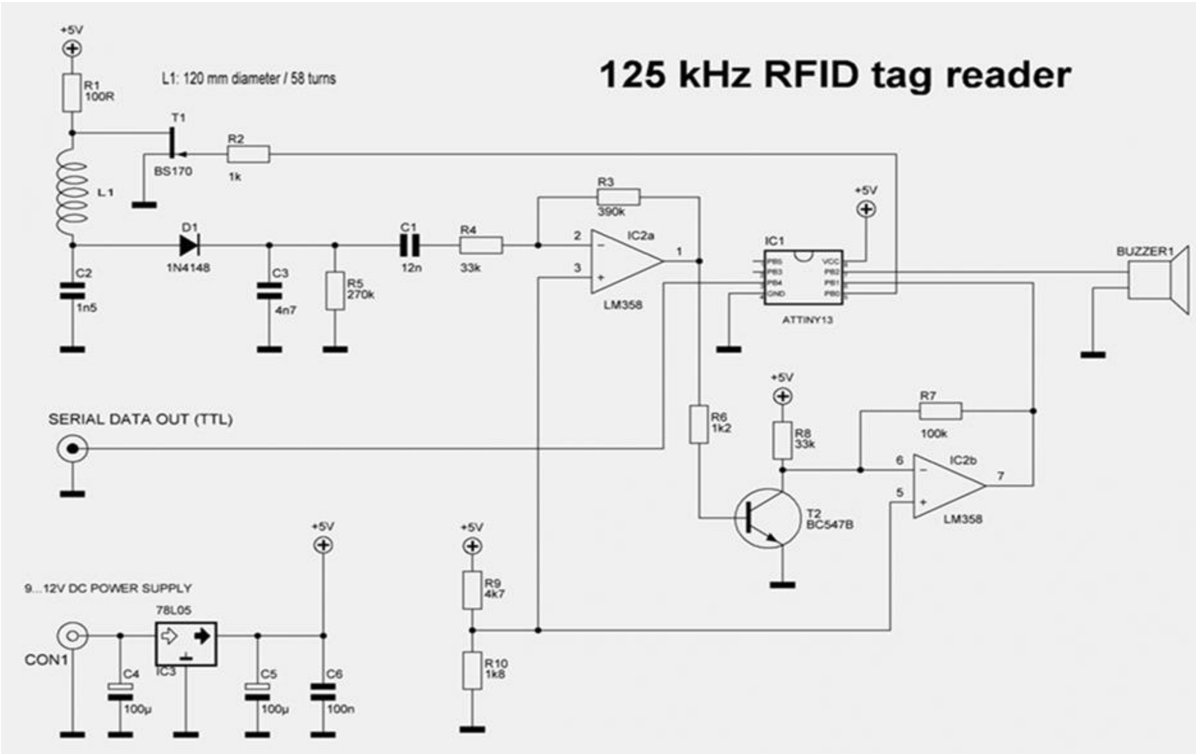

Figure 2.7: Circuit diagram of RFID reader [87]

This implies that application programming starts all activities of all the reader and transponder. Based on the hierarchical system structure the application is the master while the reader is the slave. The reader is only activated when it receives a command from the application software and therefore, the reader perform read or write operations of RFID transponders that are in its interrogation area [88]

2.5.1. Components of RFID Reader

An RFID reader consists of three main parts shown in Figure 2.8. These main three components are:

I. Control section
II. High frequency (HF) interface; and
III. Antenna.

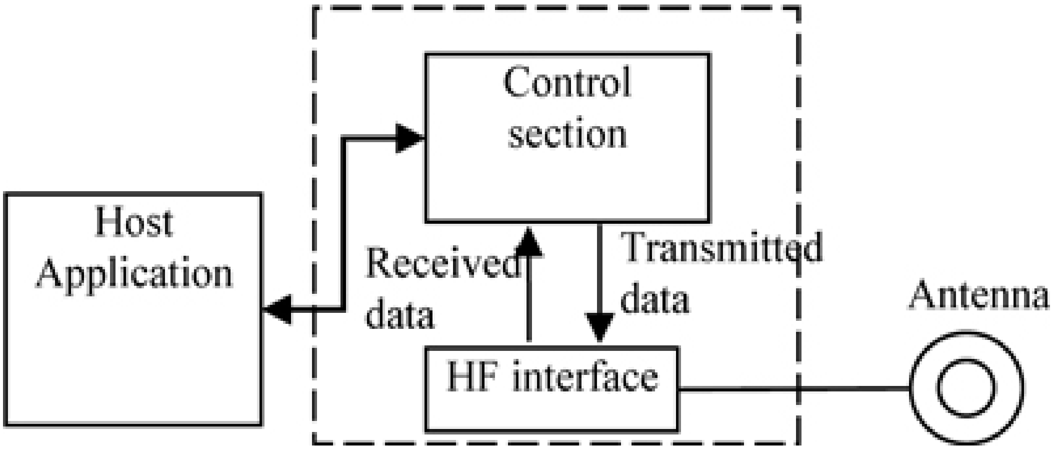

Figure 2.8: Main components of the RFID reader [88].

2.5.2.1 RFID reader control area

The control area of the RFID reader performs computerized flag handling and methods over the information obtained from the RFID transponder. Similarly, the control area empowers the reader to communicate with the transponders remotely by performing balance, anti-collision systems and interpreting the information from the transponders. This information is generally used to investigate labels (read) or to reinvent the tag (compose). This area more often than not comprises of a microchip, a memory, a couple of analogy-to digital converters and a communication block for the product application [89] as shown in figure 2.8 and 2.9.

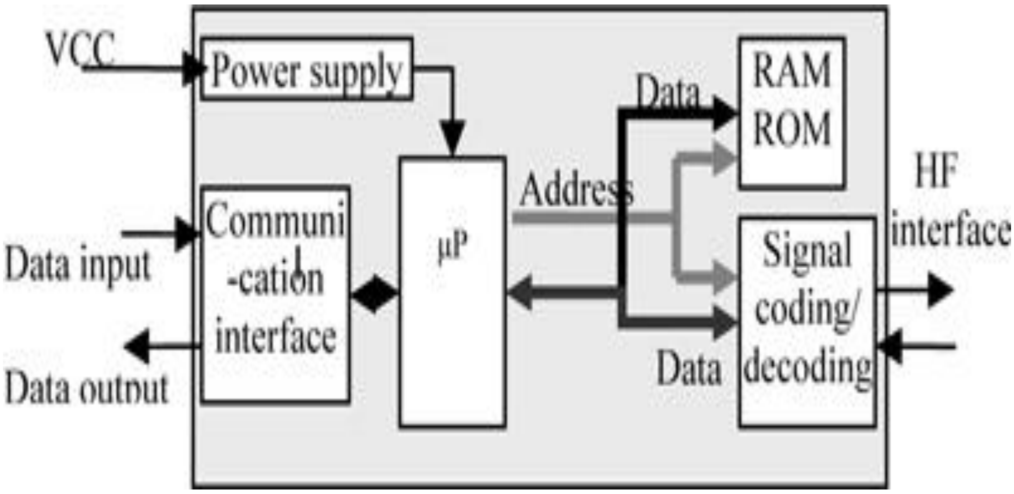

Figure 2.8: Block diagram of the RFID reader control unit [98]

2.5.2.2 HF interface Module

Figure 2.9 shows the HF interface module of a RFID reader [89] [90] .The high frequency interface of the reader is used for RF signal transmission and reception .HF interfaces consist of two separate signal paths to correspond with the two directional data flows from and to the transponder [91][92].

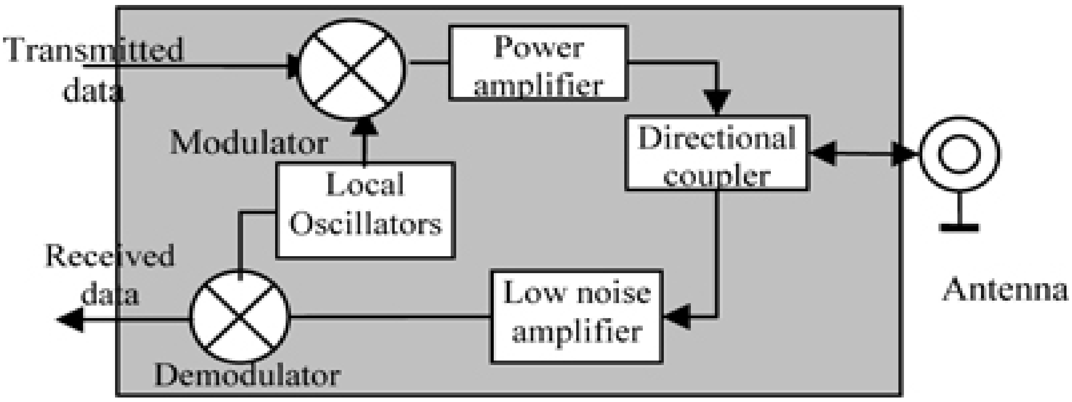

Figure 2.9: Block diagram of the HF interface of a RFID reader operating in the 2.4 GHz ISM band [93].

The local oscillator prompts the RF carrier signal, a modulator modulates the signal, the modulated signal is amplified by the potency amplifier, and the amplified signal is transmitted through the antenna [93].A directional coupler separates the system's transmitted signal and the received weak back-scattered signal from the tag [94]. The HF interface is a complex section of the reader and is protected from electromagnetic interference using metal cages. When decoding the data from the transponder, different demodulation techniques are used.

Binary phase shift keying (BPSK) is used in operating most RFID systems and amplitude shift keying (ASK) [94]. Figure 2.10 shows a simple HF interface for a continuous wave (CW) RFID reader operating in the 2.45 GHz Industrial, Scientific and medical (ISM) band, using ASK demodulation[93][94]. The reader transmits a CW signal at 2.4 GHz ISM band.

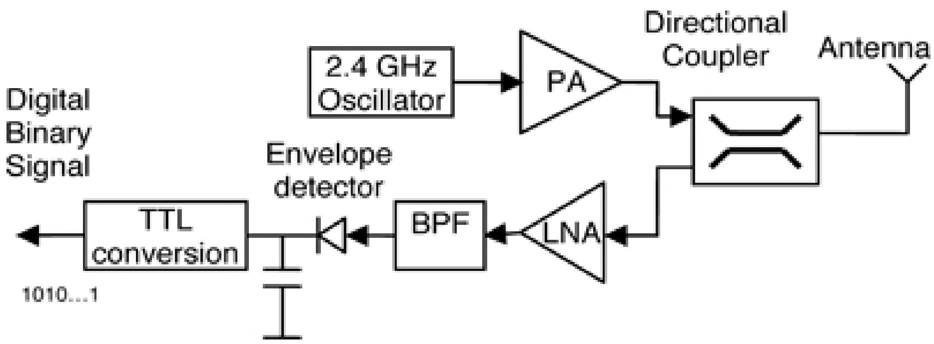

Figure 2.10: Block diagram of a RFID reader operating at 2.45 GHz with ASK demodulation technique [93].

The interrogation range and zone determines the intensity of the radiation of the reader antenna [95] .Depending on the RFID system’s uses, the RFID reader can be designed in different ways where the antenna’s resonating frequency, gain, directivity and radiation pattern can vary [96] [97]. Antennas are spatial filters. Adaptive antennas are a promising technique for implementing this spatial diversity into RFID readers. Article reports an adaptive antenna for RFID reader and their various applications [98]. This antenna is a 5-element rectangular patch antenna array with an intelligent beam forming network at 2.45 GHz as shown in figure 2.11.

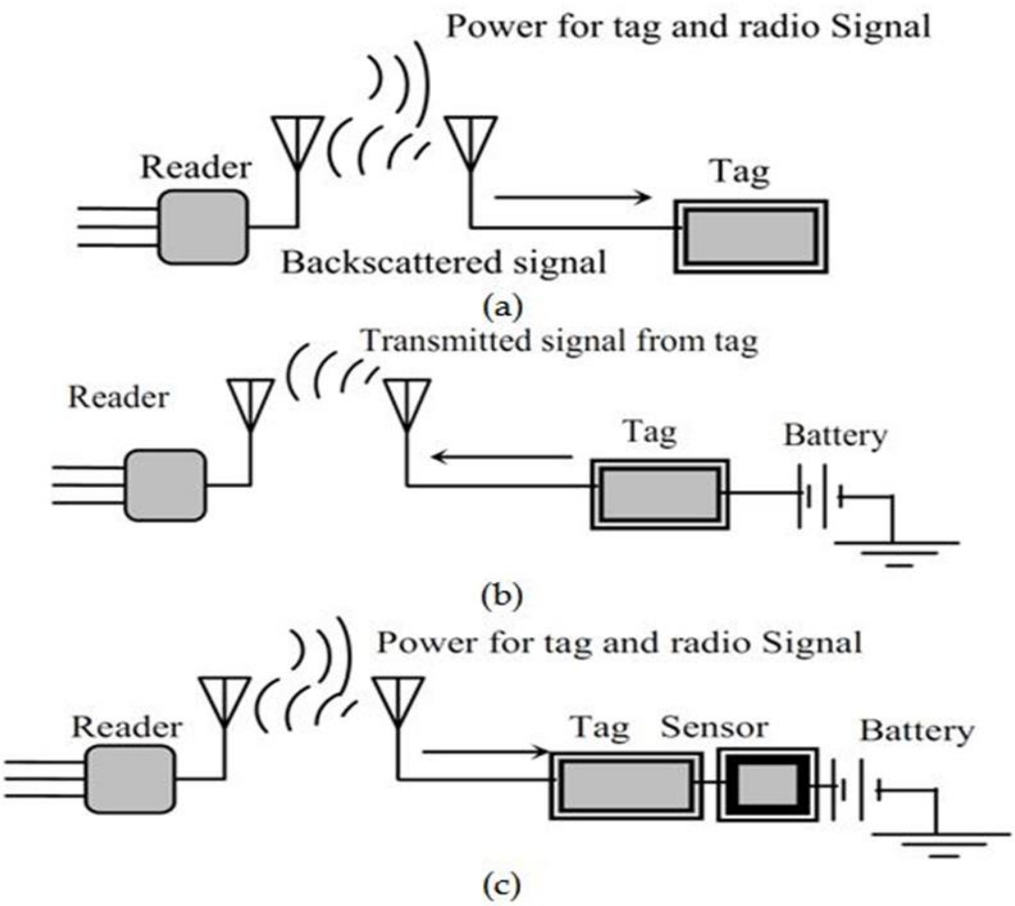

Figure 2.11: Communication between (a) reader and passive tag (b) reader and active tag (c) reader and semi active tags [93]

2.5.3 Classification of Readers

Based on an exploration and comprehensive literature review on RFID readers by Stevan and Karmata [99] readers can be classified based on the;

I. Power Supply
II. Tag Interrogation,
III. Frequency Response,
IV. Supporting Protocols of the Reader
V. Mobility

2.5.3.1 Power Supply

Based on their power supply, the classification of the RFID reader brings forth two types of readers [100]:

I. Readers supplied from the power network; and
II. Battery powered (BP) readers.

RFID readers are electronic devices, they need DC voltage supply for their electronic circuits and components [101] [102]. An appropriate AC/DC adapter is used for the power supply of such readers [103]. Most readers that use this type of power supply are fixed stationary readers and their operating power supply ranges from 5V-12V [104] but there are examples of readers that operate at voltage levels as high as 24 V [105].

Battery powered (BP) readers are light in weight and portable [106] . The battery is mainly used to power up the motherboard of the reader. Most BP readers are handheld and use from 5V up to 12V batteries [106].

2.5.3.2 Communication Interface

Based on this communication interface, they are two types:

• Serial; and

• Network.

Serial readers use a serial communication link to communicate with their host computers or software applications. The reader is physically connected to a host computer using the RS-232 [31]RS-485, IC2 or USB serial connection serial readers are more reliable for data transmission than network readers.

Network use wired or wireless network to connect to the host computer. They are like standard network device and very simple to configure [107]. RFID readers support multiple network protocols such as Ethernet, TCP/IP, UDP/IP, HTTP, LAN, WLAN and others [108] .This allows easier tracking and maintenance of the readers installed in the system. The data transmission rate of network readers is far greater than that with serial readers (up to 10Mbps for Ethernet) and thus data is collected at a higher rate [106] . The drawback of network readers is that the communication link is not as dependable as serial communication. When the communication link goes down, the back end cannot be accessed. As a result, the RFID system might come to a complete standstill. RFID readers have internal memory to store received data from the tags, so short time network failures may be compensated.

2.5.3.3 Mobility

Based on mobility, there are two types of readers;

I. Stationary
II. Handheld

Stationary RFID readers have the ability to be mounted on walls, portals or other objects where they can perform active transponder readings and are not supposed to be moved [108] as shown in figure 2.12. Wireless data capture in supply chain management, asset tracking and product control. Today's fixed RFID readers are used for personnel identification and authentication for restricted access areas installed and mounted on portals and doors. Stationary readers operate in standalone and in networking mode, and they support multiple protocols for transponder reader communication. They use power supply from 12V DC up to 24V, weigh from 1.5 kg up to 5kg and can achieve reading ranges up to 300 m.

In comparison to fixed (stationary readers), Handheld RFID readers are mobile readers that can be carried and operated by users as handheld units. Handheld readers have built in antennas and usually do not have connectors for additional antennas. They are battery powered and are light weight (from 82g up to 700g). They have shorter reading ranges than fixed readers (up to a 100 m). These are mainly used in tracking livestock, human beings [108] [109] locating items in stores and in stock.

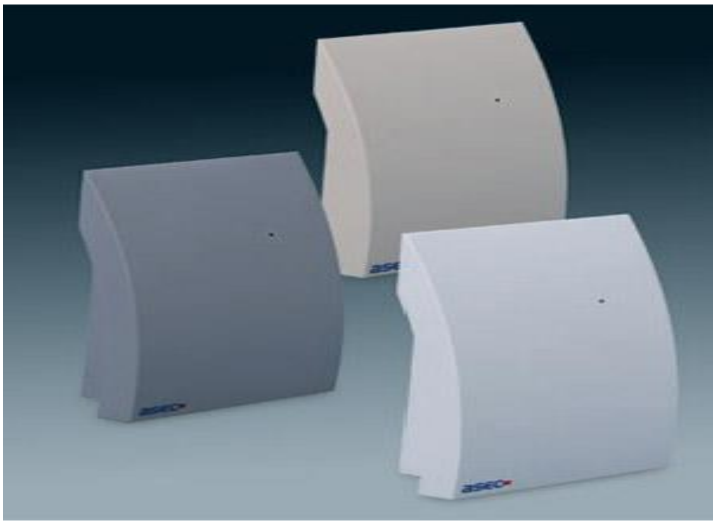

Figure 2.12: Stationary RFID reader [108]

Communication with the host computer is via wireless communication protocols and they contain memory blocks to save information. Wired communication is basically for the transfer of the captured data from the reader to the database. They are also integrated with barcode scanners to enable users perform both tag and barcode identification simultaneously. A handheld reader by SAVI Technology [108] is shown in Figure 2.13.

Figure 2.13: Hand held Reader [108]

2.5.3.4 Interrogation Protocol

Classification can also be based on whether the reader can perform both listening and calling out of tags [109] and can achieve successful area location of the transponder. Hence transponders must have a demodulating circuitry to enable them to decode the reader's command.

Binary search algorithms are mostly used by active readers that combine listening and calling. Binary search algorithm implementation requires that the precise bit position of data collision is recognized in the reader [110]. In such implementations, a suitable bit coding is required (NRZ, Manchester coding, etc.). The block diagram of an active RFID reader is shown in Figure 2.14.

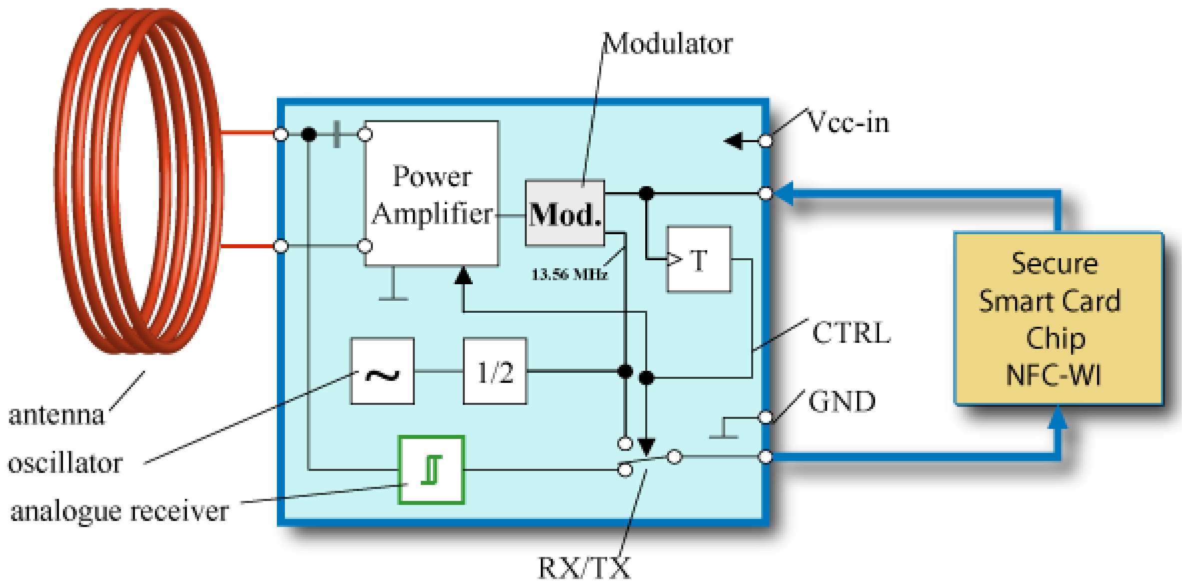

Figure 2.14: Simplified block diagram of the required active RFID interface module, connected with smart card chip (secure element) [111] [112].

2.5.3.5 Frequency Spectrum

Classification of readers under frequency spectrum is based on the transponder frequency responses that they listen to as:

I. Unique frequency response-based readers; and
II. Non-unique frequency response-based readers.

RFID reader's also use other frequency bands besides using their frequencies to perform data transmission and reception [107]. Unique frequency response-based readers operate at a defined frequency range and use this frequency for both data transmission and reception [106]. The vast majority of RFID readers that can be found on the market today are unique frequency response-based readers [112].

On the contrary, none-unique frequency response based readers function using one frequency for sending a command or just provide a carrier signal at a certain frequency and listen for an integer multiple of its carrier frequency, generally in the form of a 2nd harmonic, or a frequency divided signal as the transponder's response [107]. The use of two RF frequencies for communication by the reader to the RFID system allows fast and reliable full-duplex communication though a complex RF system is needed for both the reader and transponder module. Other RFID system uses multiple antennas to enable multiple frequency operating at different predefined frequencies [108].

2.5.3.5 Data Encoding Protocols

Apart from RFID readers using multiple frequencies for data transmission and reception they can also use multiple protocols to communicate with transponders. Therefore, RFID readers are classified based on their ability to communicate with transponders using diverse protocols [107].

Based upon their ability to communicate with transponders in regards to data encoding protocol, a distinguish can be made between two types of RFID readers;

I. Simple RFID readers; and
II. Agile RFID readers.

A unique protocol for communication and data transmission between transponders is used by simple RFID readers in the interrogation zone. Once a transponder that supports the reader's interrogation protocol is established in the interrogation area of the reader, the tag is automatically recognized and detected. When a transponder that operates using a different protocol is put into the interrogation area, no data transmission will take place, because of the unfamiliarity of the reader's interrogation protocol to the transponder. simple RFID readers are easy to debug due to the fact that their interrogation protocol is unique and they have greater tag reading speeds (up to 2000 tags per second), but they lack flexibility and cannot interact with different types of RFID systems due to their ability to support only one protocol.

Agile readers use multiple protocols to operate and perform interrogations and data transmission with transponders. This allows users to use a reader from one manufacturer and transponders from other manufacturers. Some agile reader companies allow programming the reader using special reader system software that permits the user to increase the number of protocols used by the reader for tag cross-examination and therefore create a more powerful and efficient reader [113].

Agile readers put flexibility into the RFID system though a more complex data and signal processing architecture and advanced software support is required. The protocols commonly used for data transmission between transponders and readers are EPC Gen2, ISO 1800, TIRIS, EPC Gen1, etc. Most RFID readers found in the market are made for multiple protocols and multi-tag readings [108] [113].

2.5.3.6 RFID Reader Antenna

The reader antenna is an important component of the RFID system. The RFID reader's efficiency in terms of transponder interrogation and detection is dependent on the reader antenna. A distinguishes can be made between two types of RFID reader based on their antennas:

I. Fixed beam RFID reader; and
II. Scanned array RFID reader.

Fixed Beam antennas have a unique and fixed beam radiation pattern as shown in figure 2.15. Most RFID readers are armed with Omni-directional or wide beam width antennas in order to cover as much area as possible [107] [108]. Fixed beam RFID reader have the advantage of easy installation and no logic is required to control their radiation patterns. The drawback of these antennas is that they pick up multipath signals alongside with the transponders signal which can result in errors during interrogation.

Figure 2.15: Fixed beam readers [109]

Smart antenna systems technology is used in Scanned Array RFID reader (figure 2.16) to reduce the number of transponders within their main lobe radiation zone thus reduce reading errors and collisions among tags. Spatial diversity technique is exploited among tags locations and direct beam reduces the effects of multi- pathing. The effects of multi-pathing can be reduced by the use of directional antennas. The smart antenna technology integrated in RFID readers has reduced reflections from surroundings and thus decreased the degradation of the system performance due to multipath and other unwanted effects

Figure 2.16: Scanned array readers [107].

A few RFID companies like RFID Inc, and Omron Corporation have incorporated this new RFID antenna technology. RFID tags are prune to multipath interference an inherent problem of electromagnetic signals. The interference makes RFID tags unreadable even if it is within the reading range of the reader. To resolve this problem, a new category of antenna technology is used that can electronically regulator the main beam emitted from the reader's antenna.

2.6 What is the Internet of Things?

The Internet of Things (IoT) is a system of interrelated registering gadgets, mechanical and computerized machines, items, creatures or individuals that are given exceptional identifiers and the capacity to exchange information over a system without expecting human-to-human or human-to-PC cooperation. Lopez defines internet of Things as "a paradigm in which objects equipped with sensors, actuators, and processors communicate with each other to serve a meaningful purpose" [91]. Jaiswal et al. defines the Internet of Things as simply an interaction between the physical and digital worlds [18].

The digital world interacts with the physical world using a plethora of sensors and actuators. Another definition by Peña-López et al defines the Internet of Things as a paradigm in which computing and networking capabilities are embedded in any kind of conceivable object [91]. We utilize these abilities to inquiry the condition of the question and to change its state if conceivable. In like manner speech, the Internet of Things alludes to another sort of world where every one of the gadgets and machines that we utilize are associated with a system. We can utilize them cooperatively to accomplish complex assignments that require a high level of knowledge

IoT has developed from the meeting of remote advancements, small scale electromechanical frameworks (MEMS), micro services and the web. The merging has helped tear down the silo walls between operational innovation (OT) and data innovation (IT), permitting unstructured machine-produced information to be investigated for bits of knowledge that will drive enhancements.

The rapid growth of the IOT is pictured in Figure 2.17 comparing the number of devices on the Internet to the number of people on the Internet. Connected devices surpassed connected people in 2008. Whitemore et al estimates that by 2020 there will be 50 billion connected devices, 7 times the world’s population [97]. Similarly, the Connected Life initiative sponsored by the GSMA (GSM Association, an industry-association for worldwide mobile operators) found that in 2011, there were 9 billion total Internet-connected devices (compared to the total human population of less than 7 billion), two-thirds (6 billion) of which were mobile, and estimates that in 2020, there will be 24 billion total Internet-connected devices, 12 billion mobile [2] . Moreover, these 24 billion Internet-connected devices are estimated to have an economic impact of over $4.5 trillion in 2020 [3].

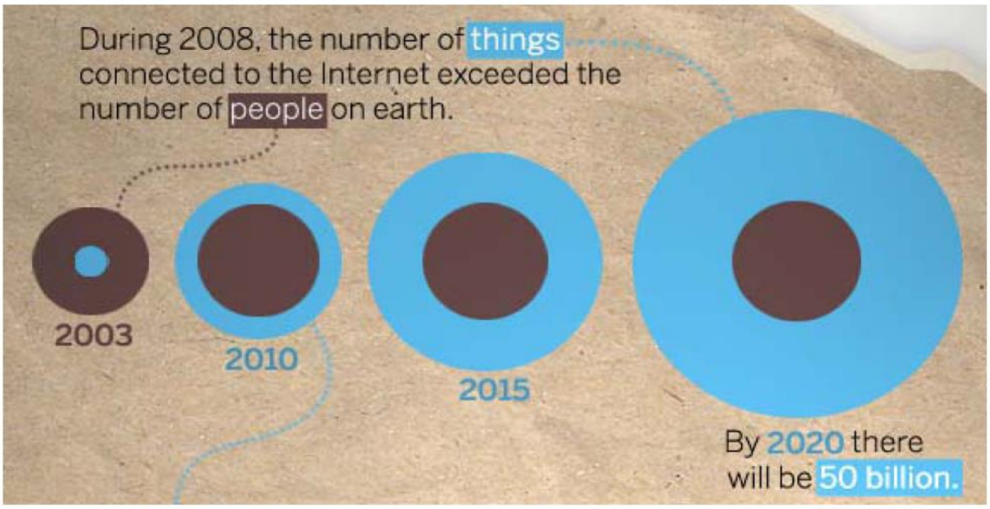

Figure 2.17. The accelerated growth of Internet-connected devices [2]

2.6.1 Internet of Things and Healthcare

The need of healthcare on IoT is swelling each day hence improving access to care, quality of care and reducing the cost of care [99]. Personalised healthcare is now based on an individual's unique biological, behavioural, social and cultural characteristics, the integrated practice of wellbeing, healthcare and patient support [7].

This allows each and every individual by following the basic healthcare principle of "the right care for the right person at the right time", which leads to healthier results and enhancement in satisfaction thus making healthcare cost-effective. A supportable service emphasis on the prevention, early pathology detection, and homecare instead of the costly clinical one, and checks the overall well-being to forestall needs and ensure compliance to healthcare plans.

The use of Internet of Things promises to manage the personalization of care services and can maintain a digital identity for every person. Different equipment is used in healthcare, to communicate and to make the universal system-of-system. The classifications of IoT based personalised healthcare systems are Clinical care and remote monitoring [58].

IoT-driven, non-invasive monitoring systems are used for hospitalized patients whose physiological status requires constant close attention [25]. These monitoring systems employ sensors to collect physiological information, which is analysed and stored using gateways and the cloud. This information is then sent wirelessly to caregivers for further analysis and review hence, rendering a health professional having to check the patients' vital signs after regular intervals unnecessary. Instead, it provides a continuous automated flow of information [7][8]. Thus, the quality of care is improved through constant attention which in turn lowers the cost of care and eliminates the need for a caregiver to actively engage in data collection and analysis as pictured in figure 2.18.

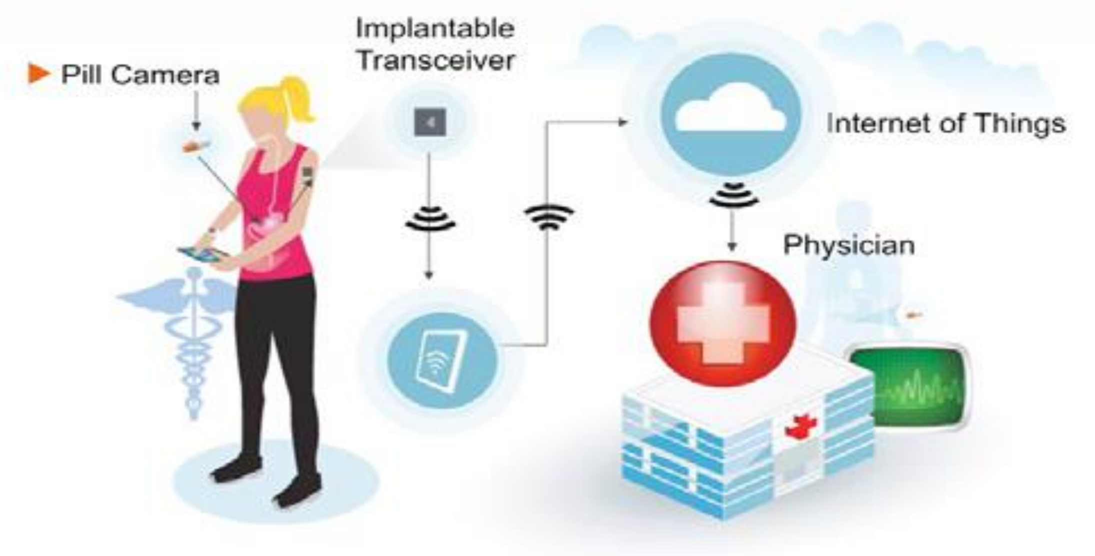

Figure 2.18: Application of IOT in Health Monitoring [8]

2.6.1 Internet of Things Taxonomy

The Internet of Things is built from several architectural layers as illustrated in figure 2.19. Perception layer is the first architectural component of IoT. It collects data using sensors, which are the most important drivers of the Internet of Things [37]. There are different types of sensors used in diverse IoT applications. The most basic sensor accessible today is the smart phone. This is because the smart phone has many types of sensors fixed in it such as the location sensor (GPS), accelerometer, speedometer, camera, magnetometer, proximity sensor, thermometer etc. [34].

These are being heavily used in different IoT applications. Many other types of sensors are beginning to be used such as sensors for measuring temperature, pressure, humidity, medical parameters of the body, chemical and biochemical substances, and neural signals [93] [96]. A class of sensors that stand out is infrared sensors that predate smart phones. They are now being used widely in many IoT applications: IR cameras, motion detectors, measuring the distance to nearby objects, presence of smoke and gases, and as moisture sensors

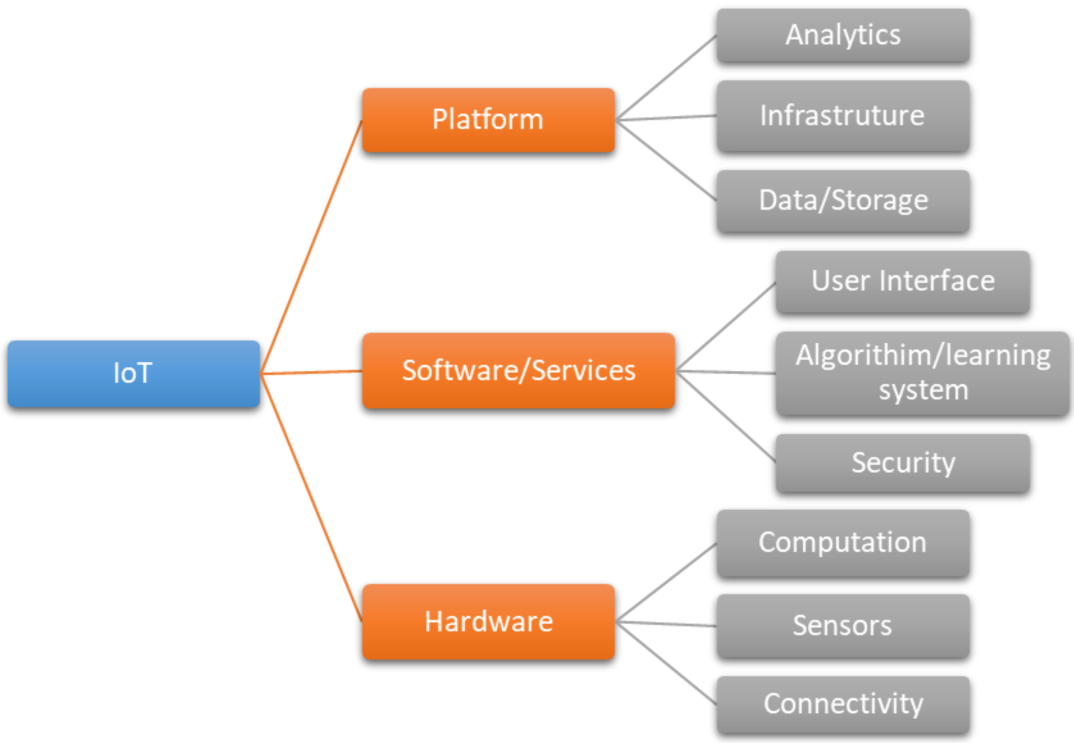

Figure 2.19: Taxonomy of the Internet of Things [34]

The second architectural component is communication. Distinctive entities communicate over the network utilizing a various set of protocols and standards [83]. The most well-known communication technologies for short range low power communication are RFID (Radio Frequency Identification) and NFC (Near Field Communication). For the medium range, they are Bluetooth, Zigbee, and Wi-Fi. Correspondence in the IoT world requires extraordinary systems administration conventions and instruments. In this way, new instruments and conventions have been proposed and executed for each layer of the systems administration stack, as indicated by the necessities forced by IoT gadgets [34] [83].

There is likewise the middleware which makes a reflection for the software engineer with the end goal that the details of the hardware can be hidden. This improves interoperability of smart things and makes it simple to offer various types of services. There are numerous business and open source offerings for giving middleware services to IoT gadgets. A few cases are OpenIoT [4], MiddleWhere [5], Hydra [6], FiWare [7], and Oracle Fusion Middleware.

2.6.2 Architecture of IoT

There is no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers.

2.1. Three- and Five-Layer Architectures

The most basic architecture is a three-layer architecture [34] as shown in Figure 2.20. It has three layers, namely, the perception, network, and application layers.

(i) The perception layer outlines the physical layer, which has sensors for sensing and collecting data about the environment. It identifies and senses physical parameters in the environment.

(ii) The features for network layer are used for transmitting and processing sensor data. But the main function is to connect other smart devices, network devices and servers.

(iii) The third layer responsible for delivering application precise services to the user. It delineates various applications in which the Internet of Things can be deployed e.g. smart hospital, smart homes, and smart schools.

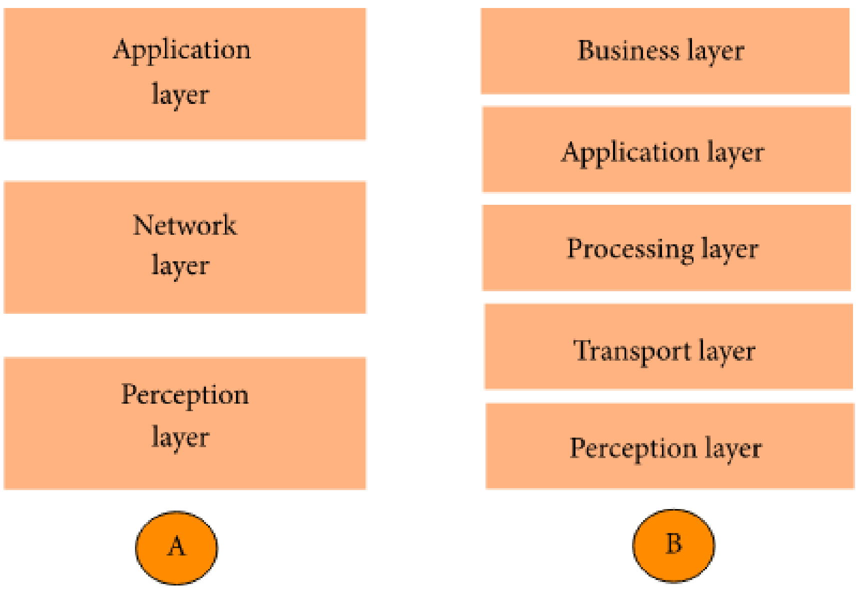

Figure 2.20: Basic architecture is three-layer architecture [34]

Architecture is the five-layer architecture, which in addition consist of the processing and business layers [83]. These five layers are perception, transport, processing, application, and business layers (Figure 2.20). The role of the perception and application layers is the same as the architecture with three layers.

(i) The transport layer is responsible for transferring data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G, LAN, Bluetooth, RFID, and NFC.

(ii) The middleware layer stores, analyses and processes data that comes from the transport layer. It provides diverse set of services to the lower layers and uses many technologies such as databases, cloud computing and data processing modules.

(iii) The business layer is responsible for managing the whole IoT system, including applications, business and profit models, and users' privacy.

Another architecture proposed by MacEwen [114] is inspired by the layers of processing in the human brain. It is inspired by the intelligence and ability of human beings to think, feel, remember, make decisions, and react to the physical environment. It is constituted of three parts. First is the human brain, which is analogous to the processing and data management unit or the data centre. Second is the spinal cord, which is analogous to the distributed network of data processing nodes and smart gateways. Third is the network of nerves, which corresponds to the networking components and sensors.

2.7 Applications of RFID

RFID technologies are used in various areas of applications in computerizing the operations for the purpose of achieving efficiency, effectiveness and realizing optimal benefits from the business. Some of the areas of applications in which these technologies can be employed are discussed below.

2.7.1 RFID in Distribution Chain

The usage of RFID system across many applications creates good impact to users and community. The RFID tag can be affixed to an object and used to track and manage inventory, assets, people, etc. For example, it can be affixed to vehicles, patients, books, mobile phones, etc [13]. According to Luigi Patrono [94], in 2010 three factors drove a significant increase in RFID usage: decreased cost of equipment and tags, increased performance to a reliability of 99.9% and a stable international standard around UHF passive RFID. The adoption of these standards were driven by EPCglobal, a joint venture between GS1 and GS1 US, which were responsible for driving global adoption of the barcode in the 1970s and 1980s [70] .

RFID offers advantages over use of bar codes or manual systems. The tag can be read if passed near a reader, even if it is covered by the object or not visible. The tag can be read inside a case, carton, box or other container, and unlike barcodes, RFID tags can be read hundreds at a time. Bar codes can only be read one at a time using current devices. This advantage over barcodes is what makes it more popular in supply chain management [74] [77].

RFID technology can be used to monitor and manage the movement of the finished products throughout a supply chain [13] [67]. RFID tags can be attached directly to the items and materials or they can be attached to the containers that carry them. Pallets, trailers, totes, carts, cargo containers, and reusable transport items can all be tagged. Readers placed throughout a facility can monitor movement and location of inventory, thus providing real time data. This can be within a warehouse, a freight yard or within a retail location as shown in figure 2.21.

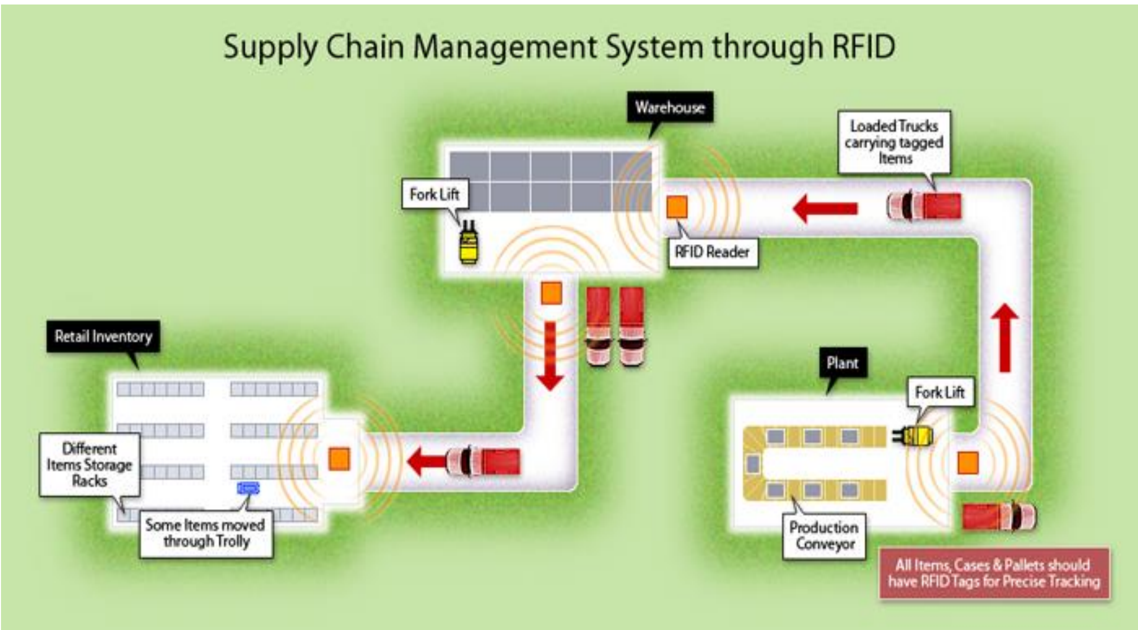

Figure 2.21: RFID uses in supply chain management [67]

RFID applications in the supply chain enable more frequent and accurate inventory counts RFID applications in the supply chain can also decrease costs associated with inventory counting. In addition, RFID applications in fleet management have demonstrated significant ROI. RFID applications in fleet management enable a more cost-effective long-range tracking solution, global tracking of containers and cargo, reliable tracking of capital and inventory assets during transportation and increased security. By placing RFID tags on long range vehicles, trailers or other mobile assets, companies can gain visibility into their business' assets' utilization [13].

2.7.2 RFID in Brand Protection

RFID applications can be used to protect brand identity by product marketing managers and to protect consumers from counterfeited products. RFID applications in anti-counterfeiting are, generally, aimed at high-value end consumer products. The unique identification number on standard RFID tags can be used to verify the authenticity of the products to which they are attached. These unique numbers combined with encryption algorithms can create authentication schemes that are extremely difficult for counterfeiters to circumvent [69].

RFID applications in anti-counterfeiting can be used in many industries, including pharmaceuticals, electronics, entertainment, retail, IT and many more. By placing RFID tags on products at the point of manufacture, manufacturers can trace products throughout the supply chain.

The pharmaceutical industry is creating an RFID application that will document the authenticity of their products at retail. Not only will the products have a unique ID, but information about the chain of custody for the product will be stored on the RFID tag or in an associated database. If the product is not properly tagged or the tag is not associated with the proper chain of custody – then you know the product is counterfeit.

2.7.3 RFID Product Marketing

As in the distribution chain, RFID application in retail can greatly aid in reducing the cost of keeping accurate inventory data [74]. With fewer people and less time, retailers can keep accurate inventories. Associates can spend more time providing service to customers rather than counting product.

RFID Applications in retail can greatly aid in ensuring proper product mix and availability are maintained for customers. The accuracy of the real time inventory data that is provided by RFID applications, enables product marketing managers to ensure that hot selling items are properly stocked and to ensure replenishment order for these items are placed as quickly as possible. Slow moving items can be quickly identified. This allows product marketing managers to take corrective action to goose demand through promotional or advertising activity before a ‘fire sale’ is needed. Thus, RFID applications help product marketing managers maintain their margins.

RFID applications are, also, a significant aid in deterring theft in retail environments. Items tagged with RFID devices can trigger alarms when they are removed from the store without being properly deactivated [86]. RFID applications have been successfully deployed for anti-theft purposes for several decades.

2.7.4 Animal Identification

The process of identifying and tracking animals is called animal identification (figure 2.22). It is conducted for the purpose of verification of ownership, biosecurity control, record keeping, efficient farm management and prevention of theft of animals. Proper identification of animals will provide a base to improve the management of herd.

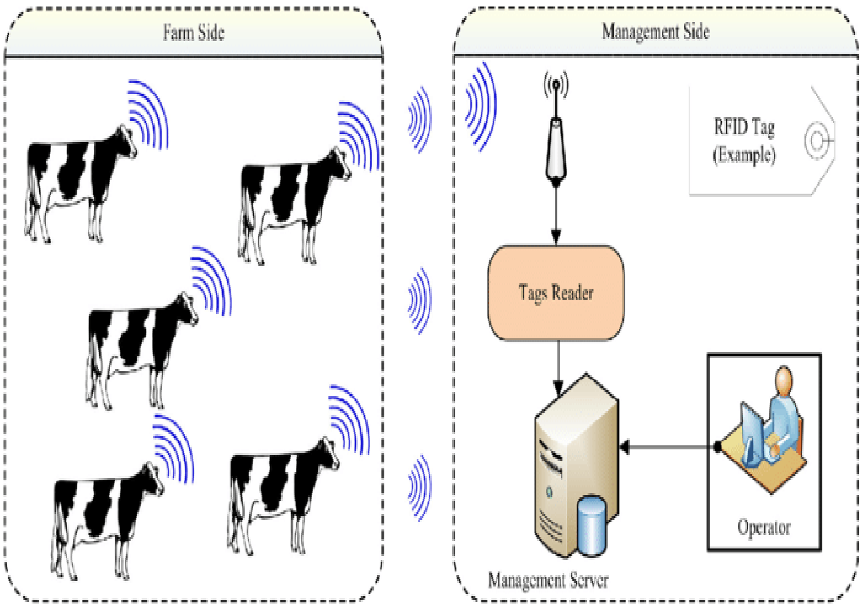

Figure 2.22: RFID in Animal tracking

According to Singh, RFID technology is used in livestock agriculture to achieve animal identification. RFID technology provides automatic data collection by taking advantage of the cabled network or wireless network that allows electronic transmission of information. The RFID tag or transponder is implanted either at the ear, the bolus, and collar in form of a microchip. Animals are identified with a wand by waving it near the ear where the chip is attached, which transmits the data to a handheld computer. RFID tags are read by use of wand connected either physically or via wireless to a portable computer as shown in figure 2.22. Using the developed software with RFID technology, the data is processed and then transmitted to the database [108].

2.7.5 Tracking of Construction Materials

According to a study conducted by Karmarkar [106] [108], RFID technology is also employed in automated management of construction materials and components. Materials management plays a pivotal role in successful completion of any project in the domain of construction. The fundamental part of an effective materials management system is the identification and tracking of materials throughout the construction process. Automating the task of identifying and tracking the construction materials provides timely and accurate information on materials availability for the manager.

There are actually two methods used for tagging construction materials. On one hand, if the target material is made of prefabricated items or packed materials such as bricks, a tag is attached to each component and package unit. On the other hand, if the target material is a bulk, non-packed material such as sand, which is delivered on site using bags and containers, the invoice is associated with an RFID tag. Stationary RFID readers are installed at entry and exit gates and portable readers are also used by key workers to collect and identify tagged items by walking around. A database server application could use different software for collecting, storing, updating, modifying, filtering, and sharing data. It acts as a supply chain management, inventory control, materials location information and materials status tool

2.7.6 Tracking of Workforce in the Construction Industry

According to Mattern [107], workforce management can contribute highly in reducing the project costs and increase productivity since significant percentage of labor cost is involved in a project. In context to this, RFID based solution can be implemented to track the number of workers on site, as well as their identities by utilizing the Workforce Monitor Service, construction project managers and supervisors can capture the identity of each worker entering or leaving a site, by means of Workforce Management Stations-RFID portals that reads RFID tags attached to the hardhats of workers.

Workforce monitor software application processes the data from readers related to individuals passing through the portal, providing a user with such details as which contractors have employees on site, the number of workers at the particular location, whether those personnel have the necessary training or certification required to be present, workforce demographics and the workers pin code. The RFID based solution also provides information on which workers have gone underground on sites and in which trenches or tunnels Thus, in case of emergency or occurrence of mishap, RFID technology can be used effectively.

2.7.7 Tracking of Vehicles during Manufacturing

A study carried out by stated the technological advantage of using RFID in automotive manufacturing industry. He noted that the use of RFID technology has become necessary by improving the efficiency with regards to the manufacturing of vehicles. It enables efficiency and effectiveness in tracking each vehicle during the postproduction process. The need to effectively track vehicles is due to the high volume of vehicles produced. In South Africa for example, the Toyota facility in Durban produces 220 000 cars per year [97] .The vehicle tracking is accomplished with reusable highly robust RFID tags mounted to each vehicle during assembly, the RFID tag then communicates with a reader at each station along the assembly line, updating the facility's vehicle tracking server with the vehicle position and the time spent at each station as illustrated in figure 2.23.

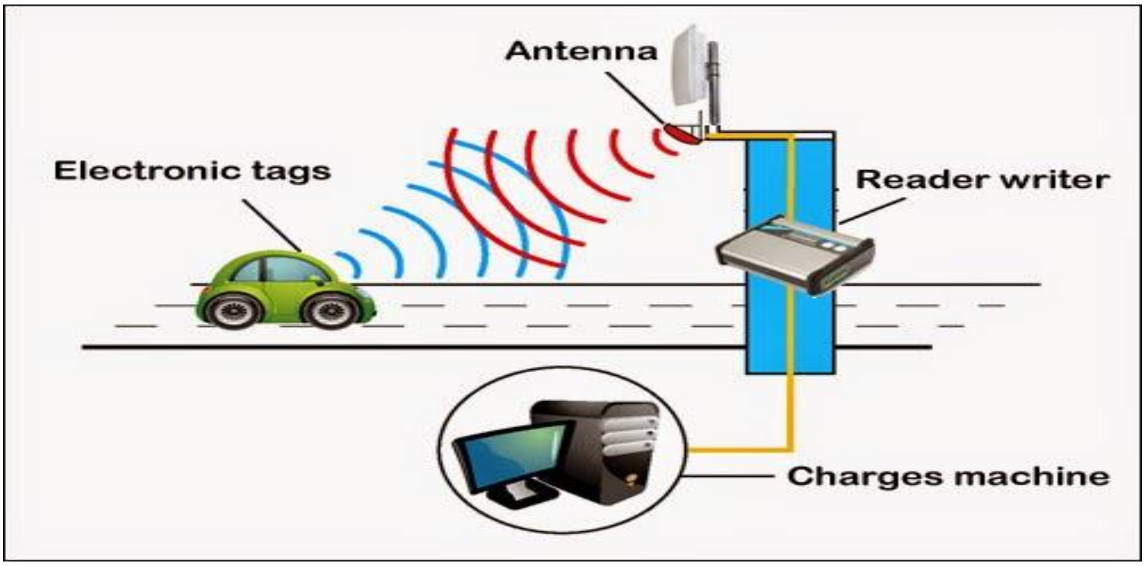

Figure 2.23: vehicle tracking using RFID [13]

2.9 Radio Frequency Identification and Internet of Things - Security and Privacy

Security is the core agenda that needs to be included into RFID systems and protocols. Several previous works on RFID protocols were proposed, which try to protect against some security issues such as eavesdropping, message intercepting, denial of service attacks, man in the middle attacks, relay attacks, replay attacks and many more and including also the physical attacks [16].

Since RFID tags can be attached to cash, clothing, and possessions, or implanted in animals and people, the possibility of reading personally-linked information without consent has raised serious privacy concerns [17]. These concerns resulted in standard specifications development addressing privacy and security issues. ISO/IEC 18000 and ISO/IEC 29167 use on-chip cryptography methods for un-traceability, tag and reader authentication, and over-the-air privacy [71] [81]. ISO/IEC 20248 specifies a digital signature data structure for RFID and barcodes providing data, source and read method authenticity [114]. This work is done within ISO/IEC JTC 1/SC 31 Automatic identification and data capture techniques [114].

Encryption has so far proven to be the best security solution to ensure message protection between the RFID frameworks segments [17]. This has allowed messages travelling through remote radio recurrence correspondence to be listened stealthily or obstructed by foe between RFID readers and labels. AES and ECC offers the best security to RFID framework and a study by Abugida [17], Indicated that open key cryptography plan is not suitable for RFID framework due to the constrained hoarding limit in tag.

Trusted computing (TC) is another option for securing information but encryption alone can’t ensure data against malware and mask. Here, Trusted Platform Module (TPM) is carefully designed equipment [16] which can ensure and give respectability approximations and data fixing for processing stage. TPM is not the antivirus programming but rather its capacity to do trust boot and chain of trust can without much of a stretch identify any change at the framework level, improves it an answer in this circumstance. Other than securing information in movement and information very still, another part is to ensure information being used or at the application level. Security and trust is required at this level [16].

Another technology that shields information from attacks is Security Enhancing Technology [98 . This technology secures information against traceability and area following. Security, Trust and Privacy are three ranges, which should be satisfied by RFID system with a specific end goal to comprehend the significant issues

Considerable attention to the development of IoT applications and related security measures has been devoted by both the industry and academia. Seith et al in 2017 presented a simple multicast authentication scheme for minor IoT applications [20] Specific characteristics of the fast accumulator proposed by K. Nyberg were exploited, i.e. the permeability property and the one-way and quasi-communicative property, to construct a simple multicast authentication mechanism [98]. The authors evaluated seven principal criteria required by multicast authentications for affordable applications in the course of a performance analysis, to test their scheme’s practicability. The subsequent year, Bello and Zeadally investigated the option of self-collaborated device-to-device communications without any centralized control [17]. Aquee et al. [66] in 2016 also demonstrated a scheme for data collection for location-based authentication in IoT networks These two validation schemes are aimed to fit the security requirements for body sensor networks and distributed wireless sensor networks, respectively. Therefore, from the standpoint of authentication analysis, the underlying architectures can respectively be characterized as being client-server and client-server-server.

2.8 Related Works

2.8.1 Patient Identification

Many health professionals are concerned about the growing number of patients who are misidentified before, during or after medical treatment. According to Amondola et al [105], the use of RFID in hospitals and medical facilities can improve the patients' care, optimize the workflows, reduce the operating costs, help avoiding severe mistakes (such as patients' misidentification) and reduce costly thefts.

J best stated [80] that RFID has the potential to be used not just for the monitoring of patients' physiological parameters, but also for management of medical equipment, dangerous medical substances and drugs, inventory control, and the identification and locating of patients. Nichols et al [8]describe a RFID chip enabled card that allows patients to have their medical information read and even written to by physician even if the patient has undergone medical treatment in another hospital. Chang [38] presents a solution where RFID is used for patient appointment where a card is used for making appointment at hospital and patients served based on priority.

Indeed, patient identification error may lead to improper dosage of medication of patients, as well as having invasive procedure done. Other related patient identification errors could lead to inaccurate lab work and results reported for the wrong person, having effects such as misdiagnoses and serious medication errors [14].

Figure 2.24: Patient identification using RFID [113]

Over the past years several RFID- based patient identification and tracking pilot projects have been launched, to cut clinical errors and improve patient care. For example, Jacobi Medical Centre in New York, in the Birmingham Heartlands Hospital is among some of the hospitals that have rolled out this technology [80]. To implement such a system Birmingham hospital installed RFID readers around the hospital. Patients admitted to the hospital were given an RFID-based wristband resembling a watch with a passive RFID chip in it (figure 2.24). The chip stored a unique patient ID number and some relevant medical information such as the patient's blood type, in order to speed treatment. To ensure patient privacy and to avoid that medical records are improperly disclosed, further medical data were not stored on the devices but are rather stored in a secure database that links the unique patient's ID with its data. The caregiver here was given a handheld computer with an RFID interrogator (an RFID-enabled PDA) to read the data encoded on the patient's ID bracelets. Over a wireless LAN connection, the hospital staffs were able to access the patient's encrypted confidential medical history as well as treatment record and can obtain information on which drugs and what dosages the patients required. Patients were able to check their own records by scanning their wristbands using information terminals.

2.8.2 Smart Operating Theatres and Blood Tracking

A study by joint commission on Accreditation of Health (JCAHO) declared that the most commonly reported surgical errors involved surgery on the wrong body part or site, the wrong patient or the wrong surgical procedure [80]. As mentioned in [47], surgical identification can raise significant problems, according to recent federal reports.

A pilot project of the RFID technology on patient undergoing ear, nose and throat surgery was launched at the Birmingham Heartlands Hospital [9]. The aim of the system was to ensure that correct operations were carried out on the right patients. The patients got a RFID-tagged wristband containing relevant information and a digital picture of them. The system allows the clinical team to easily confirm they have the right patient, and the electronic record ensures they perform the correct procedure. If the wrong patients entered the operating room, the medical staffs were automatically and instantly warned of the mismatch. Thus, radio tagging made the operating theatre safer and more efficient. Moreover, the risk of litigation resulting from surgery mistakes and the costs they generate were significantly reduced.

Nichols in his report points out those blood transfusion errors (i.e. blood transfusion of the incorrect type or blood given to the wrong patient) are unacceptably frequent and serious [11]. A study by Sun Microsystems HealthCare Division [23], showed that miss-transfusion typically result from an error made during the bedside check just prior to transfusion. Studies have documented that such errors are most likely to occur among surgical patients. Currently the bedside check is done by humans using eye-readable information, and in operating rooms this task is particularly difficult.

As quoted in [3], “in the transfusion environment, misidentification is the most prevalent cause of transfusion errors that result in death”. Indeed, blood is often given under circumstances of extreme urgency and distraction. Patients are unconscious during the transfusion and cannot state their name, and caregivers in the operating rooms may not “know” the patient as well as nurses on non-surgical floors [11]. To address the issues of misidentification and mis- transfusion RFID technology has been adopted in some hospitals. RFID technology does not have the practical problems of bar codes, and recently several hospitals have deployed pilot programs using this technology to track bags of blood to record transfusions and ensure that correct blood is given to each patient.

In the smart hospital project as described in [21][17], each bag of blood arriving at the hospital gets a self-adhesive RFID label. This chip has memory for storing a unique identification number and information on the contained blood type. These numbers are also saved in a secure database containing details about the blood’s origin, its designated purpose and, once dispended, its recipient. When a nurse wants to prepare a blood transfusion, she uses a reader-equipped PDA to read the data encoded on the blood bag’s RFID chip and on the patient ID bracelet. The data from the patient and the bag must match before the blood can be used. With this solution the overall process of managing blood bags is eased and less time-consuming. Moreover, the risk of patients receiving the wrong type of blood is minimized.

2.8.3 Limitations of Remote Tracking and Monitoring

Remote monitoring has drastically changed the delivery of health care and the health industry [21]. The ability to monitor patients in real- time using sensory devices has triggered a positive disruptive change to healthcare [112]. Remote monitoring coupled with IoT has changed the face of health care in a great way by giving patients the ability to share their information in real time with their care givers. Dr. Yanick Beaulieu, CEO and Founder of IIT, said in a statement. "For years, clinicians in the field have been trying to piece together systems that offer real-time, interactive tele ultrasound capabilities [9].

In as much as remote monitoring is positively changing the health care industry, it has its own limitations like any other system. The system is greatly dependent on the patient's willingness to change improve their health and participate in their care [14] [15]. The cost of the monitoring devices is another setback and there are also prune to fail during implementation [15]. Privacy and confidentiality are also an issue and there are no clear guidelines with respect to how far clinicians have to intervene when they get an alert message regardless of the urgency [66].

The continuous flowing of patient data needs a devoted team of healthcare providers to handle the data, which is likely to increase the workload. Though technology is introduced with the intent to increase productivity, the technological competence amongst the healthcare providers is a challenge to the growth of remote monitoring in health institutions [98] [104].

2.8.3 Overview IOT existing systems

The area of health in recent years has been rapidly integrating technology in the monitoring, diagnosis and treatment of patients remotely and in situ [115] [116]. Thus, achieving to improve the quality of life of patients and greater traceability of information from them. Most studies reviewed point to a chronic disease monitoring in particular as in which are responsible for the first monitoring sleep through gyroscope Smartphone, the second remote monitoring of vital signs and the third of a tele medical ECG system of a patient [117] [118].

Other systems have special features which make use of these developments, in the case of, which developed a prototype device electrocardiography, which integrated with a Smartphone for displaying results [119]. Telemedicine was also developed to offer interactive media which contributed to improved consultation and clinical monitoring as well as home health care [120]. Another system developed in [115] who proposed a terminal for the integration of medical services from home using external sensors for measuring vital signs. Although [10] also integrate external sensors measuring vital signs, this has linked to structural health monitoring SHM approach, under a proposed scheme to eliminate environmental effects of IoT environments.

Other systems such as those proposed in [62] are fixed systems. It brings in the advantages in terms of perception, transmission and application of information in the field perspectives of health and medical care. Enabling smart, an accessible and communication system based on IoT hosting segments such as medical equipment, information management control medication of patients, telemedicine, mobile medical care, and personal health management, among others. Some teams that were responsible for analysing and developing monitoring systems of diabetic patients based on IoT IPv*6 with a type of connectivity, making non-invasive patients measurements with this disease, which would provide a better approach to the interpretation of these measurements were also found by the specialists in the field [116].

2.9 Summary

In this chapter a comprehensive overview of the background theory and some examples of the related works to RFID, IoT, remote monitoring in the health care and other fields. Applications of RFID in agriculture and other fields such as health care, libraries and human identification are many and varied. Application of technology in the health sector will enhance productive and efficiency in the health sector. This will also minimize medical errors and provide accountability to these errors. With the introduction of the smart health system in Zambia, embracing IoT and RFID in the health sector will improve the quality of services being provided by the government. IoT is a relatively new technology but its application is vast and a significant proportion of RFID deployments in other fields remain exploratory.

CHAPTER 3

METHODOLOGY

3.0 Introduction

The chapter outlines the methodology that was used to conduct the research. The method that was used to conduct the baseline study is presented. The steps for the design model and implementation of the prototype are outlined.

3.1 Baseline study

The purpose of the baseline study was first to establish the challenges faced by the University Teaching Hospital (UTH) regarding the retrieving of patients' medical records. Secondly to highlight the challenges patients face during registration i.e. long queues both at the registry counter and during the process of taking vitals (temperature, Blood pressure and weight). Thirdly to establish the challenges faced by the medical personnel to track and monitor patients within the hospital. Baseline study included getting statistical information from the hospital. These amongst others included;

i. Number of patients visiting the mother to child hospital (which was the study's target area and 20 women were targeted in the study)

ii. The number of patients who had experience with files/ medical records getting misplaced or lost

I. Patients with mobile phones and access to internet

A mixed methods research methodology was used in this study. The methodology comprised of a combination of qualitative and quantitative research types [121]. Mixed methods research is a methodology for conducting research that involves collecting, analysing and integrating quantitative (e.g., experiments, surveys) and qualitative (e.g., focus groups, interviews) research [122]. This approach to research was used because the integration provided a better understanding of the research problem than either of each alone.

The importance of mixing both quantitative and qualitative data was that it provided depth understanding and corroboration of the subject matter while offsetting the weaknesses inherent to using each approach by itself. Further, the mixed methods research provided several means (methods, data sources and researchers) to examine the same phenomenon. Triangulation [121][123] allows one to identify aspects of a phenomenon more accurately by approaching it from different vantage points using different methods and techniques. Successful triangulation requires careful analysis of the type of information provided by each method, including its strengths and weaknesses. Triangulation was adopted in this research because it facilitated the validation of data through cross verification from different sources. Furthermore, biasness in terms of sampling and measurement were minimised because data from different sources and instruments were combined to give sufficient information. In the study, data from designed prototype and questionnaires was combined to give an overall view of the need of a remote monitoring system. Hence conclusive results were generated from the use of the triangulation method.

A descriptive research design was utilized. In this, research design allowed the description of the phenomenon.

3.2 Study setting

The study was conducted in Lusaka at the University Teaching Hospital, Mother and Child Hospital (formerly maternity ward) in Lusaka. Purposively sampling was used to identify the participants who include; Doctors, nurses, data clerks and patients. Women particular expectant mothers were targeted in the baseline study.

3.2.1 Sampling

The study population was purposively sampled. The purposive sampling technique that was used was extreme case sampling [123]. Extreme (or deviant) case sampling is a type of purposive sampling that is used to focus on cases that are special or unusual, typically in the sense that the cases highlight notable outcomes, failures or successes [123][124].

These extreme (or deviant) cases are useful because they often provide significant insight into a particular phenomenon, which can act as lessons (or cases of best practice) that guide future research and practice [125].In some cases, extreme (or deviant) case sampling is thought to reflect the purest form of insight into the phenomenon being studied [124] [125]. The sample size selected was 30 participants, which included doctors, nurses, patients and administration staff.

3.2.2 Inclusion criterion

The study was made up of four target groups of the health system which included medical doctors, nurses, administrators (registry clerks) and patients. Particular attention was given to expectant mothers because of their health condition delicacy. The target area was at mother and child hospital at the University Teaching Hospital (UTH).

Medical doctors and nurses were key to this study because they provided hands-on care to patients i.e. recording patient's vitals at every hospital visit (temperature, weight and blood pressure), observing and monitoring patients, managing intravenous lines and collaborating with doctors. And doctors on the other hand were responsible for the supervision of implementation of care and treatment plans and also coordinated with nurses in providing the best health care to expectant mothers.

The registry clerks were included in this study because they were the first contact personnel a patient had when visiting the hospital and they ensured that the patient's medical file and records are rightly placed in the records room and ensured easy retrieval of the medical files.

Expectant women (outpatients) were particularly included in this research because of the sensitive and delicateness of their condition which needed regular monitoring, prompt and fast attention by the medical personnel.

3.2.3 Data collection

Data collection was carried out over a period of ten weeks starting from march 2016 to second week of May 2016. During data collection, the researcher carried out interviews with pregnant women and ward nurses at the maternity wards. The researcher distributed the self-administered questionnaires to the data clerks and doctors in the first three weeks. Thirty (30) questionnaires were distributed and twenty (20) questionnaires were collected. The researcher gave the respondents sufficient time to answer the questionnaires. The researcher collected the questionnaires in the first month of June. Interviews, surveys and distribution of questionnaires were done simultaneously.

3.2.4 Data processing and Analysis

Microsoft Excel 2016 was used to analyse the data collected from the questionnaires and interviews. Qualitative data were analysed by bringing out emerging themes that were categorised and interpreted. These responses were grouped according to themes of the questions.

Descriptive statistics were applied to the processed data by showing variable frequency distributions from the responses obtained. Statistical functions, data analysis tool Pak and charts were tools that were used in Microsoft excel to generate charts and graphs. Data were presented using graphs, charts, tables and percentages.

3.2.5 Ethical consideration

All the respondents who answered the questionnaires were not required to reveal their identities by writing their names or any information that would give away their identities on the questionnaires. Thus, the respondents were assured of confidentiality and non- persecution arising from their responses.

3.3 Study design

Design science research strategy was incorporated for the design of the monitoring and tracking prototype. Johannsson [125][126] states that the key purpose of design science research is attaining knowledge and understanding of a problem domain by building and application of a designed artefact. Figure 3.1 underneath demonstrates the sequence of steps in design science research methodology as exhibited by Dresch and Antunes [127] .It includes the following stages: identification of the problem through investigation of requirements and development of a conceptual model, design and development of a system prototype, and test and assessment of the outcomes [126][128] . A study by Chiumya [45] also demonstrated the use of Design research in the development of Signal Acquisition system for Body Area Network for Mobile Health. The seven-sequence development process shown in figure 3.1 was used to design the RFID tracking and monitoring system.

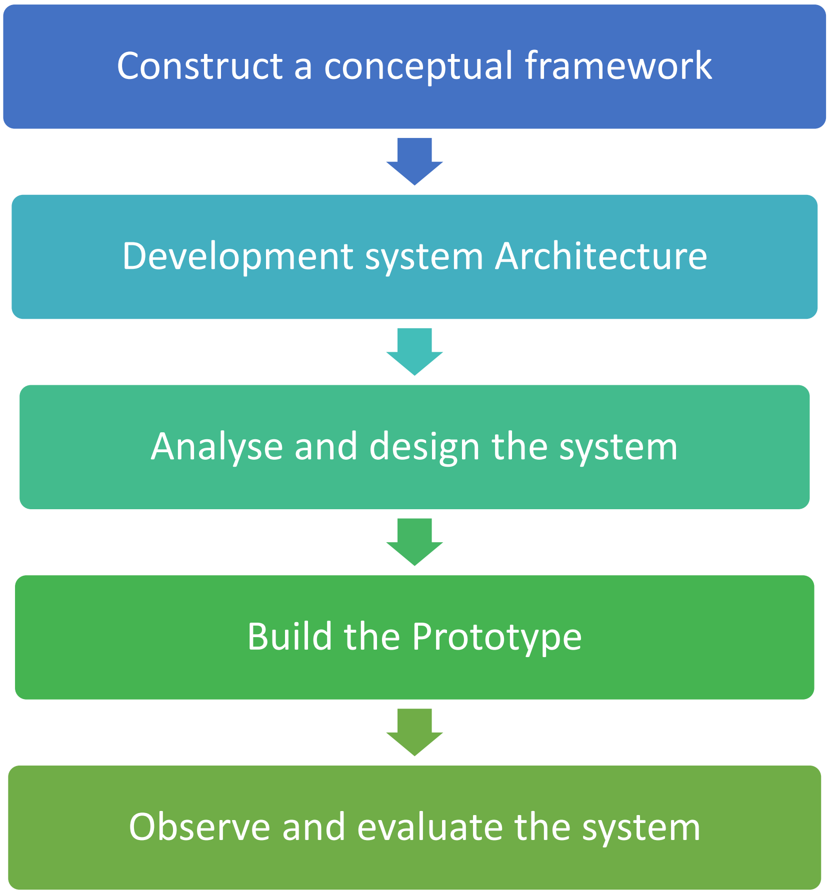

Figure 3.1: Sequence of steps in design science [129]

The creation and evaluation of artefacts thus forms an important part in the DSR process which was described by Hevner et al. [130] and supported by March and Storey [131] as revolving around "build and evaluate". Though Pandely [132] did not capture the awareness of a problem as a key segment in determination of requirements in a conceptual frame, their model of design science is widely used mostly because it eliminates the component of baseline study which can be tedious at times. A different approach by Vaishnavi and Kuechler [128] demonstrated the necessity of including the awareness of a problem as a key segment in the determination of requirement. It is usually up to the researcher to determine the ideal approach for their project because different researchers have adopted different DSR process based on their type of project. For this project awareness of the problem was included to enable the researcher understand the core problems being faced in the health sector when it comes to record management and monitoring of patients. Hence, the framework consists of the following sequence of steps: awareness of a problem; suggestion; development of an artefact; evaluation and conclusion.

3.4 Conceptual Framework

A conceptual framework which is the researcher's understanding of how the particular variables in the study connect with each other was developed as shown in figure 3.2. The design of the tracking and monitoring artefact was dependent on determining the requirements for development of the system. Requirements were generated based on the gaps identified in the reviewed literature. The parameters for this study included determining user interface devices; IoT communication; sensory devices; communication modules; and determining the server.

The conceptual framework identified the variables required in the research investigation [129]. It is the researcher's "map" in pursuing the investigation [130]. The conceptual framework sets the stage for the presentation of the particular research question that drives the investigation being reported based on the problem statement [131] [132].

The technique used to develop the requirements included a review of existing literature. After determination of the required user interface device, IoT communication, sensory devices, communication modules and server, design and development of the RFID tracking and monitoring system was embarked on.

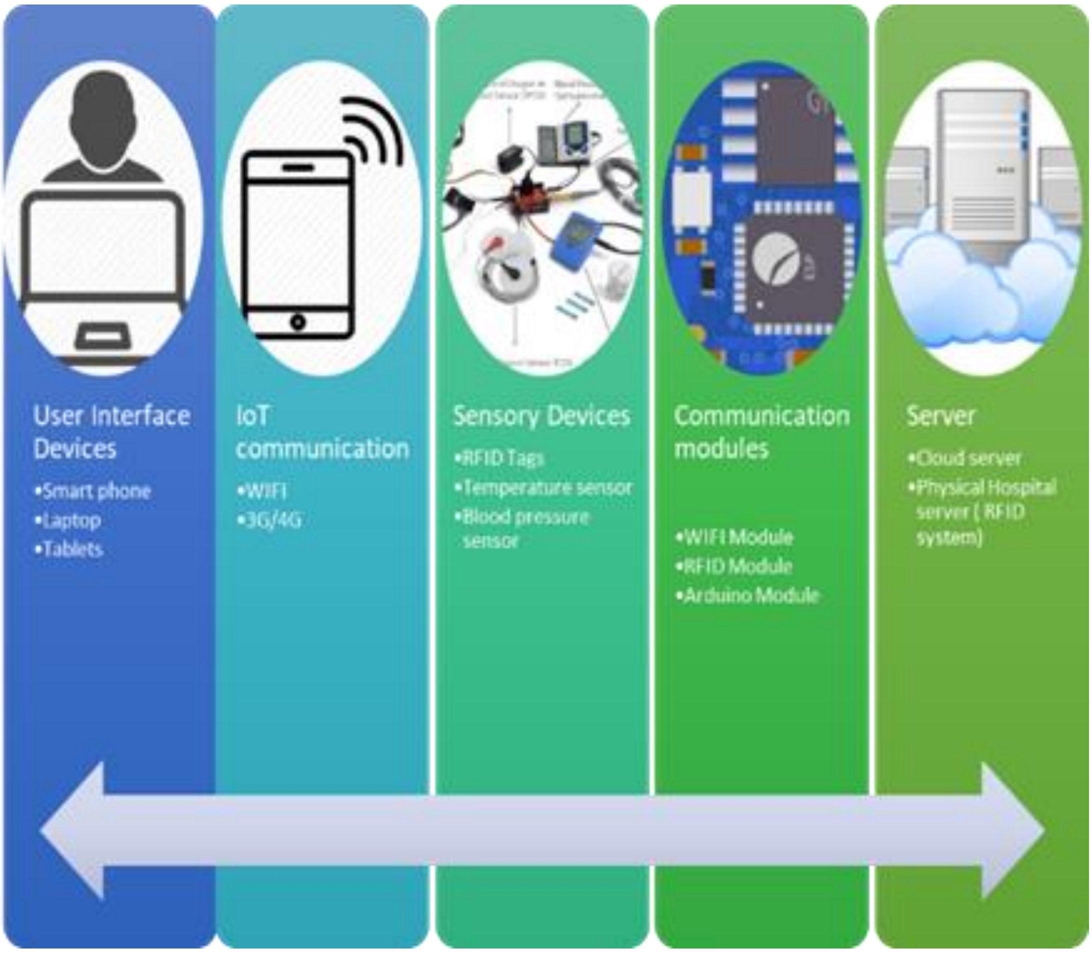

Figure 3.2: Conceptual Framework for the Tracking and Monitoring System

3.5 System Architecture

The main objective of the designed system was to remotely monitor patients online as well as provide a safer and faster way of retrieving patients' records by the medical personnel (doctors and nurses).

Development of the artefact was done in two parts.

I. The monitoring sections were designed to remotely measure and record a patient's physiological parameters (temperature and blood pressure). The system allows patients to have their physiological parameters (Temperature and Blood pressure) measured remotely and recorded.

II. The tracking section was designed to replace the physical paper work of monitoring the patient's progress by introducing a digital format that allows doctors and care givers to track the patient's progress online and anywhere. The system permits the patients to have a digital medical file and eliminates any form of paper. Using this system, the medical personnel can track the patient's overall medical progress by tracking and monitoring them every time they visit the health centre.

3.5.1 System Architecture of the RFID component

The diagram below shows the block diagram of for the RFID section.

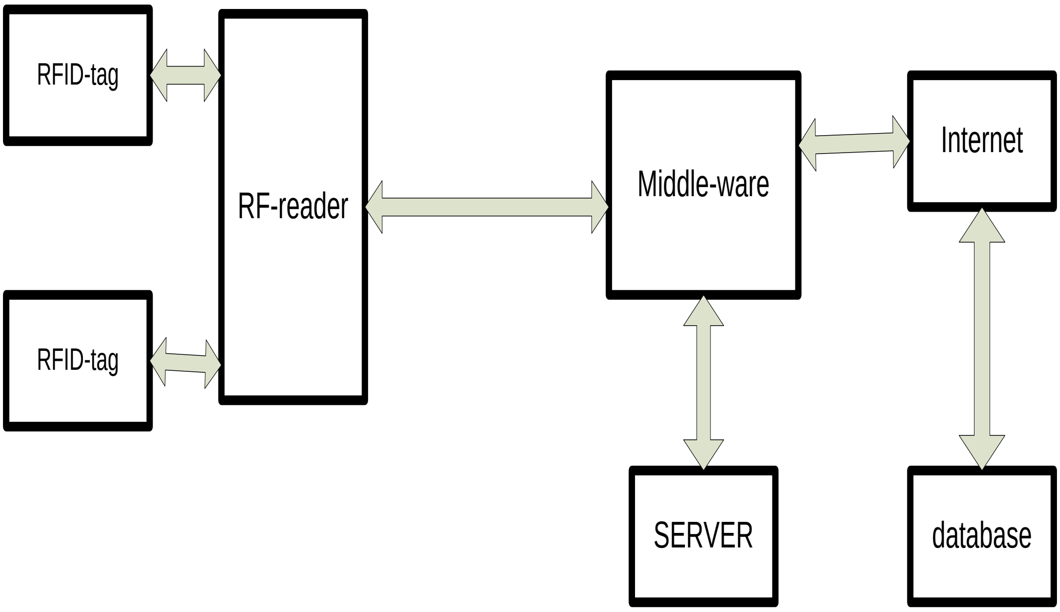

Figure 3.3: Block diagram for the development of the RFID section

The RFID tracking system consisted of the RFID module board, micro controller and tags as shown in the figure 3.3 above. The tag information was specific to a patient and included the patient's physical address, age and gender. Tag was coupled with the passive reader, which was connected to the server and hospitals database. The RFID component was able to capture tag information and using the Gecko platform temperature and blood pressure were able to be monitored and tracked online as illustrated in figure 3.4.

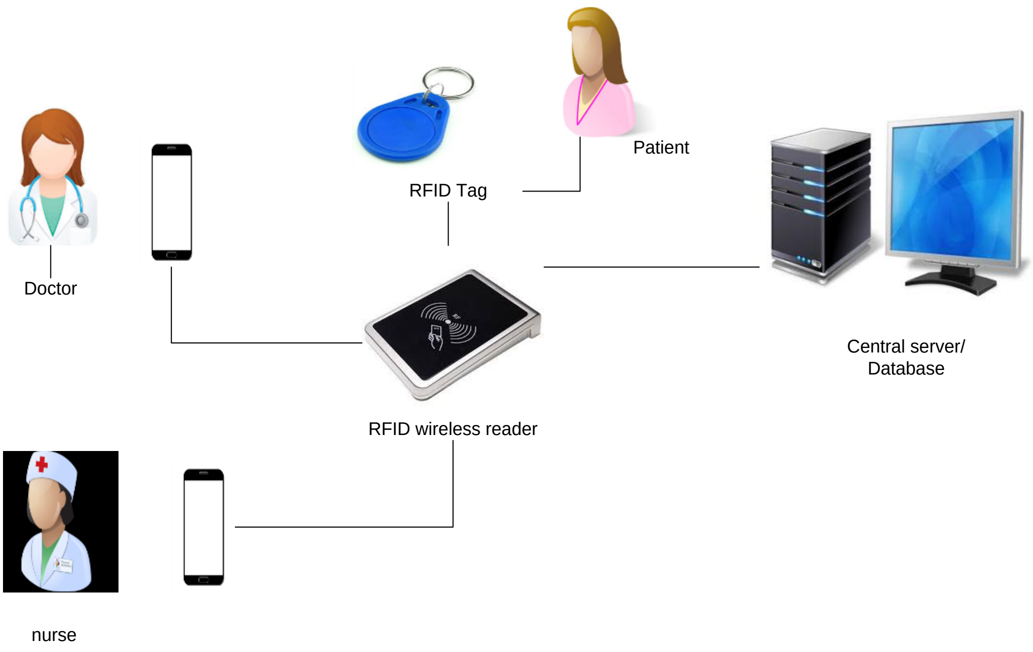

Figure 3.4: Systematic diagram for RFID tracking components

3.5.2 System Architecture of the IoT Tracking and Monitoring Component

The monitoring system consisted of the Atmega controller, temperature, WI-FI module and blood pressure sensor. The schematic diagram for IoT is as shown in figure 3.5.

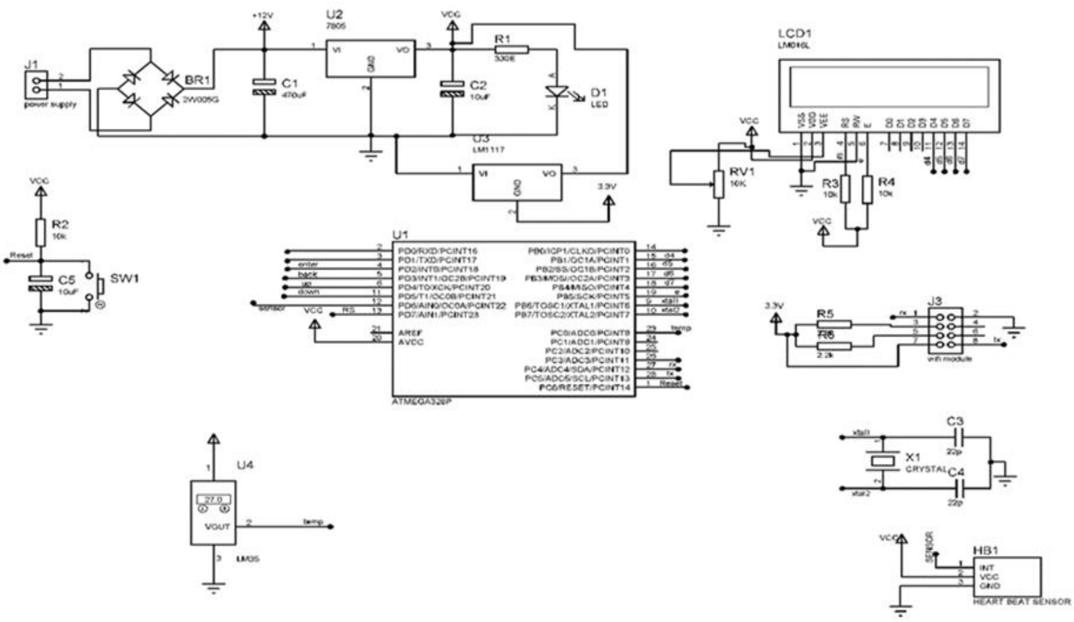

Figure 3.5: Schematic diagram for the IoT monitoring system

The system comprised of capacitors, resistors, LEDs, resistors, diodes, temperature sensor and controllers. The block diagram below illustrates the arrangement of the components.

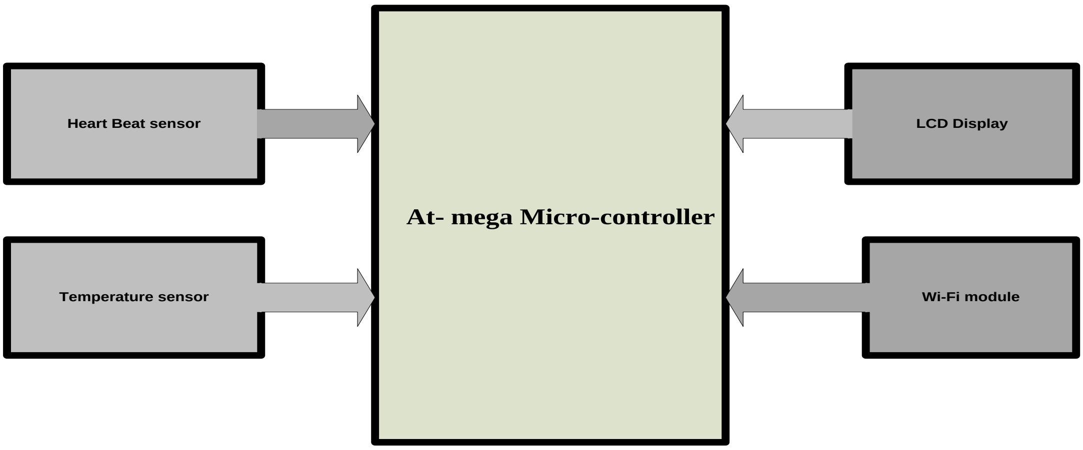

Figure 3.6: Block diagram for the Monitoring Section with IOT platform

The final step in the architecture design of the RFID- IoT tracking system included combining the two parts or sections to make the RFID-IoT tracking and monitoring system as shown in figure 3.7. In this study, cloud database was used as an alternative database because its capacity was limitless and easily accessible.

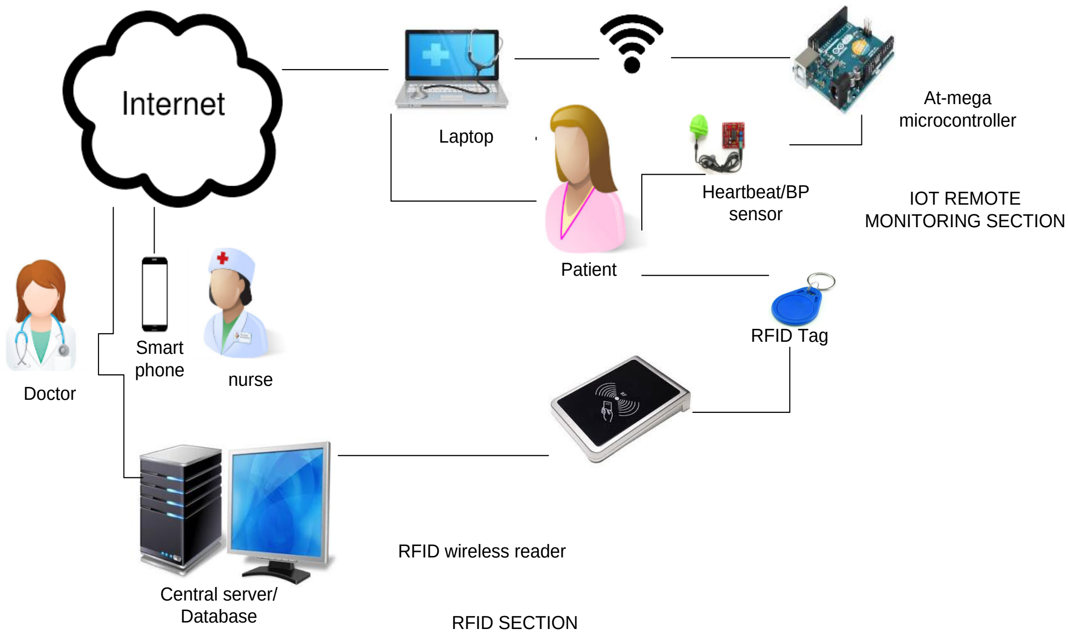

Figure 3.7: System Architecture for IoT RFID tracking and monitoring system

3.5.3 Middleware Architecture

The middleware module for the RFID tracking component comprised of an application interface, event control, data processing and device management.

Inherently, each RFID tag was given a unique ID, which enabled the reader to distinguish it amongst other tags. Although this uniqueness was vital for the RFID application, it didn't not give much insight on the local properties of the tag, most importantly its locale. The tag's number was linked to the patient's particulars which included registration number, date of birth and residential address. The reader was placed at the registry clerk's desk but was able to read up to 5m away.

Arduino environment version 1.8.8 an open source software was downloaded to develop a source code for Arduino Uno controller. Arduino 1.8.8 was used as the middleware for the RFID component.

1.5.4 System Components

Table 3.1 and Table 3.2 shows the materials that were used to design IoT- RFID tracking and monitoring prototype in order to address the fourth research objective which is; To design a prototype that uses RFID and IoT technologies for patient monitoring and tracking. All the materials were purchased online and assembled by the researcher.

Table 3.1: Shows the materials used to build the monitoring component

Item	Description
1	10cm *10cm printed board
2	Heart beat sensor
3	Temperature sensor
4	Atmega 328 microcontroller
5	WiFi modem
6	LCD
7	Diodes
8	Capacitor
7	Transformer

System components for the design of the hardware architecture for the RFID tracking section are listed below in table 3.2.

Table 3.2: Materials used to build the RFID tracking component

Item	Description
1	2* RFID tags
2	10cm *10cm printed board
3	RFID reader
4	LCD
5	Laptop

3.5.5 Description of System Components

The section describes the hardware components that were used to design the hardware architecture of the IoT-RFID tracking and monitoring prototype.

3.5.5.1 Atmega Micro-controller

The Atmel ATmega328P used in this study was a 32K 8-bit microcontroller based totally on the AVR architecture (figure 3.8). Many instructions are carried out in a single clock cycle supplying a throughput of nearly 20 MIPS at 20MHz.The ATMEGA328-PU used in the study comes in a PDIP 28 pin package and is suitable for use on the 28 pin AVR development Board [110]

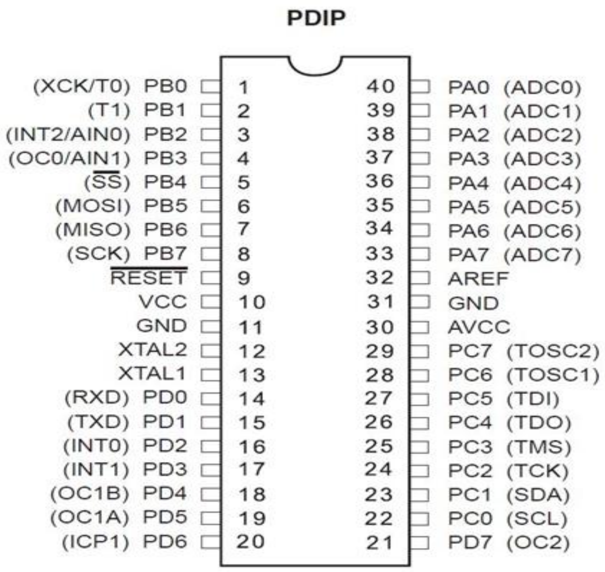

Figure 3.8: Atmega Microcontroller [110]

3.5.5.2 Heart Beat Sensor

Heart beat sensor used in this study was made to give digital output of heart beat when a finger is placed on it. The heart rate was measured just at the fingertip. It worked by allowing the LED flash to be in unison with each heartbeat. For this study the digital output was coupled to the Atmega microcontroller to measure the beat per minute rate (bpm). The sensor worked by causing a variation in the blood capacity, which is then detected, by our heartbeat sensor [133]. Light modulation principle by blood flow through the finger at each pulse was used. The sensor used infrared light source on one side of finger and a photo detector on another side to measure the variation in the blood flowing [134]. This variation was changed to electrical pulse, intensified and generated through an amplifier which outputs +5V logic level signal [135].

Figure 3.9: Heartbeat sensor [134]

3.5.5.3 Temperature sensor

The LM35 series sensor (figure 3.10) was used in the project to measure temperature. The LM35 series have an output voltage linearly proportional to the centigrade temperature and fall under a family of integrated circuit temperature devices [135]. The LM35 device has an advantage over linear temperature sensors as the device does not require external calibration or trimming to give typical accuracies of ±¼°C at room temperature and ±¾°Cover a full −55°C to 150°C temperature range [134].The LM35 is a basic device that does not require the user to subtract a big constant voltage from the output to obtain an appropriate centigrade scaling. The LM35 sensor was able to operate over a −55°C to 150°C temperature range. It had a low self-heating of less than 0.1°C in still air and only draw 60 μA from the supply.

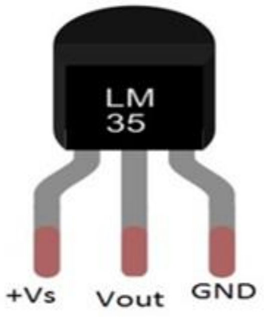

Figure 3.10: LM35 series temperature sensor [136]

3.5.5.4 Arduino

Arduino an open-source prototyping platform based on easy-to-use hardware and software program was used for the development of IOT component [136]. The Arduino software was adopted in this project because it was easy-to-use for novices, yet bendy sufficient for advanced users. Figure 3.11 shows the Arduino board (hardware) that was used in the study.

Figure 3.11: Arduino board [137]

3.5.5.5 RC522 RFID Module 13.56MHz

For RFID communication, the low cost MFRC522 based RFID Reader Module was adopted. MFRC522 is used in a wide range of applications and easy to implement [138].The MFRC522 is an assimilated reader/writer IC for contactless communication at 13.56MHz [139] .Its intrinsic transmitter energies a reader/writer antenna designed to communicate with ISO/IEC 14443 A/MIFARE [143] cards and transponders without extra active circuitry [140]. Figure 3.12 shows an RFID (MFRC522 chip based) module and figure 3.13 illustrates how the RFID module connects with the Arduino board.

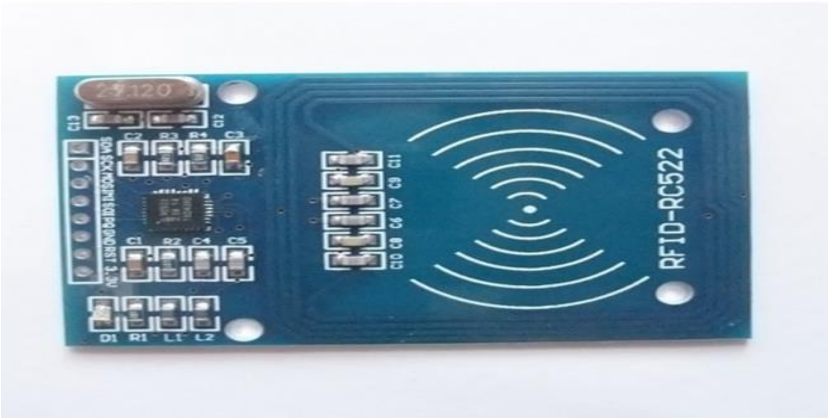

Figure 3.11: MFRC522 chip based board [138]

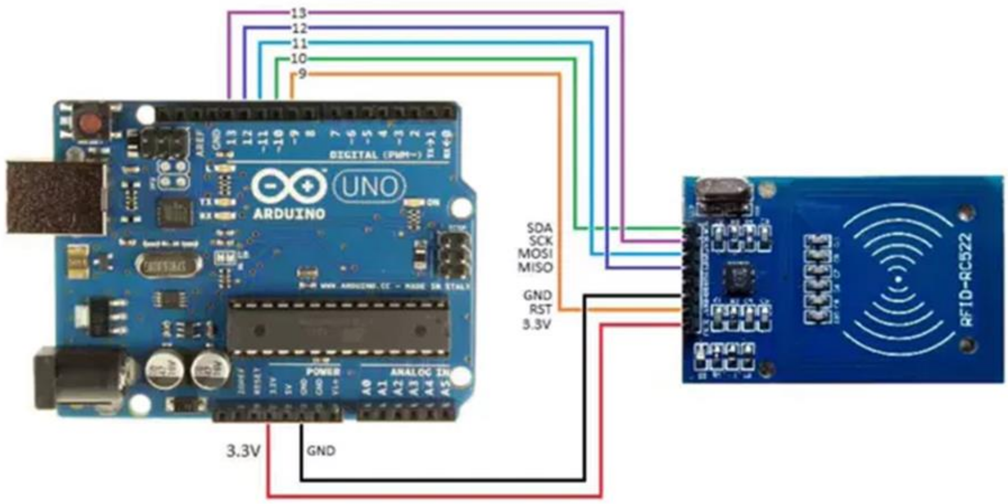

Figure 3.12: UNO Arduino and RFID board [138]

3. 6 System Requirement Specifications

The system requirements specifications phase in this research study used Object-Oriented Analysis. Omarl El Gabry [141] describes OOAD as a structured method for analysing and designing a system by applying the object-orientated concepts and developing a set of graphical system models during the development life cycle of the software .The OOAD process is a chronological set of steps that starts with acquiring a clear understanding of the needs and requirements of the client and ends with a final blueprint or design of the application that matches, as thoroughly as possible, the requirements of the client [141].

System requirements entail what the system is able to do, through provision of services and also constraints faced by its operation. In fact, requirements involve the needs for the user of the system intended to serve a particular purpose. Software system requirements are demarcated into two categories called functional and non-functional requirements. Functional requirements entail statements of services provided by the system coupled with how the system should react to certain inputs and how the system should behave in particular situations [142]. Table 2 and Table 3 details the functional requirements and non-functional requirements used in the study.

The system requirements specifications for the patient monitoring and tracking system for the hospital illustrated an overview of the functionalities and specifications of the model.

3.6.1.1 Functional Requirements

Table 3.3 details the functional requirements required for all the modules for the mobile payment system.

Table 3.3: Functional requirements

FR 1	The system administrator shall create the new system user
FR 2	The system administrator shall be the super user and will have all the privileges or the entire system
FR 3	The system administrator blocks and updates agents of the system
FR 4	System will have different types of users and every user will have access constraints
FR 5	Doctors will have access to the monitoring application with restriction to database access
FR 6	Users will relevant rights shall have the ability to change their password anytime
FR 7	Users will be able to login in anytime and anywhere to view their medical history
FR 8	Administrator will have full access to the system to resolve any issues
FR 9	The system shall return a unique pass code to the user which they will need in order to login

3.6.1.2 Non-functional Requirements

Table 3.4 details the non- functional requirements for both the IoT monitoring and RFID tracking system. In this study nine non- functional requirements were used

Table 1.4: Non-functional requirements

NFR1	The system shall be easily maintainable in case of requiring forwarding criteria changes without stopping the whole system
NFR 2	The system failure shall not affect data integrity
NFR 3	All software application modules shall be debugged
NFR 4	Database backup and recovery plan should be proper in order to avoid any unexpected downtown of application
NFR 4	The system shall be faster when multi-core central processing is used
NFR 5	System should not be easily breakable
NFR 6	All local crash shall not disseminate to other parts of the system, as such crashes shall be isolated
NFR 7	The software system and application code shall be well documented, and this will be written in a familiar language
NFR 8	The system shall provide the documentation that shall have all functionality and any user maintenance for the system administrators

3.6.2 System Modeling and Design

3.6.2.1 Introduction of Unified Modeling Language (UML) Diagrams

In this section, unified modeling languages (UML) was used to: visualize, specify, construct and document the dynamic aspect of the system [143]. As such, the behavioral diagrams are categorized as follows: Use case diagrams, interaction diagrams, state-chart diagrams and activity diagrams

3.6.2.2 Flowcharts

A flowchart is a diagram that depicts a process, system or computer algorithm. They are widely used in multiple fields to document, study and plan, improve and communicate often complex processes in clear easy-to-understand diagrams [143].

3.6.2.3 RFID Section

Figure 3.13 below shows the flowchart diagram depicting the patient registration process on the IoT platform and figure 3.14 shows the flowchart diagram depicting the process of issuing of the RFID tag to a patient.

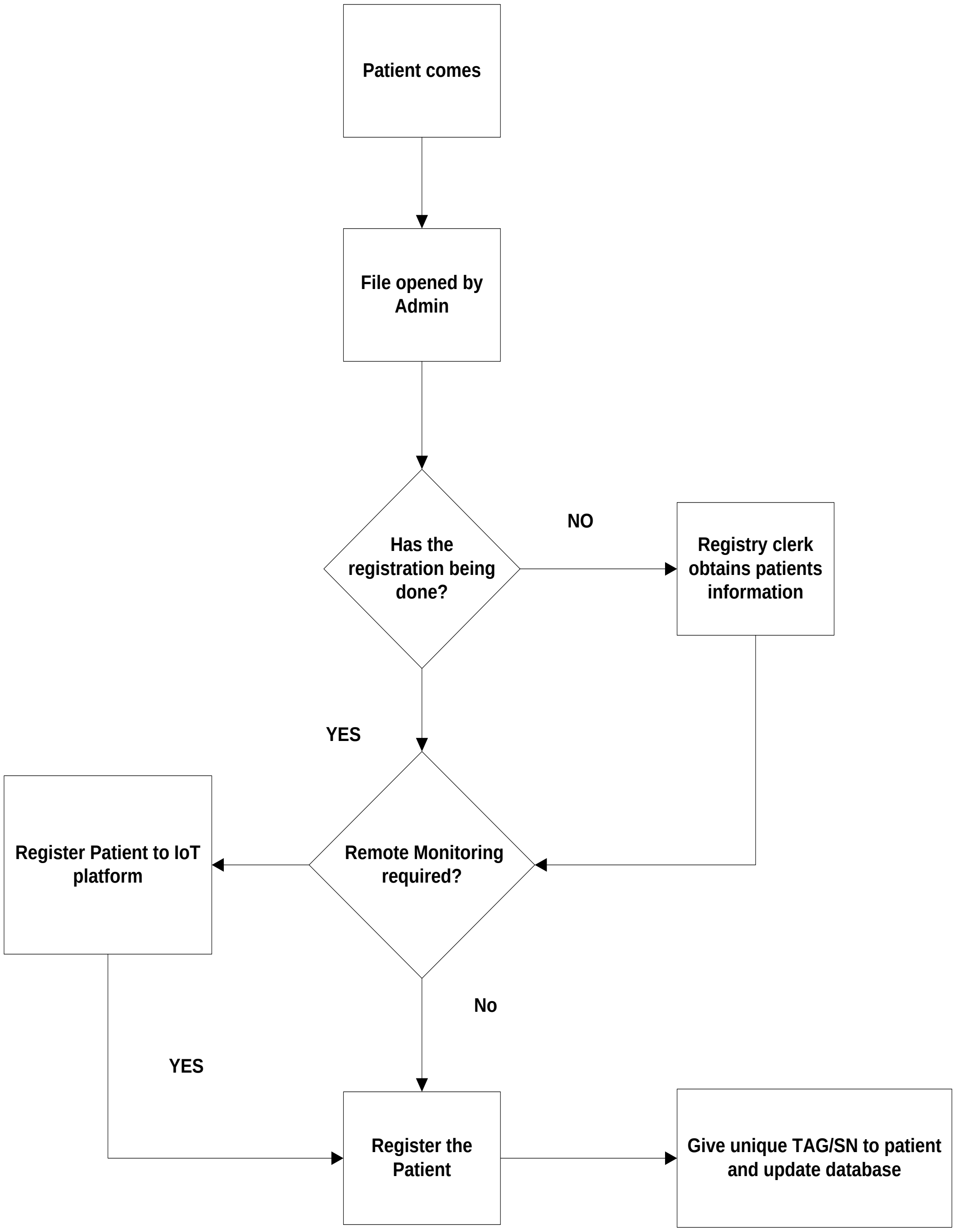

Figure 3.13: Flow Chart for Registration of patients on IoT Platform

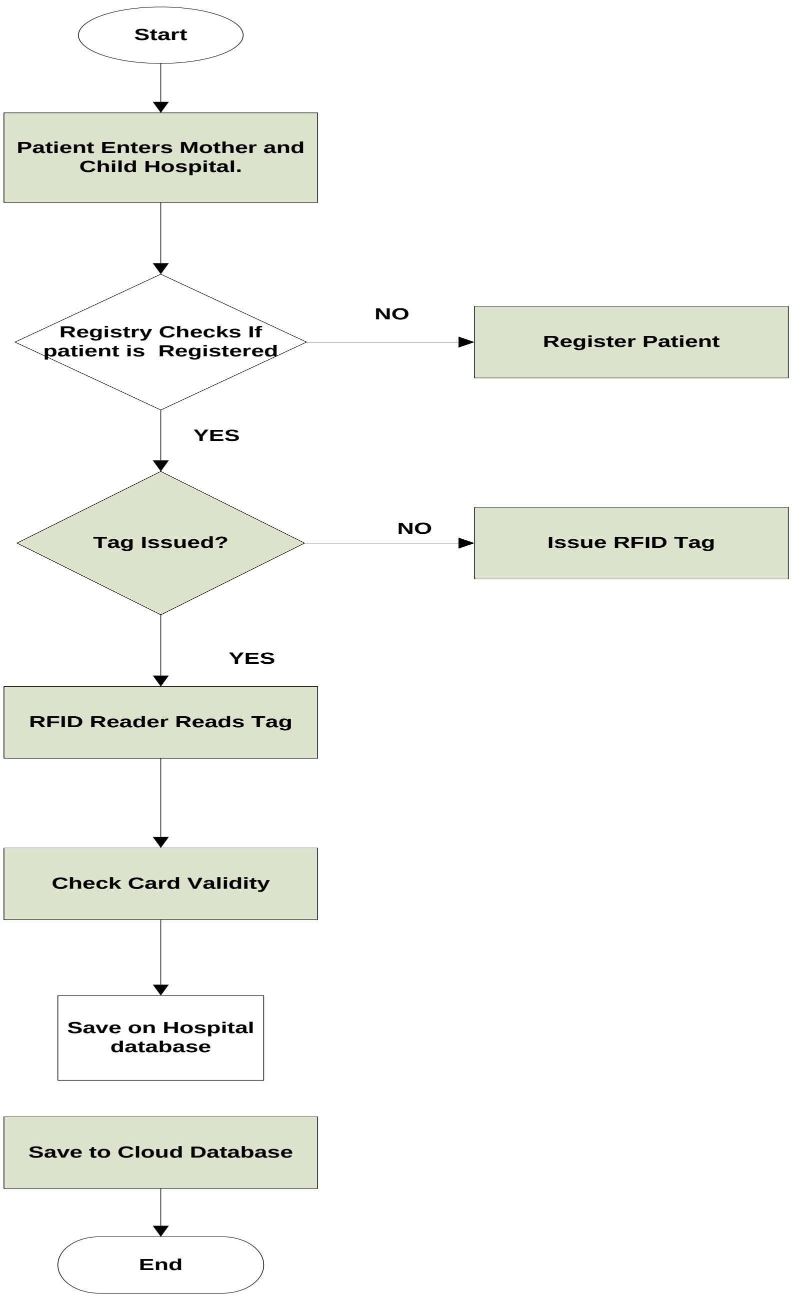

Figure 3.14: Flowchart for the issuing of the RFID card

3.6.2. IoT Section

The diagram below shows the flowchart diagram for read body temperature using the IoT gecko platform. The IoT monitoring was developed to read and send alert signals in case of any abnormal conditions. Using the Gecko platform once connected to the physical setup vitals were read online and stored on the hospital or cloud server.

3.6.2.5 Use case diagrams

The use case diagram in figure 3.15 illustrated the sequence of actions performed by the system in order to yield visible results. The use case describes how outside things interact with the system itself such that it may be applied to the whole system as well as part of the system [143]. An actor represents the roles that users of the cases play and it can denote a person (e.g. doctor, patient), a device (e.g. smart phone) or rather system (e.g. hospital).

Table 3.5: Description of Actors for the Tracking and Monitoring system

Actor	Description
Patient	The patient must register at the hospital their particulars and if the intend to be monitored remotely.
Doctor	The doctor will have real time access to the patient information and will be able to put inputs after the patient's visit and also if required indicate medication given.
Registry clerk	The clerk will be responsible for the registration of the patient and also giving them their tag serial number.
Administrator	The administrator is the super user of the system and shall have all the privileges for the system
Middleware	It is responsible for providing various computation for the system

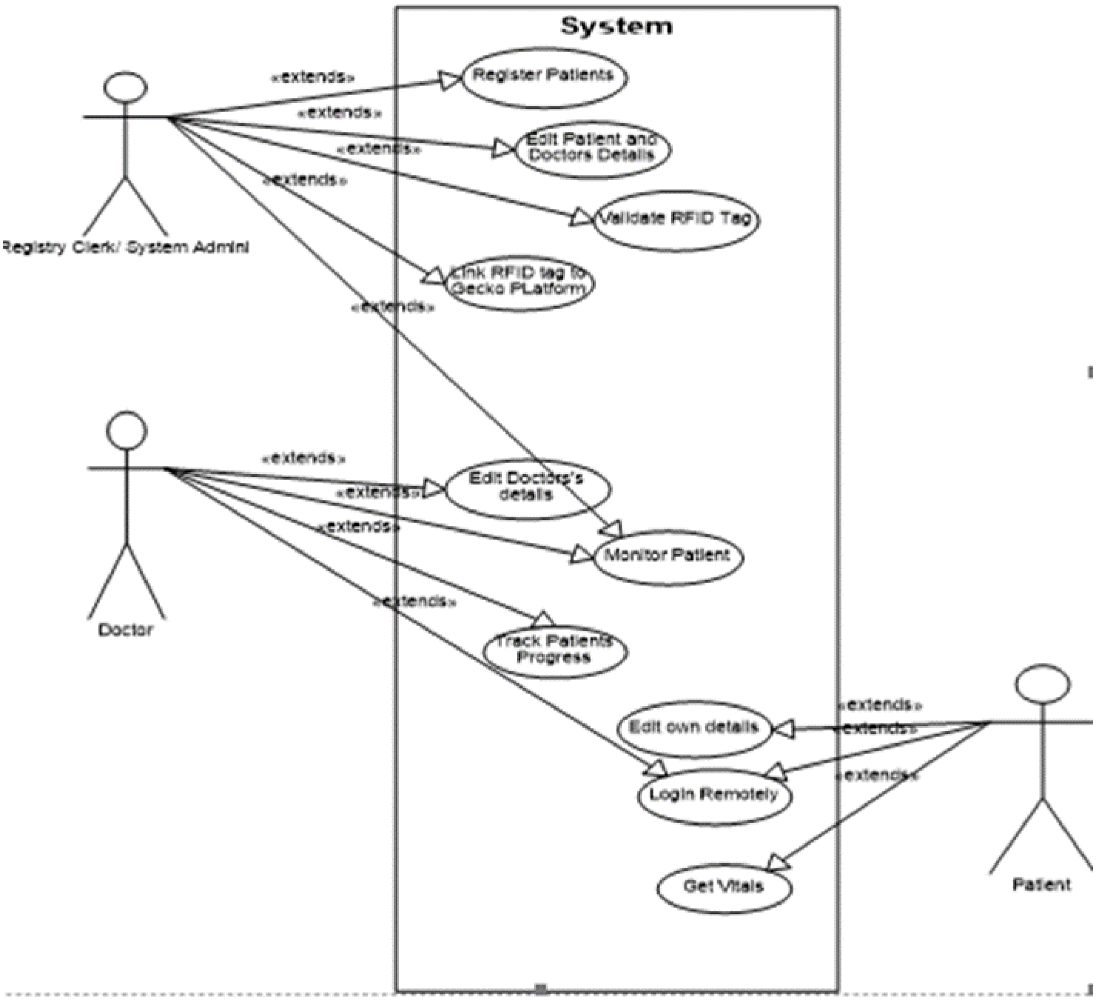

Figure 3.15: Use case diagram depicting the role of each actor in the system

3.6.3 Interaction models – sequence diagrams

3.6.3.1 Sequence diagrams

Sequence diagrams are not only used to model the interactions between the actors and the objects in a system but also show interactions between the objects themselves [143].As such, the sequence diagram is the interaction diagram which shows the dynamic side of the system As the matter of fact, the communication and sequence diagrams have three symbols which are used in the communication diagram and these are: Boundary class stereotype, control class and entity class stereotype. In this section, sequence diagrams for each use case in Table 3.5 are described.

Figure 3.16 shows how the login user interface (UI) is launched by initiating the control object. As such, the control object prompts the user for login credentials in order for the user to be authenticated upon supplying correct login credentials as shown in figure 3.17. Subsequently, a request is sent to the user entity object to get the user account from the database. It is at this moment that the control object will finally ask the boundary object to display the welcome screen to the user at the application interface of their mobile device.

Figure 3.18 shows the administrator's interface (UI) is launched by instantiating the control object. The control object prompts the admin or doctor for login credentials in order for the admin to be authenticated upon supplying correct login credentials. Once authenticated the admin will have access to the database as depicted in figure 3.19 and 3.20.

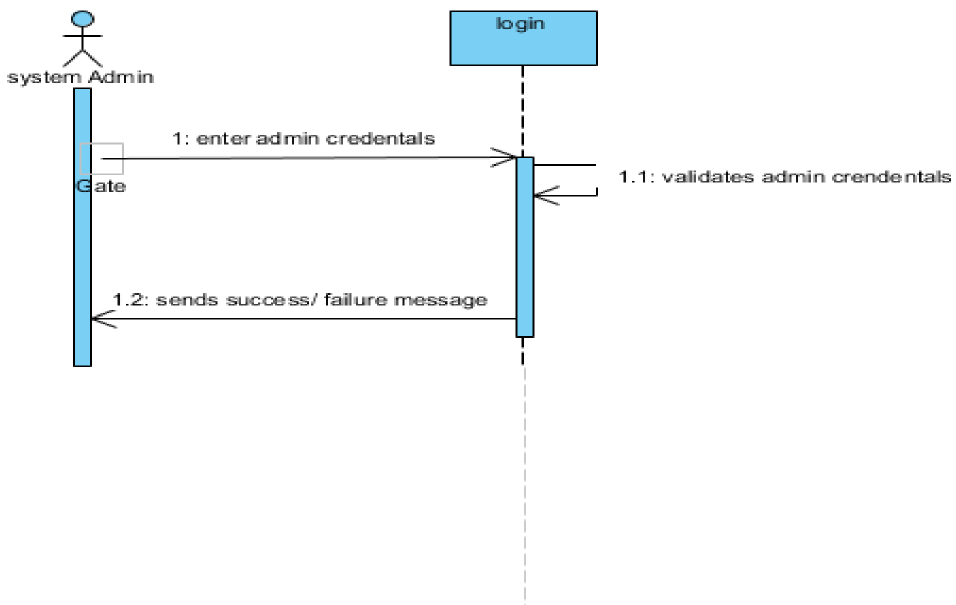

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Figure 3.16: Sequence diagram for the login in of the system Administrator

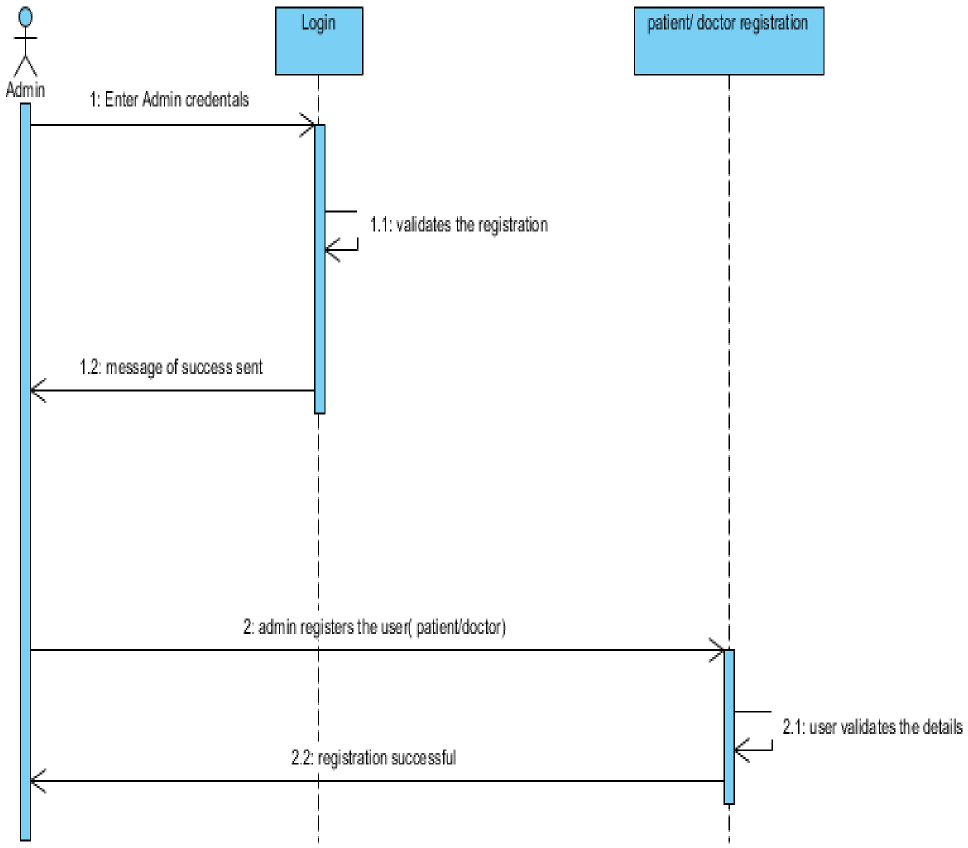

Figure 3.17: Sequence diagram the registration of users in the system

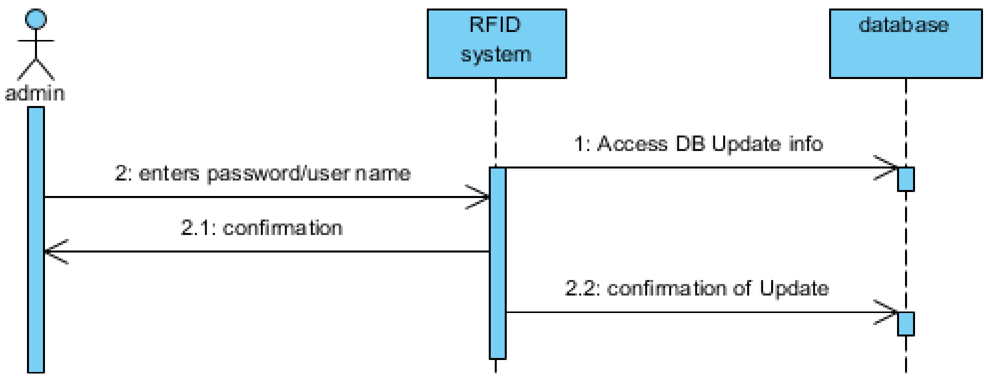

Figure 3.18: Sequence diagram for the administrator interacting with the system

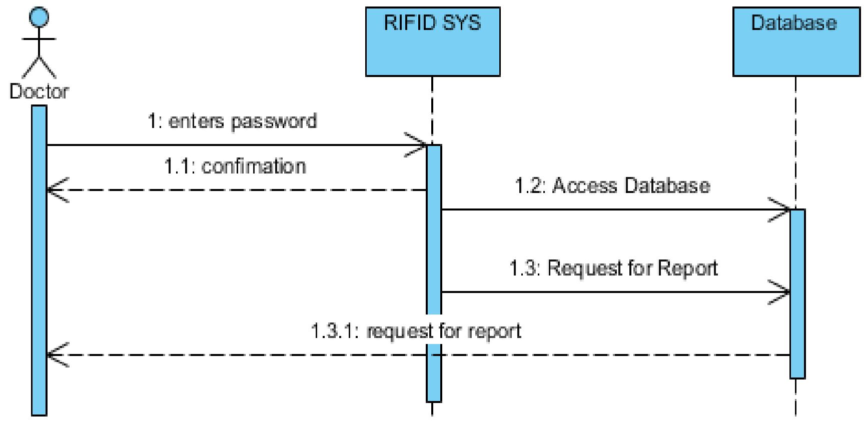

Figure 3.19: Sequence diagram for the restricted user (doctor) interacting with the system

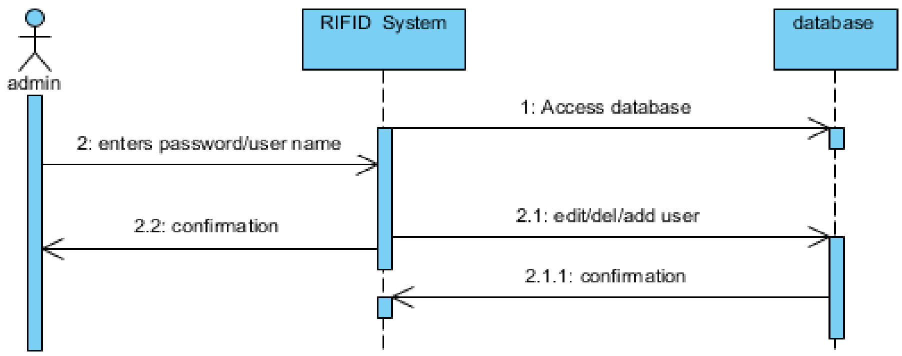

Figure 3.20: Sequence diagram for the admin interacting with the system

3.6.3.2 Structural models – class diagrams

Structural models involve class diagrams that show the classes in a system and the association between these classes [141]. As such, an object class can be a general definition of one kind of system object, whereas an association is a link between classes which shows relationship between these classes [141]. As the matter of fact, objects represent something in the real world, such a person and a transaction just to mention a few. Figure 3.21 shows the classes and associations used in the development of monitoring system. The administrative clerk is associated with the patient and the patient is associated with the doctor.

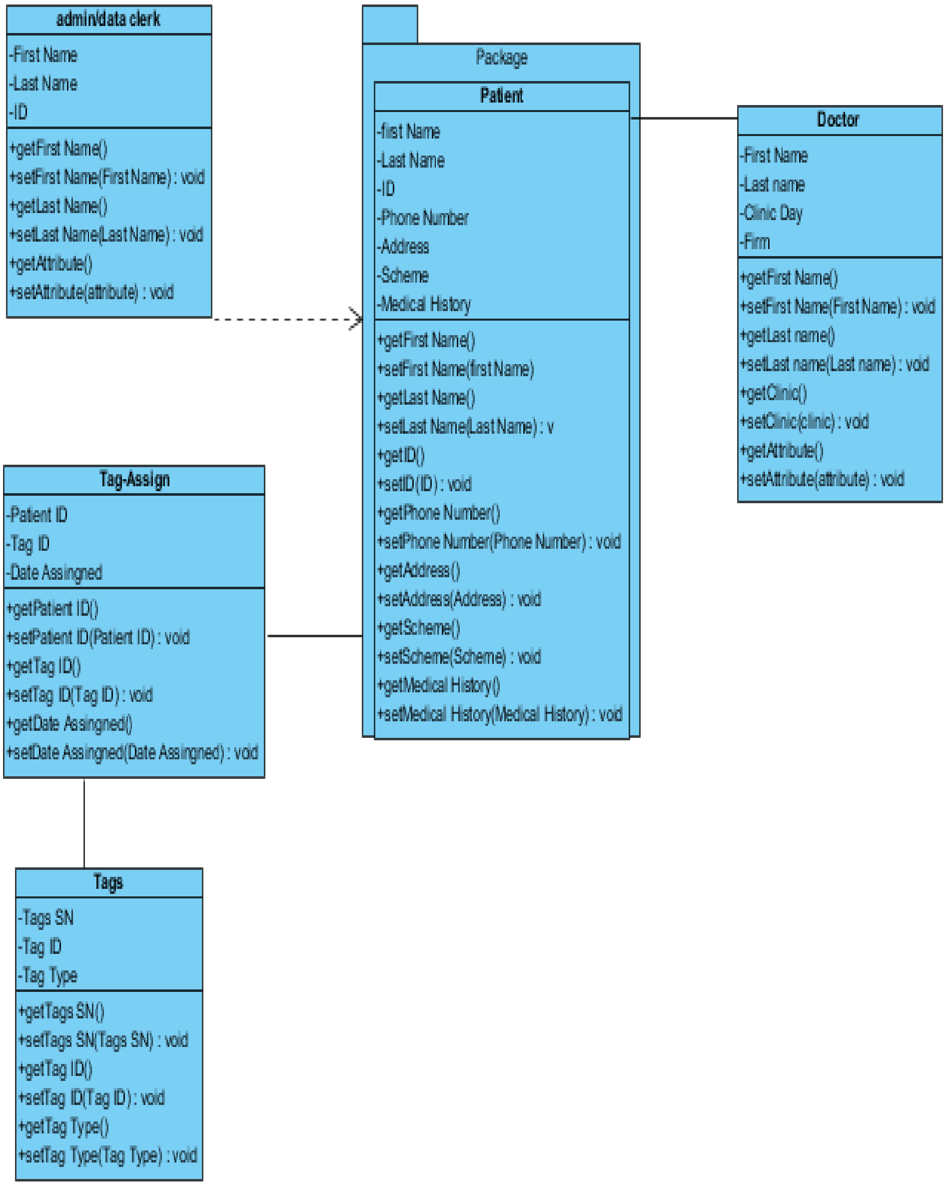

Figure 3.21: Class diagram for the systems database

3.7 Applications Development

The various applications and software were used in the application development of the RFID- IoT tracking and monitoring systems. These included; JavaScript; Arduino IDE; PHP; Apache Webserver and MySQL.

3.7.1 Software development

The application development for the artefact was done in two phases. The first phase was the development for the RFID platform and the second phase was for the development of the IoT monitoring component platform. Software design of the RFID module primarily consisted of the patient data scheme. The tag information once collected by RFID communication was processed in the information system application.

For the IoT monitoring section an already existing application called Gecko platform [144] was used for the interfacing of the module, the sensors and on-line monitoring. The proposed monitoring system was adopted because it was easy to use and it did not require any expertise in programming. And most importantly was a free platform for developers in IoT projects.

3.7.2 Development Tools and platform

3.7.2.1 MySQL

This is an open source Relational SQL database management system [143]. MySQL is small and compact database server hence ideal for the project. It complies on a number of platforms and has multithreading abilities. A database for capturing the patient's information was created using MySQL.

3.7.2.2 PHP

PHP is a server-side scripting language that is embedded in HTML [145]. It is used for managing dynamic content, databases, session tracking, even building the whole e-commerce sites. PHP Syntax C-Like fetching of value from database is done by using this script [146]. The PHP was used to create a dynamic content that was able to interact with system database.

3.7.2.3 Apache server

Apache is the most commonly used web server software. It was developed and still maintained by Apache Software Foundation [144]. It is open source software available for free. Apache-tomcat 8.5.23[146] was used for web server services. A web page was created to allow doctors to monitor patients remotely and also view their medical records.

3.7.2.4 Arduino IDE

The Arduino IDE (integrated development environment) was used for loading the software to the Arduino Uno microcontroller [140]. The Arduino IDE is open source software and was downloaded from the Arduino website [140]. The Arduino Programmer uses a variation of the C and C++ programming Languages and is based on the processing IDE.

The use of Arduino IDE has increased over the years and it is the brain of thousands of projects, from IoT basic projects to complex scientific projects. A large community of developers, artists, programmers, and professionals - has gathered around this open-source platform and their contributions have added up to an incredible amount of easily reached knowledge that is extremely helpful to beginners and experts [146].

3.7.2.5 IOT Gecko Platform

IOTGecko cloud platform was used to create an interactive platform between the sensors and the users. It’s a free platform for developers with APL support over Arduino microcontrollers [145]. The IOTGecko platform provides the tools and support to design IOT based system with much easy. Hence, it reduces the time for programming of the devices.

3.8 Implementation of the IoT Monitoring and Tracking Model

The hardware and software were implemented successfully and the artefact requirements were achieved. The monitoring and tracking devices were separately assembled. The RFID tracking system consisted of the RFID module board, micro controller and tags. The monitoring system consisted of the Arduino board, temperature and blood pressure sensor. Trials on the artefact were conducted and the main objective was achieved.

3.8.1 Experimental validation

A controlled simulation experiment was used for experimental validation. The artefact was set up as shown in the figures 3.22 and 3.23 below. Three Patients were randomly sampled and tested using the artefact. The results obtained were compared to the clinical values obtained using a digital thermometer and a digital blood pressure machine.

For the RFID tracking section, the system was tested for two consecutive weeks and registration time for patients coming for the first time was calculated and compared without the RFID system. Results were collected and analysed.

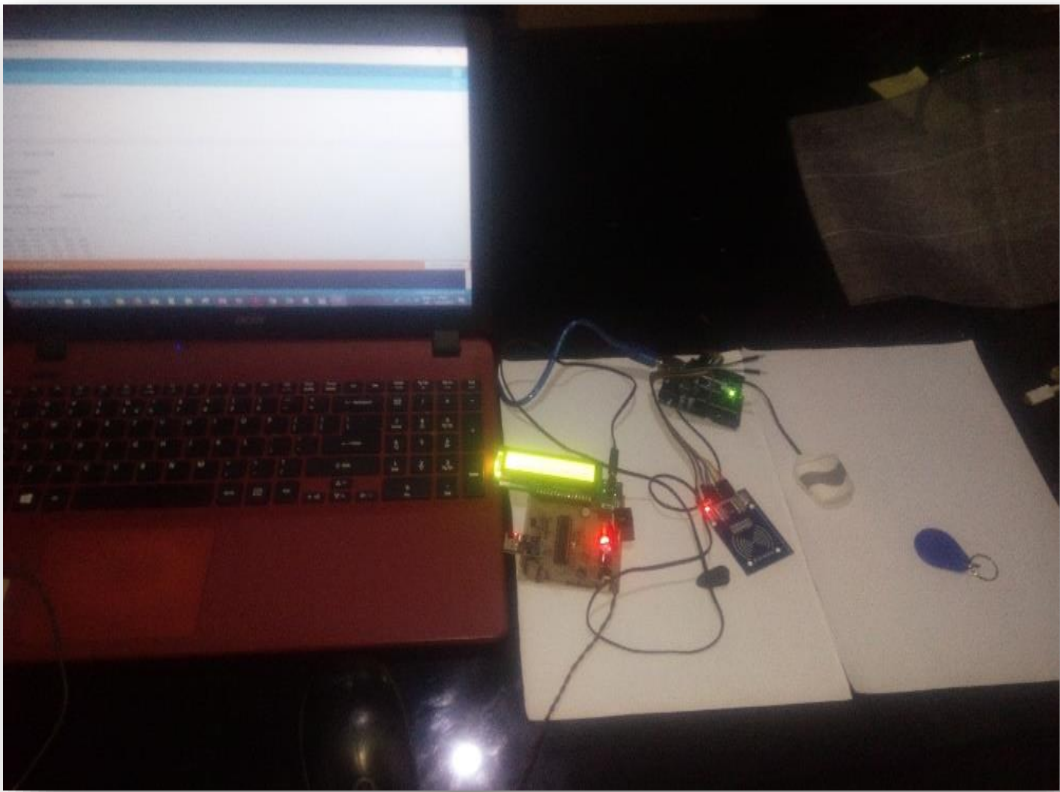

Figure 3.22: Physical setup of the system

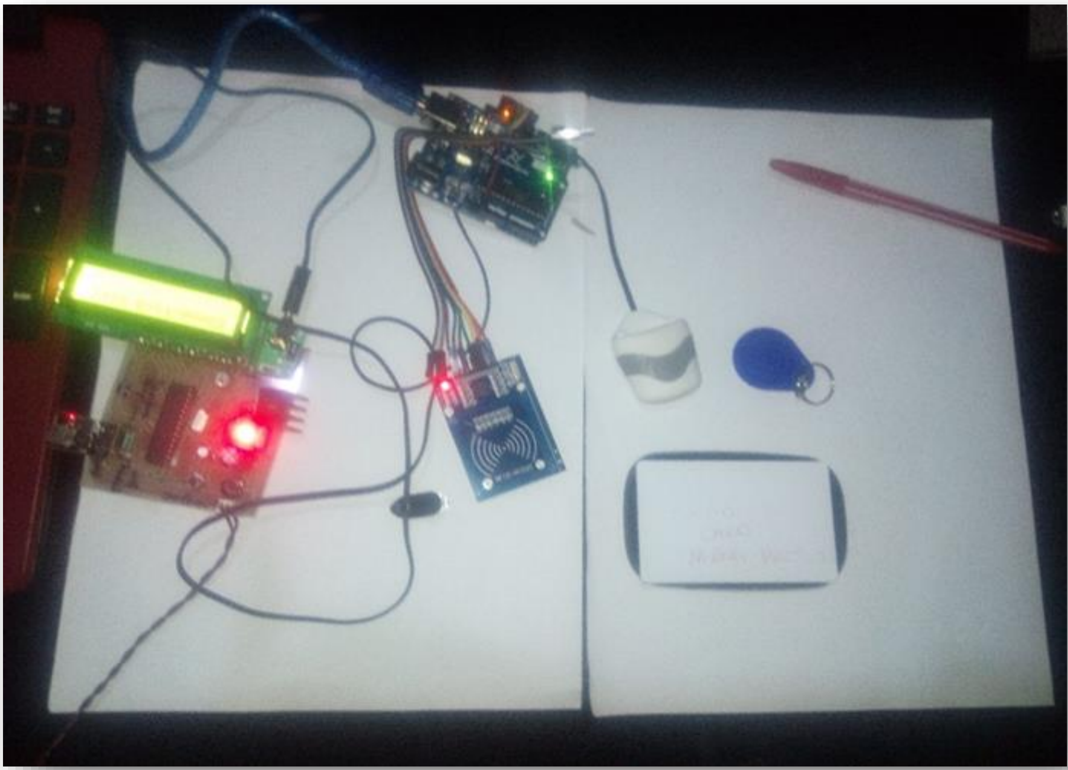

Figure 3.23: Physical Components of the system

3.9 Summary

This chapter focused on the methodology for the design and implementation of an RFID monitoring and tracking system using IoT. Design science research approach was adopted in building and implementation of the system. Conceptual framework and system architecture of the designed model are elaborated in this chapter. Interaction models use case diagrams and flow charts are also presented. System modeling and design steps are described to detail and the physical setup of the system with the entire component are presented. Furthermore, an overview of system tools, software and platforms adopted in the study are presented. The artifact was implemented successfully and experimental validation was conducted.

CHAPTER 4

RESULTS

4.0 Introduction

This chapter presents results that were derived from the baseline study and presents the assembled prototype of the tracking and monitoring systems. The presentation of results is clustered among the target groups of respondents for this study which included: general users, doctors, nurses and registry clerks. Additionally, the chapter also presents results for the implementation of the system prototype by means of screenshots of the system application.

4.1 Baseline Study

In this section the findings of the baseline study presented are as derived from the analysis of the questionnaire and interview guide. Challenges of the manual based patient registration system are presented and the possible solutions to the challenges are presented as well. The findings from both key informants and respondents were grouped according to the themes on the qualitative data. The following are themes:

i. Distribution by respondents by gender
ii. Age of respondents
iii. Level of education
iv. Level of income of respondents
v. Categories and occupation of respondents working at the hospital
vi. Mobile phone users
vii. Challenges of the current system

4.2 General User Respondents

The study sampled 20 respondents from the University Teaching Hospital (UTH), Mother and Child hospital (formerly maternity ward). In this section, research findings for the general users were based on their experience with the manual system currently being used at the hospital's maternity ward. The presentation of the results is in form of frequency tables, bar charts and pie charts.

4.2.1 Demographic information of the Respondents

This section presents data on the study participants' demographic information. These include gender, age, level of education, level of income and occupation.

4.2.1.1 Distribution of Respondents by Gender

The information collected from the respondents is shown in figure 4.1. It showed that there were fourteen (14) females representing 70% and six (6) males representing 30% of the respondents. The study targeted more females under the maternity ward because the research sought to understand challenges that pregnant women face during registration at the Hospital.

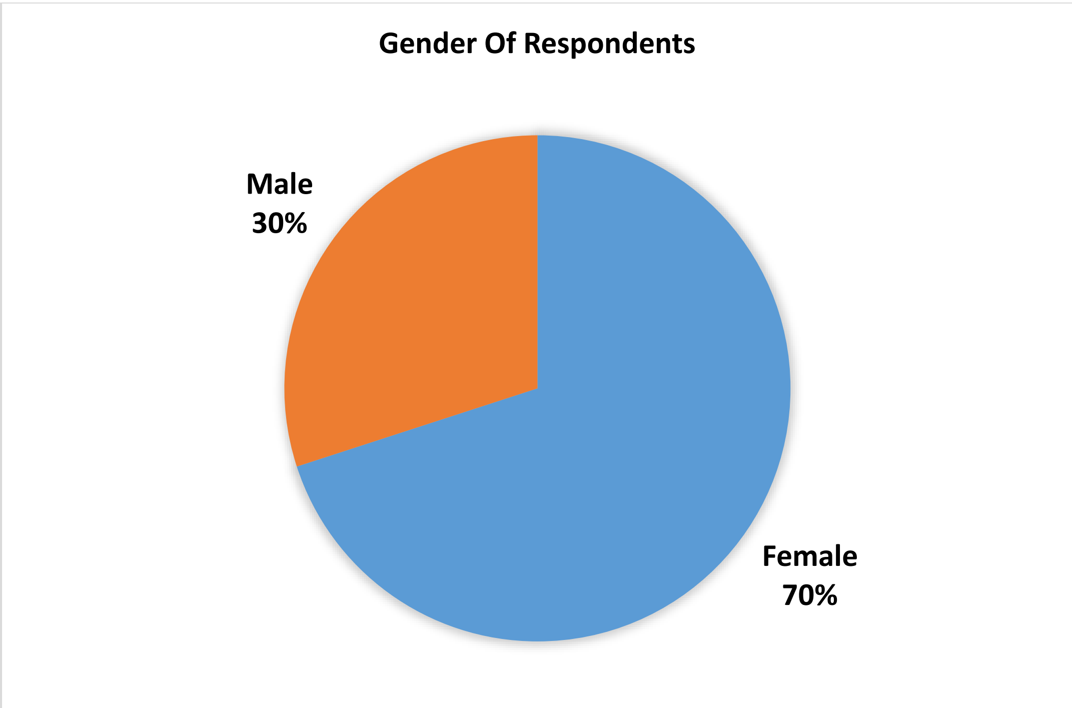

Figure 4.1: Gender of Respondents

4.2.1.2 Age of Respondents

The respondents were mainly between the ages of 18- 29 years old representing 45% of the number total respondents. The study indicated that most women who visited the maternity ward were less than 30 years old. Only seven respondents were between 30-40 years old representing 35% of the total number respondents and 15% represented the age group between 40-50yrs old. Only one respondent was above 50yrs old representing 5% of the total number respondents. The information on age was an important aspect because it helped the researcher understand the computer knowledge levels of the respondents and how easily respondents would be able to learn computers to efficiently use the tracking and monitoring system.

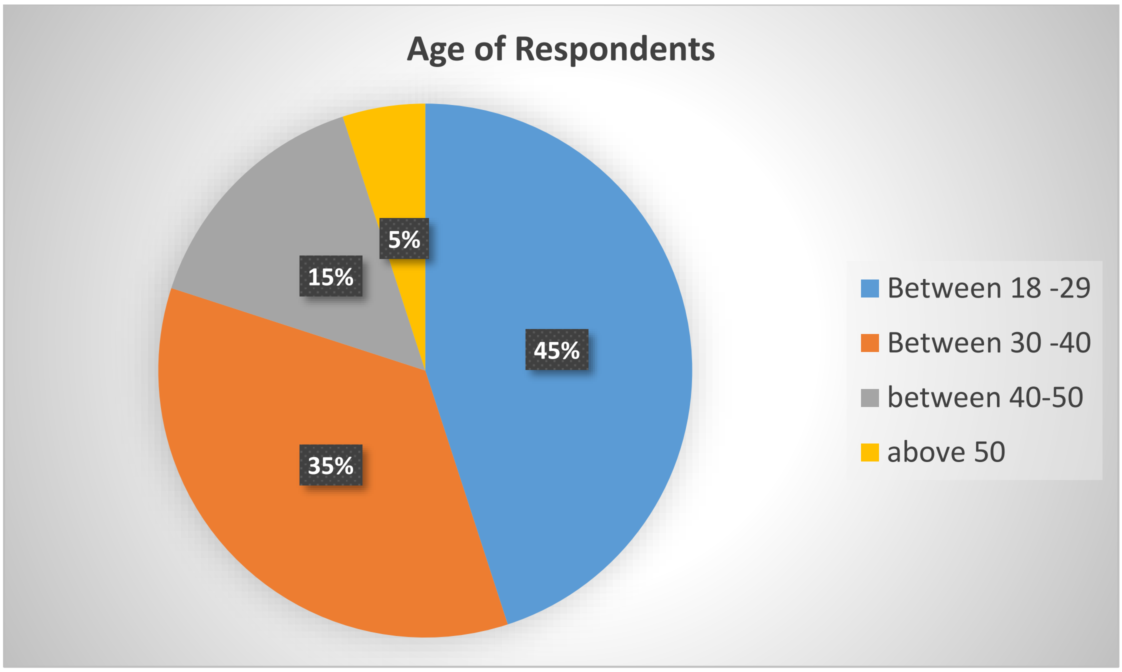

Figure 4.2: Age of Respondents

4.2.1.2 Level of Education of the Respondents

Figure 4.2 shows the highest level of education of the respondents. Two (2) respondents representing ten percent (10%) were PhD holders, seven (7) respondents were degree holders representing 35% of the respondents,25% were diploma holders and 15% represented certificate holders. 15% represented others and these included school dropouts, school leavers and those still in school. Educational levels were important because they influenced the respondents’ ways of analysing issues.

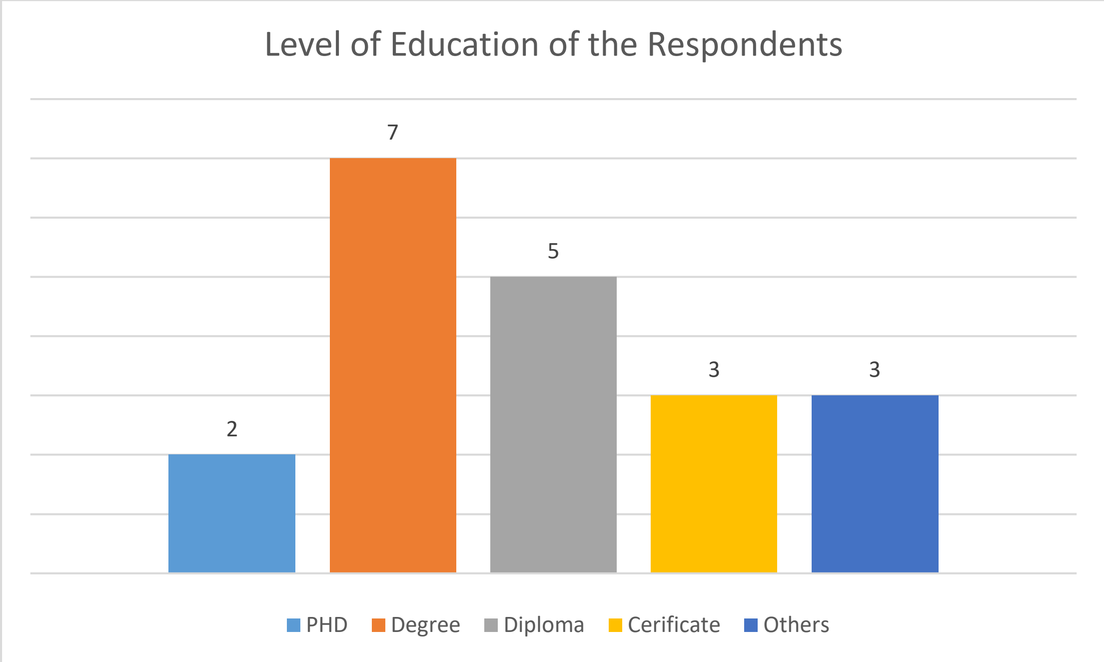

Figure 4.3: Level of Education of the Respondents

4.2.1.3 Level of income of The Respondents

The bar chart in figure 4.4 presented the levels of income of the respondents. Six (6) respondents were in the income range of K500 - K2500 representing 30% of the total number of respondents. Four (4) respondents representing 20% of the total number respondents were in the income range of K2500- K5000 and 25% of the total numbers of respondents were in the range of K5000 - K7500. Those earning above K7500 represented 15% of the respondents. The rest of the respondents (10%) either did not have a steady monthly income or didn't have any income at all. It was noted that amongst the respondents, others claimed that they were dependents or housewives hence it was difficult for them to state exactly on average their monthly income as it varied every month. Income levels were included in the study because they would determine whether the respondents would afford to acquire the Tracking and Monitoring system.

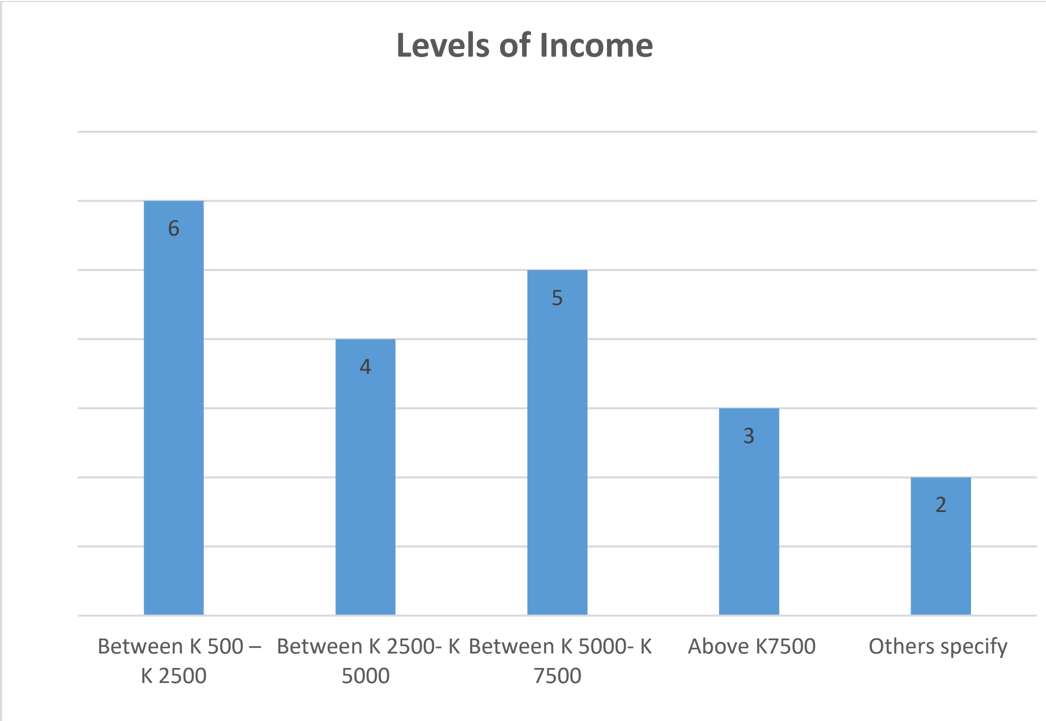

Figure 4.5: Level of Income

4.2.1.4 Categories and Occupation of Respondents working at the Hospital

The chart in figure 4.6 presented the categories and occupation of the respondents working at the hospital. From the targeted respondents, 12 were outpatients at the maternity ward indicating 60% of the total respondents and the rest of the respondents were staff members at the hospital. These included four were registry clerks indicating 20% of the total number of respondents; Clinical health workers represented 20% of the total number of respondents, i.e. 15% nurses and 5% doctors respectively as shown the figure 4.6.

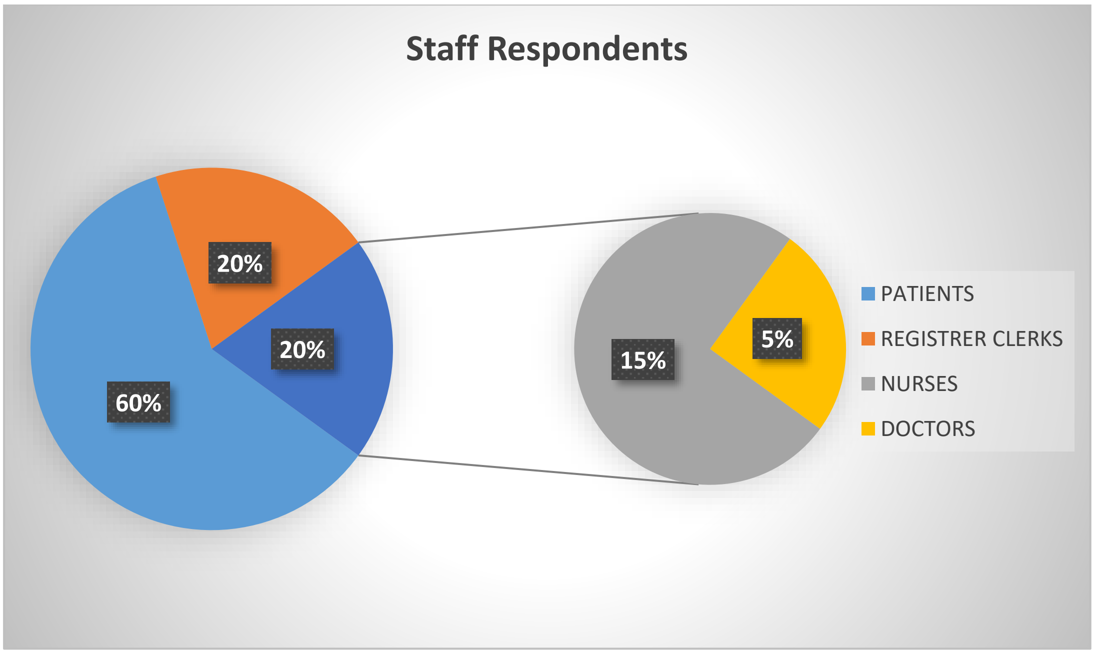

Figure 4.6: Percentage of Staff Respondents at the Hospital

4.2.2 Mobile Phones Users

From the targeted respondents, it was indicated that 93% of the total number of respondents owned a form of mobile device (phone, tablet, iPad) .7% of the total number of respondents had no mobile device.

4.2.3 Access to Smart Phones

The study showed that amongst the 93% of respondents owning a mobile device only 45% of them actually had access to a smart phone. This indicates that at least 50% of respondents that had a mobile phone had a smart phone and they can use their phone to access the internet and hence be easily connected on the Tracking and Monitoring Platform.

4.2.4 Access to Internet

The results from the study indicated that access to internet for respondents was at 85%, with respondents claiming they use the internet sporadically. The rest of the respondents claimed they rarely use the internet because internet data is expensive.

4.2.5 Challenges of the Current System

The survey results obtained as shown in figure 4.8 showed that 20% of the total respondents had their information recorded wrongly, 25% had files missing, 20% indicated that the whole registration process is tedious and only about 1% had been given the wrong medication mainly due to wrong information indicated on their file.

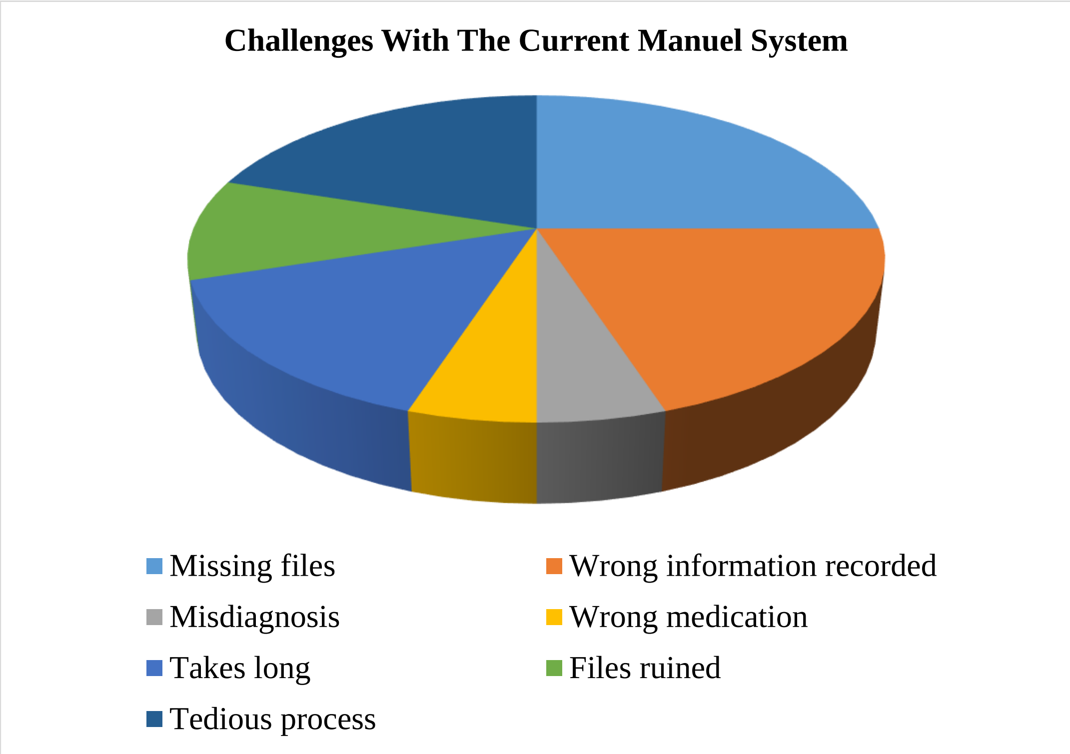

Figure 4.7: Challenges of the Current System

4.2.6 Lost Files

The study further indicated that at least 30% of the total respondents had their files misplaced or lost. Most of the files lost were untraced at the hospital's registry office hence the patients had to re-register. Some respondents claimed that to avoid the inconvenience of losing their medical files and records by the hospital's registry they started carrying their files at home.

4.2.7 Ratings for the Initial Registration Process

Figure 4.8 shows the ratings for the registration system at the hospital. 46% of the total respondents rated the process poor whilst 28% indicated it was good and only 26% indicated it was very good. The results indicated that most respondents were not satisfied with the process and indicated that if the system were improved, it would improve service delivery at the hospital.

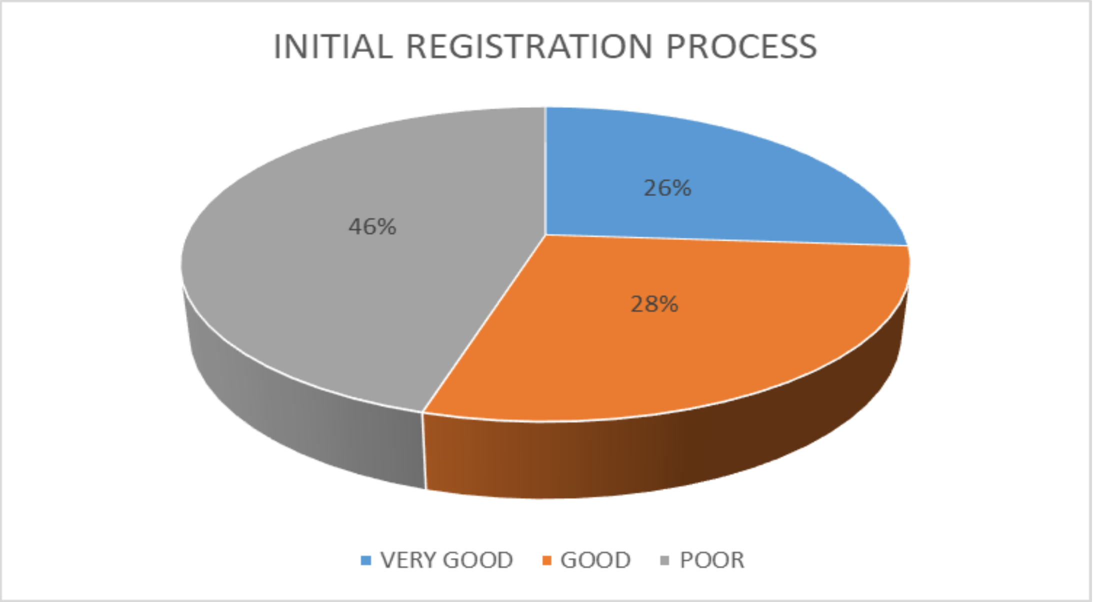

Figure 4.9: Rated Initial Registration Process

4.2.8 Process of Taking Important Vitals (Temperature and Blood Pressure)

The results shown in figure 4.10 indicate that 87% of the total number of respondents agreed that the process of taking vitals took long and only 2% of the total number of respondents disagreed. Some respondents indicated that for their monthly antenatal checkups they have to go as early as 06:30 am to avoid long queues.

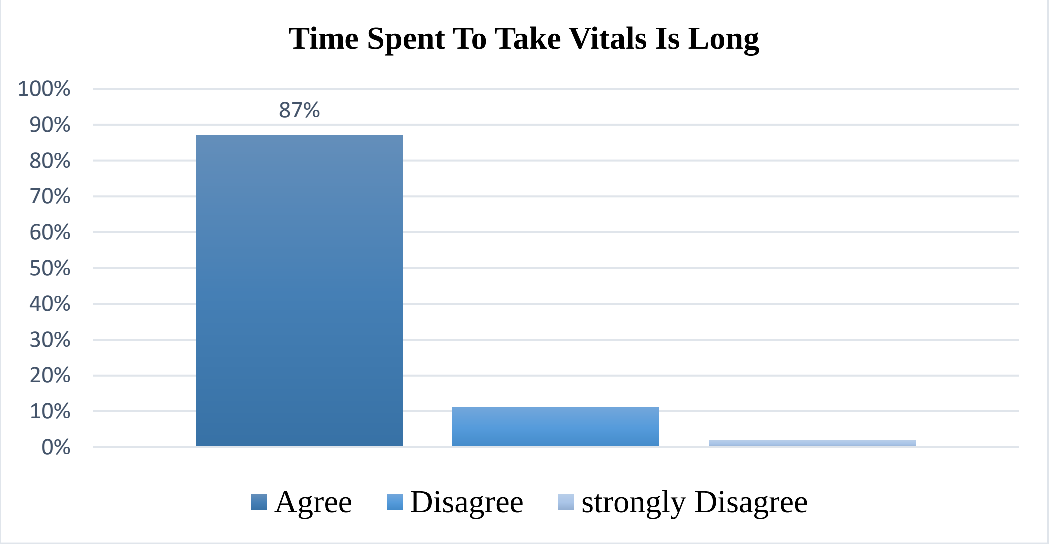

Figure 4.10: Process of Taking Important Vitals (Temperature and Blood Pressure)

4.2.9 Indication of the Need of a Digital System

Figure 4.11 shows indication of the need of a digital system at the hospital. 85% of the total number of respondents agreed that a digital registration system should be introduced at the hospital to improve the patient registration process whilst 15% of the total number of respondents did not agree.

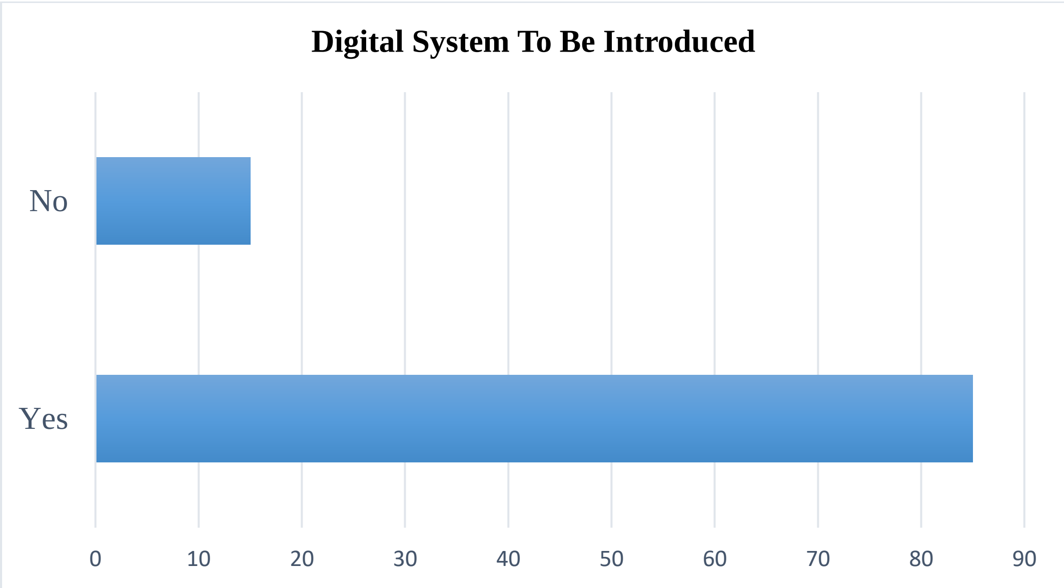

Figure 4.12: Indication of the Need of a Digital System

4.3 Comparison between Processing Time for the Manuel System and RFID System

The table below shows the calculated average process time for the proposed RFID system and the current system. The table below shows a time reduction of 76.92% and 54.16% for both registration and taking vitals respectively. The proposed system will reduce the overall process time by 74.55%.

Table 4.1: Comparison on the Process Time for the Manuel and RFID System

	Average time on process (min)		
	registration	Taking Vitals	whole process
Manuel system	6.5	2.4	11.2
RFID	1.5	1.1	2.85
time change	5	1.3	8.35
percentage change	76.92%	54.16%	74.55%

The bar chart in figure 4.13 shows that using the RFID-IoT system, there is a significant reduction in time for the whole process.

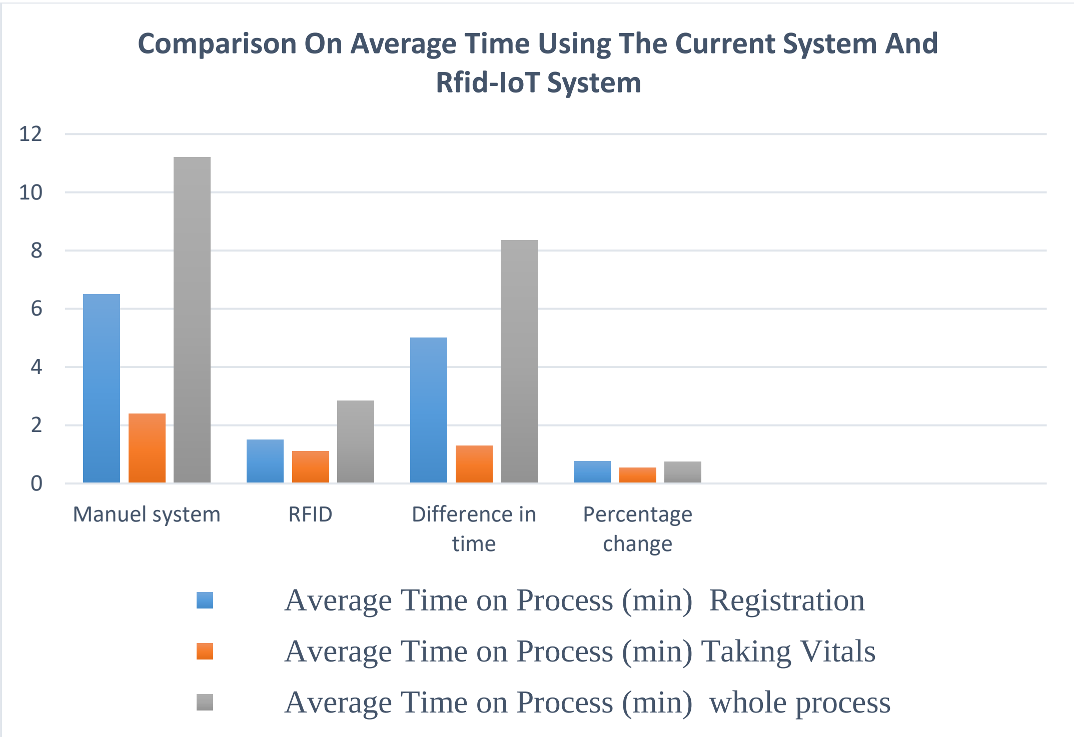

Figure 4.13: Bar chart on Comparison on the Process Time for The Manuel and RFID System

4.4 Recommendation for the Proposed System

From the study, 89% of the total number of respondents recommended the RFID system as a better alternative to the current manual registration system. 11% of the total number of respondents disagreed as some respondents indicated that they were not conversant with how the system works.

Some key informants from the hospital indicated that sometimes they were overwhelmed with work due to the high influx of patients at hospital hence mistakes were inevitable. Thus, the RFID system will definitely help to improve services at the hospital and also reduce the workload of the staff. A digital records system is recommended because it creates an easily accessible system with medical records readily available for both the patient and the doctor.

4.4 System Implementation

This section details the implementation of the IoT-RFID tracking and monitoring system. Screen shots from the prototype are presented.

4.4.1 Registration of Patients on the IoT-Gecko platform

The results demonstrated here are the procedures that the user has to follow to be registered on the platform for the purpose of online Monitoring and Tracking. Due to limited resources only temperature and Blood pressure sensors were incorporated in this prototype.

In chapter 3, users for the system were introduced, these included Doctor, System Administrator, Registry clerk and Patient. The administrator manages the users of the system and creates accounts on behalf of the users. Figure 4.14 is a screenshot for the Gecko platform. The Gecko platform is a web-based platform that users can easily access. For this study, a link specifically for monitoring system was created. The system administrator creates a profile that link the patient to the IoT profile.

The profile can easily be created by opening a page on the IOTGecko website and identifying the IoT project which has been created in the system as shown in figure 4.15. The system will automatically synchronize with the physical setup once connected and will start reading the vitals. The doctor is also given the credentials for the patients (username and password) to allow monitoring of patients anywhere as long as he is connected online.

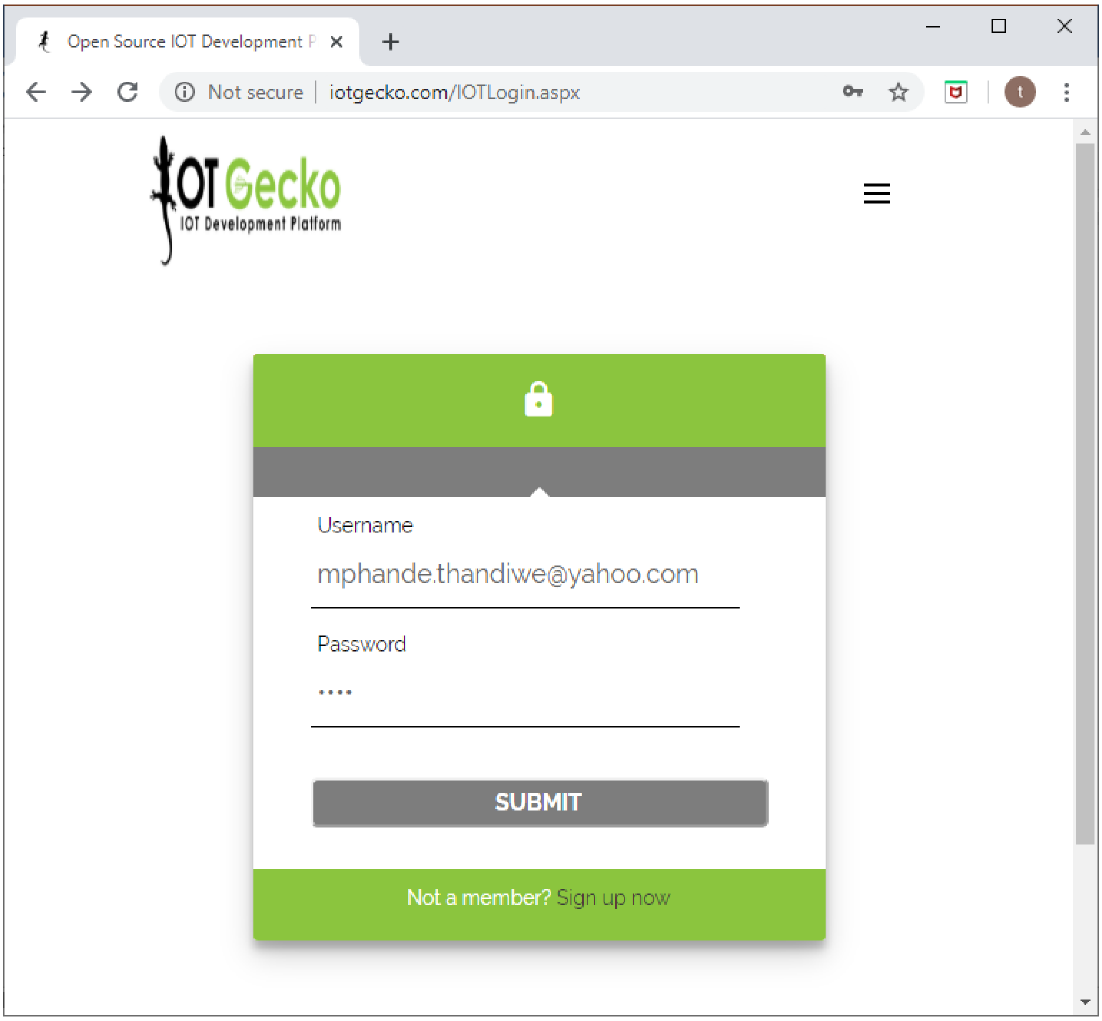

Figure 4.14: IOT login page using IoT development platform

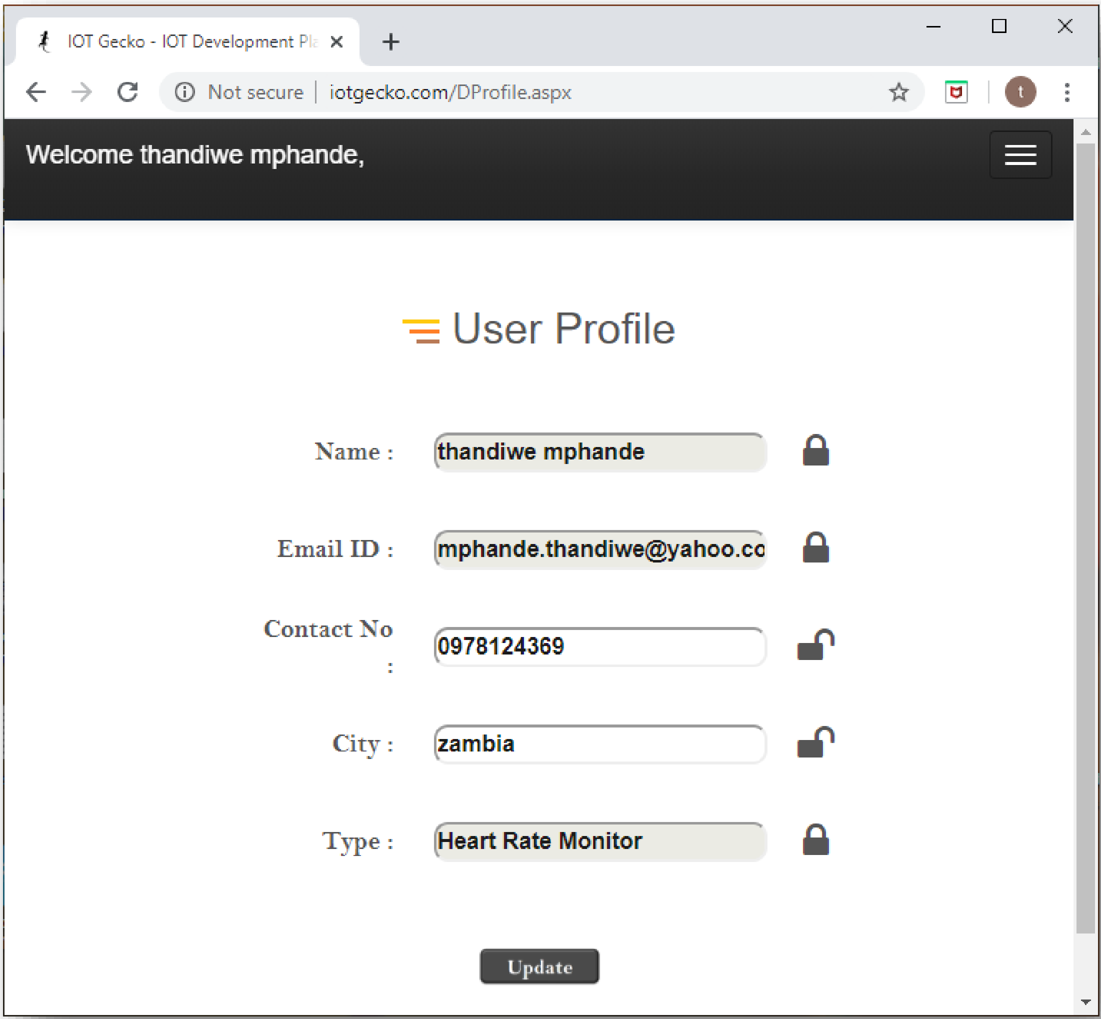

Figure 4.15: Registration page for IOT platform

4.4.2 RFID Registration

For a patient who is being registered for the first time in the system, the login page was designed as shown in figure 4.16 below. The system administrator was able to create profiles that would capture both the patient and doctor's particulars. The RFID system was designed to facilitate records management for patients and staff members at the hospital thus replacing the physical paperwork registration process.

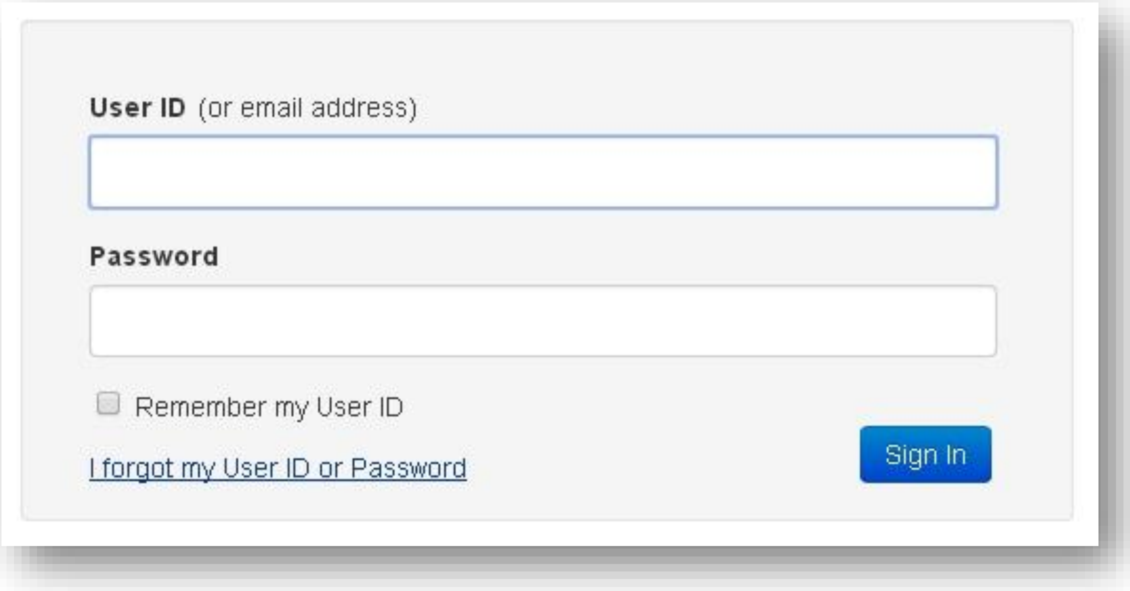

Figure 4.16: RFID registration Login page

Figure 4.17 shows the website page that was designed to capture each patient's personal details and the appointed doctor's particulars. A database was created to easily manage all the patient's information once registered. This enabled tracking of the patient's visits to the hospital and also easy tracing of their doctors in case of emergencies.

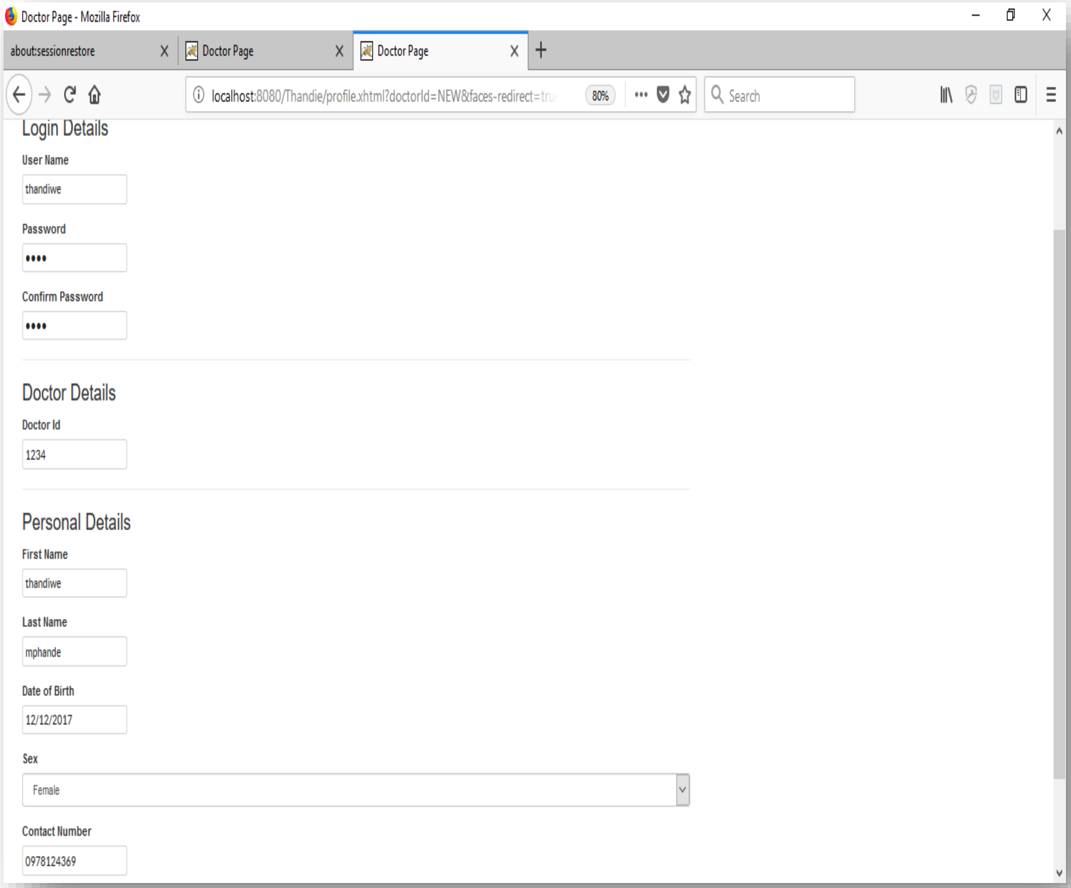

Figure 4.17: RFID doctors page for registration

4.4.3 Initialization of the devices

Once the online page was setup, the devices were confirmed and setup in Arduino environment. This also enabled the setting up of the serial monitor which allowed the computer to serially connect with the Arduino. This was important because it toke the data being received by the Arduino from sensors and displayed it in real-time to the computer. Figure 4.18 shows displays the screen shot the setup of the serial monitor in Arduino environment.

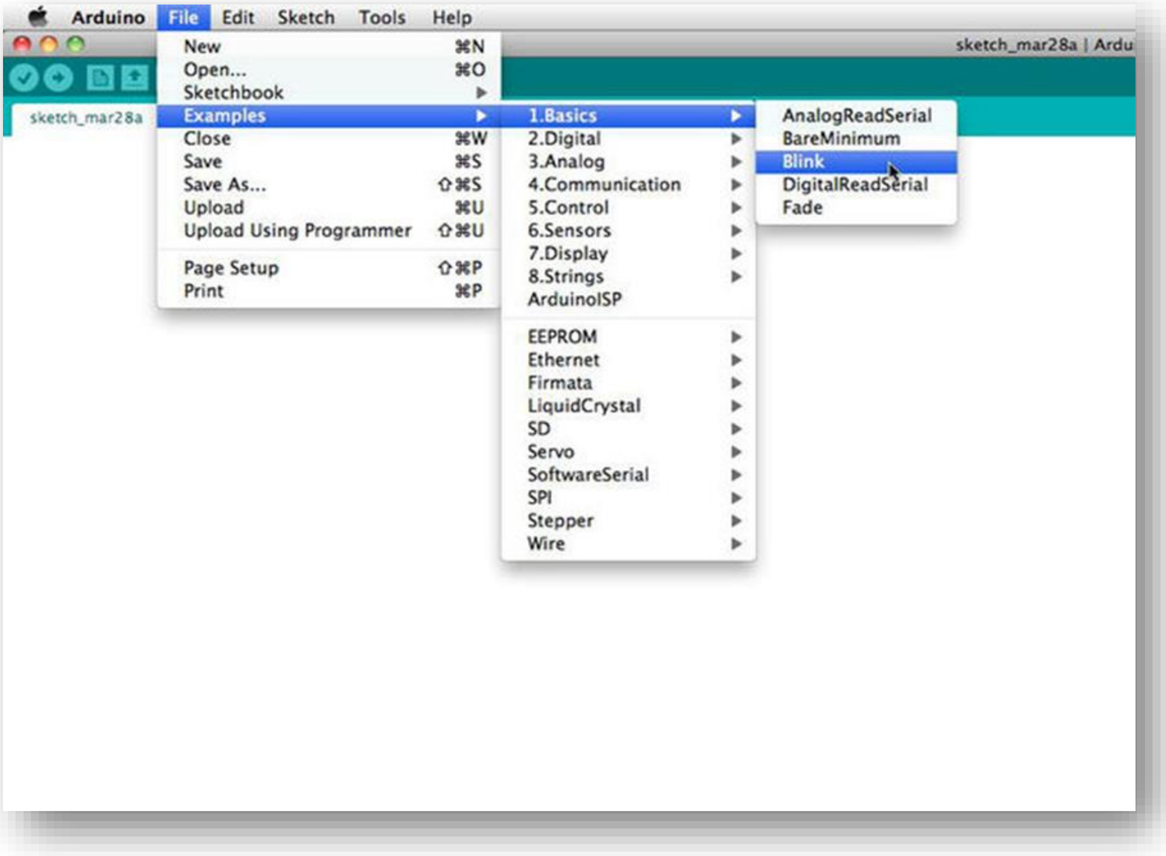

Figure 4.18: Screen shot the setup of the serial monitor in Arduino environment.

4.4.4 Results from IoT Monitoring System

Once linked to the physical setup, the system was tested and results were obtained for different case scenarios.

The first step was to set the minimum and maximum heart rate as shown in figure 65 below. In this study normal heart rate range was set between 60 and 110 beats per second (Bps) which is the normal average heart beat rate for a health person. The system administrator was able to set a normal range for both temperature and heart beat as shown in figure 4.19.

If the sensor reads a value above or below the set range, an alert message was triggered in the system.

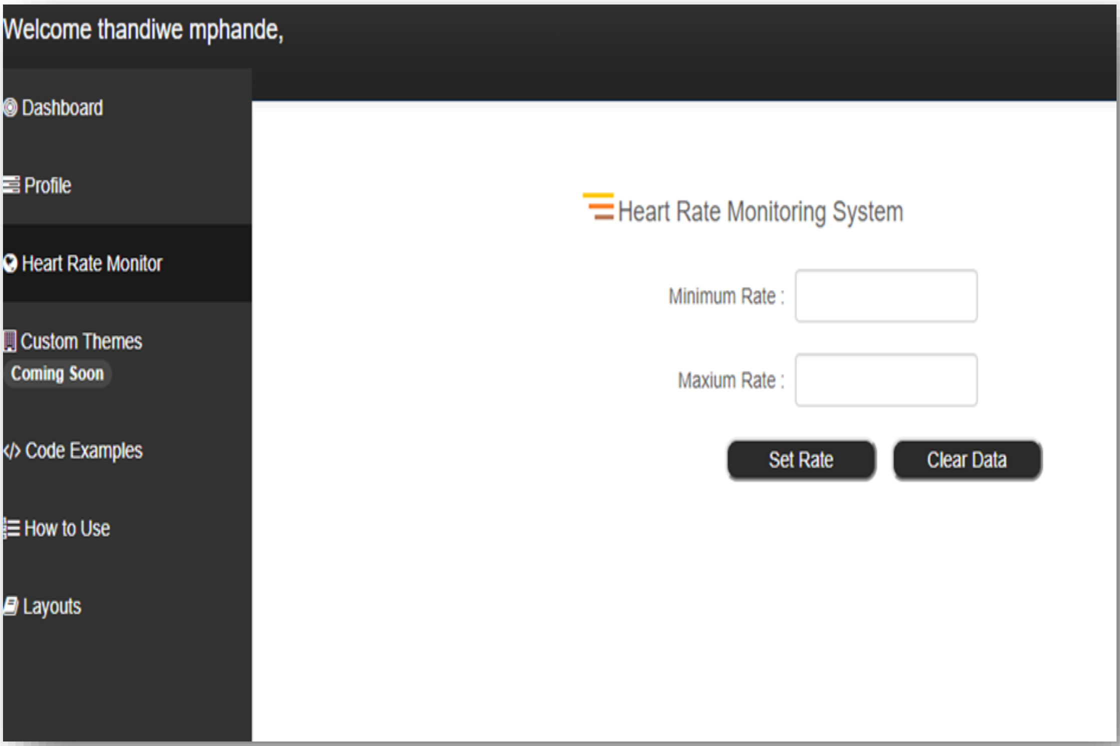

Figure 4.19: Heart rate settings for minimum rate and maximum rate

I. Case 1: Normal case scenario - Patient with normal heartbeat

Figure 4.20 shows the results of a respondent with a normal heartbeat and temperature. In this study, the nominal heart rate was set to range between 60 and 110 beats per minute, which is the average normal heartbeat for an adult. The results obtained indicate that the respondent's heart rate was within the normal range with a temperature of 31 degrees Celsius.

Figure 4.21: Results of the IoT monitoring using gecko developing platform for a normal heart rate

II. Case 2: Critical case scenario - No heart beat

In order to portray a worst-case scenario, the sensor was completely removed from the respondent's finger. Figure 4.22 shows the results obtained when the sensor is completely removed from the finger. When the sensor did not read any heart rate, an alarm /alert message was triggered. The alarm was triggered once the normal heart rate fell below the set normal heart beat that was set between 60 and 110 beats per second (Bps). For both scenarios, the actual body temperature of a patient was difficult to read because the sensor used in the study was not very sensitive. Temperature readings recorded were 3 to 4 degrees Celsius less than the actual body temperature.

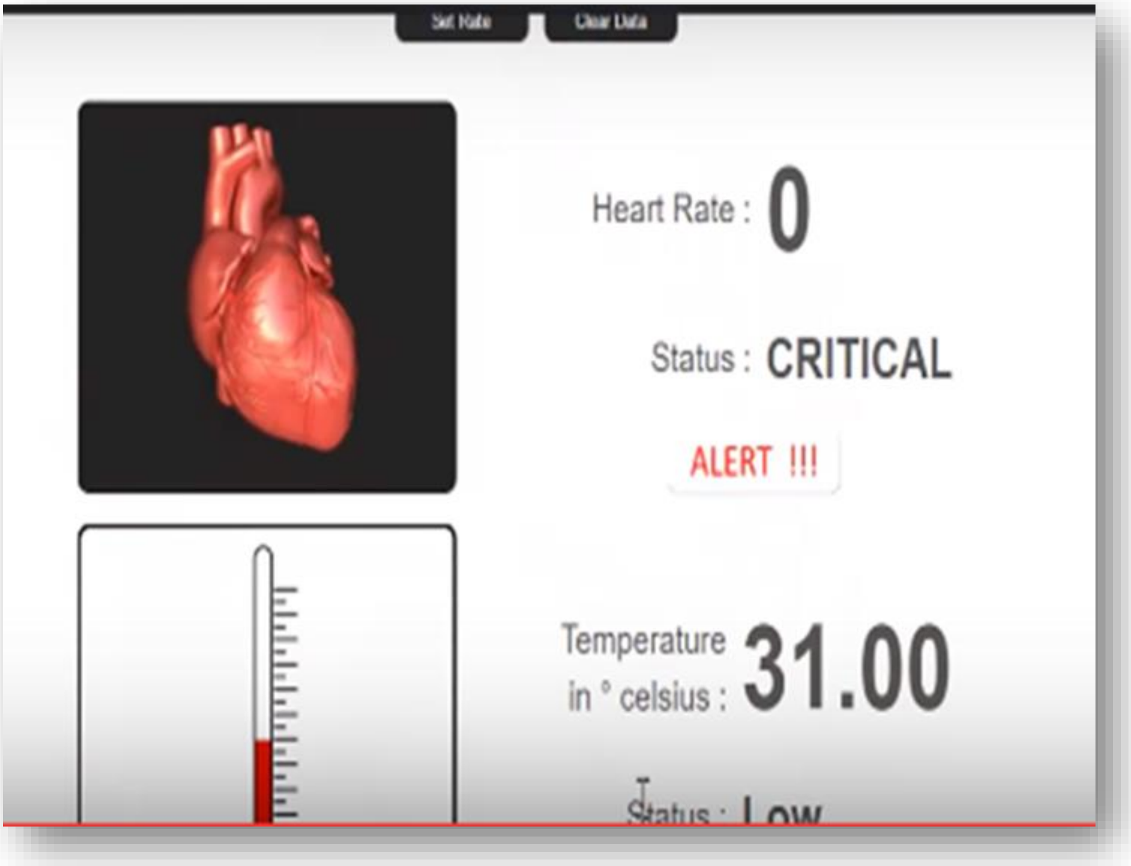

Figure 4.22: Results for a normal heart rate in using IoT monitoring

4.4.4 Physical setup of the IoT and RFID systems

Arduino microcontrollers, blood pressure and temperature sensors were adopted for this system. The hardware components used in this project included RFID module, laptop, wireless module and Arduino controllers. The physical setup and physical components is as shown in Figure 4.23 and Figure 4.24. 4G internet communication was adopted for this project. RFID passive tags were used because they were cost effective and easy it to implement. A database system was developed using MySQL to create an electronic records system. All the components were purchased online and tested by the researcher. The RFID system was modeled in such a way that the receiver would have to be positioned by the registry clerk's desk so that immediately the patients walked through the Hospital entrance, the receiver can read the tag. Figure 2.24 shows the system being tested on a volunteer.

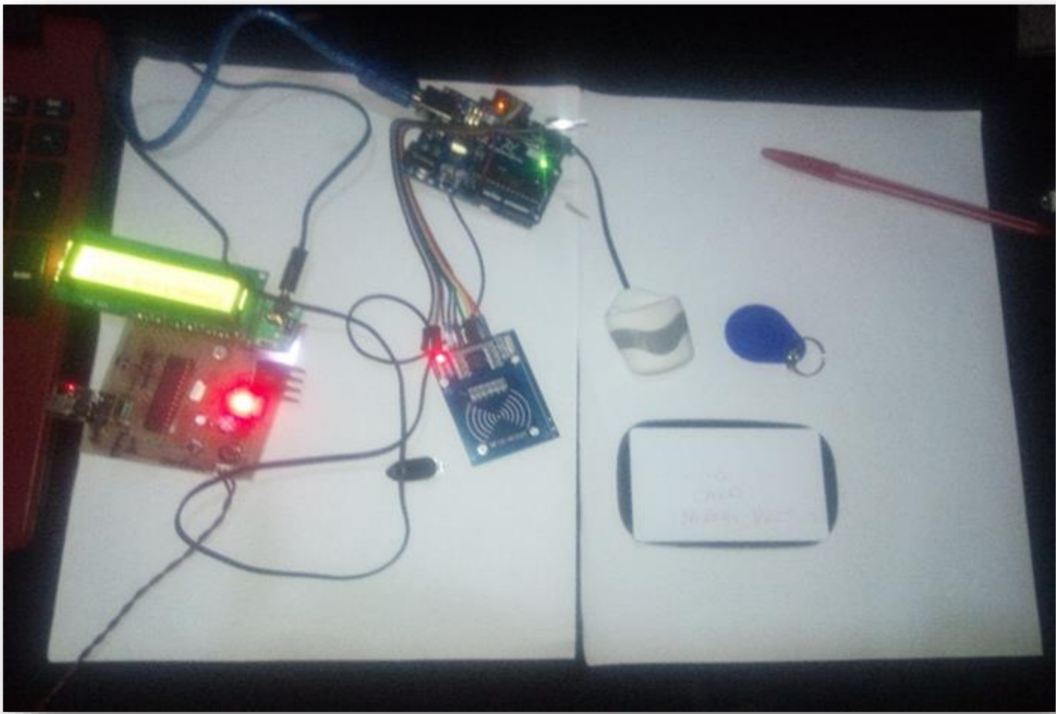

Figure 4.23: IoT temperature and monitoring system

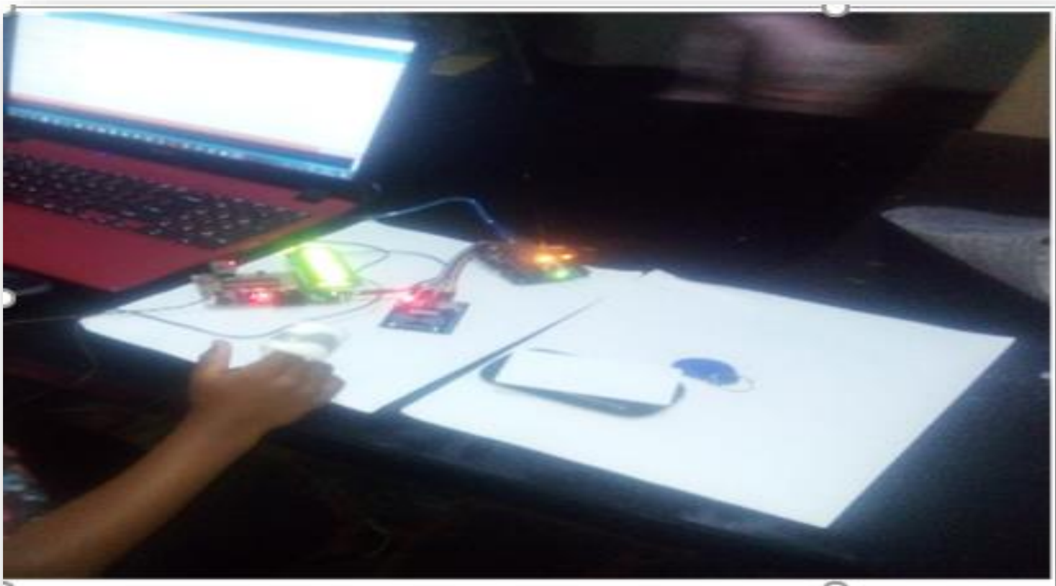

Figure 4.24: Testing Prototype on a volunteer

4.5 Summary

In this chapter, results of the baseline study, the system implementation and the system evaluation procedure conducted on the tracking and monitoring system are presented.

In the baseline study, challenges with the manual registration at the Hospital were established and the effects of not having an electronic monitoring and tracking system were identified. In the study, most participants recommended the proposed remote monitoring and tracking system that was developed and tested because the system was proved to be more efficient than the manual system. A comparison between the two systems i.e. current system at the Hospital and proposed system showed that the proposed system is faster, effective and efficient. The proposed system is a basic system that can be improved and most importantly, it is user friendly and affordable.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.0 Introduction

In this chapter, the discussion of the results that were shown in Chapter 4 is presented. The results discussed are in the baseline study with reference to objective number one and number two of the study. Furthermore, this section includes conclusion of the study, recommendations of the study and future works.

5.1 Baseline Study

This section discusses the results derived from baseline study. The main challenges deduced from the primary research are discussed in the following sections with references to figures and tables in Chapter 4. The findings from the baseline study helped to develop a solution that will enhance quality health service delivery and efficiency at the Hospital.

Information collected from the baseline study included; Demographical information, accessibility to smart phones and data, income of respondents and educational levels of the respondents.

Most of the Zambian government sectors including the education sector, agriculture sector and financial sector are embracing information and communication technologies (ICTs) to enhance service delivery and increase competitiveness [88]. Health care is no exception. ICTs can transform how health care is delivered and how health systems are run. The University Teaching Hospital is gradually embracing technologies in its daily operations to enhance service delivery.

With the current increase in the number of patients being admitted per day in the wards, patients' records management has always been a challenge. Currently the Hospital has no tracking and monitoring system that allows doctors to remotely monitor and track their patients. With government's intentions to introduce E-health system and embracing technology in service delivery, an electronic management system and Remote Monitoring system will a have good impact in the health sector.

In more practical terms, this will also ensure that the right health information is provided to the right person at the right place and time in a secure, electronic form for the purpose of optimizing the quality and efficiency of health care delivery, research, education and knowledge.

5.2 Challenges with the current system

The results obtained from the baseline study indicated that the record management system currently being used at the hospital maternity ward is all paper based. The baseline study indicated that 25% of the targeted population have had their files lost or misplaced or ruined. An additional 20% of the respondents had had wrong information recorded for them in their files, with 1% indicating wrong medication given to them due to incorrect information being recorded. The losing of files was attributed to having a large number of files without proper filling cabinets or shelves as shown in figure 4 of chapter 1. A survey conducted at the Hospital showed the records room was in a bad state with the roof leaking during rain seasons. Apart from the records room being a deplorable state, the room was not properly secured. The only security feature that was identified in records room at the time the survey was being conducted was a trellis door and a lock.

Additionally, the study also indicated that the initial stage for taking and recording of vitals was too tedious and the registration process took a lot of time. 46% of the total number respondents rated the whole process as tedious and conversely only 26% of the total number of respondents rated it as fair. This was attributed to long queues and limited resources as indicated by the medical personnel at the hospital. The average patient to nurse ratio at the time of the survey was 1: 30, indicating that for every 30 patients that came through to the hospital there was only one nurse to attend to them. This meant that patients had to wait for long hours to be attended to and nurses easily got fatigued due to the large number of patients they needed to attend to in a day. Furthermore, apart from the long tedious process of taking vitals, patients had to sit in long queues to be seen by the doctor. One of the interviewees indicated that for her monthly antenatal visits she had to come as early as 06:00am in order to avoid long queues, another indicated that sometimes she spends at least 6hrs at the hospital in queues and other hospital procedures. One of the medical doctors indicated that if the medical system was fully digitized starting from vital taking process to labs and consultations, delivery and quality service would greatly improve.

5.3 Access to Internet for Smart Phone Mobile Users

The study indicated that at 90% of the respondents had a mobile phone and 7% did not own one due to several reasons. Others attributed it to lack of money, whilst others lost their mobile phones and had not just replaced them at the time of the interview. Amongst those that owned a mobile phone, 45% had a smart phone or a tablet. Almost 80 percent of the respondent who had access to the internet use it for work or personal purposes e.g. for social media like Facebook or twitter. According to the findings in figure 59 in chapter 4, 65% of the total number of respondents access internet through their personal mobile devices, like phones, tablets or dongles, 12% of the total number of respondents access internet from their work place and that the internet is provided by their employers, while 2% of the total number of respondents access internet through public Wi-Fi and 1% of the total number of respondents accessed it through internet cafes. This means that people are able to access internet on their own in one way or another as indicated by most of them. Hence this shows the ability of the respondents to access the IoT health system anywhere away from the health facility. From the study respondents recommended the IoT system as they thought it would make it easier for them to get quality health care and also avoid long queues at the hosiptal.80% of the total number of respondents actually indicated the need to introduce the proposed system and only 15% were not sure if it would change anything. 5% of the total number of respondents had a concern with security and reliability of the system as most digital systems are prone to cyber-attacks.

5.4 Comparison on the Process Time for the Manuel and RFID System

Radio frequency identification (RFID) systems are used for maintaining and verifying patient records usually by wearing a wristband or an RFID card. The RFID wristbands or RFID card have patient information printed on them, and patient records are stored on the tags chip or associated with the tag's ID through database. Encoding of patients' information on the chip is an important way of identifying patients because it can help in case of an emergency where patients are unable to identify themselves. Patients are outfitted with RFID tags in the hospital to verify patient information, reduce wait times and bottlenecks and to locate patients.

RFID tags that were used for the prototype were able to store patients' information, which included; names, address, doctor's name and phone numbers. This coupled with the use of the IOT system was able to reduce both the waiting time and the time taken to record vitals. Using the manual registration process the average time was calculated at 6.5 minutes (this was for five different participants on different days), the average waiting time before been attended to by a doctor or nurse was 36 minutes hence giving an estimated waiting time of 40 minutes for the whole process. This shows that the current system is not able to deliver quality services in a much efficient way. As started in table 5 of chapter 4, it was shown that the time was reduced by over 75%. This shows that the use of RFID and IoT together would improve health care services by increasing efficiency and reducing on time spent on the queues. Hence in comparison, the proposed system proved to be faster and efficient then the manual system. The RFID- IoT system also allowed an interaction between the health personnel and the patient. The patient is also given the chance to verify their details and incase of admission, the ward number and doctor's particulars can be captured using RFID. This will also reduce the cases of wrong medication and privacy is also guaranteed as accessibility to the electronic records will be restricted to only those who will be given permission (passwords).

5.5 Implementation of the system

This section discusses the system implementation that was presented in Chapter 4 Section 4.3. In this study, RFID and IoT model was developed and the prototype was implemented to show how the system works. The development phases were as outlined in section and chapter 3 were followed. The system requirements were derived from the survey that was carried out at the University Teaching Hospital (UTH) and the interviews with various stakeholders (patients and administration staff).

The system requirements and interviews informed the design phase of the implementation. System models were designed (see Chapter 3 Sections 3.6, 3.6.1, 3.6.2.1 and 3.7) that were to form the basis for development of the prototype and a fully functional automated system in future. The models were developed using information obtained from primary sources, and secondary sources (literature review).

5.5 Research Objectives and Findings

This section highlights the research findings and how the research finding correlate with existing knowledge.

5.5.1 Health Monitoring Systems available on the Markets and Methods used to manage Patients medical records at The Hospital

The critical role of health information technology in the health sector can never be under estimated. RFID coupled with IoT offers great opportunities for healthcare transformation. With strong policies in place to push for the use of those technologies service delivery in the health sector can greatly improve. The University Teaching Hospital being one of the largest hospitals in Zambia has had fair a share of challenges in terms of modernising its patient's record's management systems. Some of these challenges can be attributed to lack of proper infrastructures and financing from the government. The hospital at the time the research was been conducted was using the manual system to handle patient's medical records. Patients' medical records were filed and kept in a records room, which was unsecured and in a bad state as shown in figure 2 of Chapter 2. Retrieving files and proper storage of records were other notable challenges the hospital was facing.

From the Literature reviewed in chapter 2, it was determined that there are a number of health monitoring systems available on the market. These range from full body real time monitoring to basics heart rate monitoring systems. The parameters measured using various health monitoring systems include ECG, photoplethysmography (PPG), HR, BP, body temperature, and galvanic skin response (GSR). Using RFID and IoT, these parameters are monitored remotely by the health care providers. More importantly accurate patient tracking using RFID technology can improve patient safety in many instances. Furthermore, studies have reviewed that using RFID reduces medication administration time by a considerate amount.

5.5.2 Presenting a Running System that Uses RFID and IoT for Patient Monitoring and Tracking

A prototype of the system for both the IoT and RFID was successfully developed and implemented. The prototype was developed using java programming language, MySQL, HTML and gecko platform. The prototype shows how RFID can be used for patient identifications and electronic records. The IoT prototype shows how remote monitoring of patient is used to help to take necessary vitals without physically being at the hospital. The prototype allowed doctors to check and monitor the patient online. The RFID tag can be read using an RFID reader positioned at the registry desk at the hospital. Inherently, each RFID tag is given a unique ID, which enables the reader to distinguish it amongst other tags. Patients were identified using tags because of the uniqueness of the serials. Tag serials are unique (see Chapter 2 Section 2.2.1 subsection (a)), hence each patient can be uniquely identified The unique tag number was used to locate the patients file in the database and also in the IoT platform. The IoT was tested on a volunteer patient and results are as shown in chapter 4 section 4.3.4. A comparison was made between the manual system and the developed prototype.

This prototype is a perfect example of how the Internet of Things coupled with RFID technology can be used in the health sector. RFID combined with intelligent sensors (blood pressure and temperature) can be used to remotely track and monitor patients, hence reducing the need to visit the medical centres. This prototype developed into a fully fledge system can further enable the care givers know the conditions of the patient, location of the patients and also automatically call the emergence care givers in case the condition gets worse.

The RFID system further eliminates the need to keep paper-based records as all records are kept electronically in the cloud and can be accessed by anyone with authorization anywhere in the world. RFID provides an accurate, convenient, and rapid method of identifying and managing storage patient’s data. RFID reduces errors caused by visual identification, manual counting, maintenance and monitoring to ensure that the collected records are credible and accurate.

The use of the system is very beneficial to the health sector, as it would reduce on time spent on registration of patients and similar daily duties. The RFID integrated with IoT will help in minimizing medical errors and improve the efficiency in the health sector. Apart from great improvements in patient satisfaction, there are benefits gained by the staff. With the use of the system, staff can spend less time on daily duties. No matter when and where they are, they can find and access the information they want, such as patient’ s actual personal and medical information, within a very short period. This leads to a great enhancement in staff productivity as well as in staff satisfaction. Staff can spend more time on monitoring patients due to the increased efficiency in recognizing patients’ identity or checking on the whereabouts of one patient.

5.6 Conclusions

The aim of the study was to develop a Monitoring and Tracking system that uses IoT and RFID technology. The prototype was developed to help mitigate the challenges University Teaching Hospital (UTH) is facing regarding the storing, tracking and retrieving of patients' records. The system was also developed to give doctors or nurses the ability to remotely monitor outpatients or patients who are far from health centers.

The objectives of the study were achieved. Based on the objectives for the study, the following conclusions were arrived at:

I. Patients, doctors and other clinical personnel face diverse challenges with the existing registration and record management system at the Hospital.

II. The current record management system at the maternity ward is mainly papers based and it is not efficient and effective. Hence the introduction of a digital registration and storage system will be able to solve the problem the institution is facing.

III. The result findings from the baseline study indicated that there is no implemented patient record management system at the Child and Mother Hospital.

IV. The results from the baseline were used to design an affordable Monitoring and Tracking system that was able track and monitor patients using IoT-RFID. RFID technology is affordable and can easily be integrated into any management system. IoT technology coupled with RFID does improve efficiency and patient tracking can be done remotely.

5.7 Recommendations

The study revealed that remote tracking and monitoring system is effective and efficient especially for large hospitals like the University Teaching Hospital. The adoption of RFID and IoT could positively impact the sector by opening up more doors for research and innovation. IoT is the future for health sector because it will enable hospitals country wide to easily share information and will give health professionals a platform to reach even the remotest places without them physically going there.

The government through the Ministry of Health should start working towards implementing the e-policy that will ensure that even the most remote health center has computers and internet to enable them to be incorporated in the e-health system. The technology used in the study is simple, easy to implement for technical and especially non- technical individuals. It's being used in other industries and can be applied even in the health sector. This system can easily be installed cheaply in remote health centers thus providing the government with some form of a centralized health

Since this system is on-line based, valuable information (e.g. patients admitted per day, drugs administered, deaths recorded etc.) can be easily accessed anywhere hence monitoring of government hospitals will be made easy. Such a system will enable hospitals to plan and know the space capacity of each hospital at any given time. Furthermore, paper-based records will be eliminated especially that the government is now encouraging paperless system.

The Ministry of Health's National eHealth strategy recognises the impact that eHealth is bringing to the delivery of health care and how it is making health systems more efficient and responsive to dynamic needs globally. This system can help the government achieve this goal and will enhance the integration of information and communications technology into its way of delivering quality health services to its citizens

5.8 Future works

The proposed project is a basic design and it only demonstrates the capabilities of IOT coupled with RFID. In order to fully appreciate and maximise the ability of the designed system more sensors can be connected to the system. The sensors will be able to measure various health parameters, which will be able to communicate via the internet platform for quick and easy access.

In order to fully maximise, the benefits of IoT, IoT-cloud can be integrated to enable traceability and improved health care services. Integrating IoT-cloud will help the safe transfer of medical information with the consent of the patients and other health actors. It will help build a centralized network for all health care providers (government hospitals, private hospitals, pharmacies, laboratories, doctors, nurses etc.

Furthermore, in order to enhance security and privacy, future works would be to encrypt communication during transfer of tag information to the server and also set up a virtual private network (VPN) between the hospital server and the patient's device. Encryption communication for this system would be based on RSA or RC5 block cipher method so that it could be performed easily and rapidly and most importantly the information will stay secure and confidential.

REFERENCES

[1] "International Journal of Pharmaceutics | ScienceDirect.com", Sciencedirect.com, 2019. [Online]. Available: https://www.sciencedirect.com/journal/international-journal-of-pharmaceutics. [Accessed: 10- Jan- 2019].

[2]"3 Ways Technology has Changed Healthcare | University of Illinois at Chicago", Healthinformatics.uic.edu, 2017. [Online]. Available: http://healthinformatics.uic.edu/resources/articles/3-ways-technology-has-changed-healthcare/. [Accessed: 06- Sep- 2017].

[3] "WHO Pharmaceuticals Newsletter 2000, No. 02: Medical errors", Apps.who.int, 2019. [Online]. Available: http://apps.who.int/medicinedocs/en/d/Jwhozip02e/4.html. [Accessed: 10- Jan- 2019].

[4]"How Technology Is Changing the Medical and Health Care Field", HuffPost, 2017. [Online]. Available: http://www.huffingtonpost.com/drew-hendricks/how-technology-is-changin_b_3273542.html. [Accessed: 06- Sep- 2017].

[5]P. Shalala, P. Shalala and V. Profile, "Shortage of Doctors in Zambia Now Hits 3,000", Paulshalala.blogspot.com, 2018. [Online]. Available: http://paulshalala.blogspot.com/2015/04/shortage-of-doctors-in-zambia-now-hits.html. [Accessed: 19- Jul- 2018].

[6] D. F. Sittig *et al.*, “Current challenges in health information technology–related patient safety,” *Health Informatics J.*, no. 2, pp. 1–9, 2018.

[7] D. Care, "How Technology is Improving Medical Care", King University, 2017. [Online]. Available: http://online.king.edu/healthcare/digitizing-healthcare-how-technology-is-improving-medical-care/. [Accessed: 06- Sep- 2017].

[8] K. Tabassum, “Intelligent Health Monitoring Using Internet of Things,” *Ann. Biostat. Biometric Appl.*, vol. 1, no. 1, 2018. 3]

[9]"Patient Tracking System | STANLEY Healthcare", Stanleyhealthcare.com, 2017. [Online]. Available: https://www.stanleyhealthcare.com/solutions/hospitals-health-systems/clinical-operations-workflow/patient-tracking. [Accessed: 09- Sep- 2017].

[10] R. Journal, "The Basics of RFID Technology - 2005-01-16 - Page 1 - RFID Journal", Rfidjournal.com, 2017. [Online]. Available: http://www.rfidjournal.com/article/articleview/1337/1/129/. [Accessed: 09- Sep- 2017].

[11] Nichols JH, Bartholomew C, Brunton M, Cintron C, Elliott S, McGirr J, Morsi D, Scott S, Seipel J, Sinha D. Reducing medical errors through barcoding at the point of care. Clin Leadersh Manag Rev. 2004 Nov-Dec;18(6):328-34. PMID: 15597554.

[12] Seibert, H., Maddox, R., Flynn, E., Williams, C.: Effect of barcode technology with electronic medication administration record on medication accuracy rates. Am. J. Health-Syst. Pharm. 71,209–218(2014).

[13] K. Ahsan, H. Shah, and P. Kingston, “RFID Applications: An Introductory and Exploratory Study,” vol. 7, no. 1, pp. 1–7, 2010.

[14] E. Lutton, B. Regan, and G. Skinner, “Patient Identification within a Healthcare System: The Role of Radio Frequency Identification and Bar Code Technologies,” pp. 264–269, 2009.

[15] M. Mitka, "Some Efforts to Reduce Health Care–Associated Infections Work", JAMA, vol. 310, no. 18, p. 1912, 2013. Available: 10.1001/jama.2013.281882.

[16] S. Dominikus and S. Kraxberger, "Secure Communication with RFID tags in the Internet of Things", Security and Communication Networks, vol. 7, no. 12, pp. 2639-2653, 2011. Available: 10.1002/sec.398.

[17] H. Javdani and H. Kashanian, "Internet of things in medical applications with a service-oriented and security approach: a survey", Health and Technology, vol. 8, no. 1-2, pp. 39-50, 2017. Available: 10.1007/s12553-017-0180-8.

[18] S. Jaiswal, R. Katake, B. Kute, S. Ranjane, and D. Mehetre, “Health Monitoring Management Using Internet of Things,” *Int. Res. J. Eng. Technol.*, vol. 5, no. 11, pp. 2243–2246, 2017

[19] K. Tabassum, “Intelligent Health Monitoring Using Internet of Things,” *Ann. Biostat. Biometric Appl.*, vol. 1, no. 1, 2018. [20] P. Sethi and S. Sarangi, "Internet of Things: Architectures, Protocols, and Applications", 2017. .

[20] P. Sethi and S. Sarangi, "Internet of Things: Architectures, Protocols, and Applications", 2017. .

[21]. Z. M. K., “a Review Paper on Smart Health Care System Using Internet of Things,” *Int. J. Res. Eng. Technol.*, vol. 05, no. 03, pp. 80–84, 2016.

[22] M. Swan, "Sensor Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0", Journal of Sensor and Actuator Networks, vol. 1, no. 3, pp. 217-253, 2012. Available: 10.3390/jsan1030217.

[23] Sun Microsystems Healthcare Division. Surveys Say RFID Technology Saves Money, HELP PATIENTS,” 2005. [Online]. Available: www.sun.com/br/0205. [Accessed 22 march 2017].

[24] John, “Health Problems 10th Revision, Vol 2. Instruction Manual. by World Health Organisation, 1993. 160 pp, Sw fr 40. Hardback. ISBN: 92-4-154420-1,” Journal of the Royal Society of Health, vol. 114, no. 6, p. 339, 1994

[25] S. Standing and C. Standing, “Mobile technology and healthcare: The adoption issues and systemic problems,” *Int. J. Electron. Healthc.*, vol. 4, no. 3–4, pp. 20–40, 2008.

[26]"Non-Stop Engineering", Nonstopengineering.blogspot.com, 2017. [Online]. Available: https://nonstopengineering.blogspot.com/. [Accessed: 27- Sep- 2017].

[27] H. John, “Health Problems 10th Revision, Vol 2. Instruction Manual. by World Health Organisation, 1993. 160 pp, Sw fr 40. Hardback. ISBN: 92-4-154420-1,” *Journal of the Royal Society of Health*, vol. 114, no. 6, p. 339, 1994.

[28] E. J. Topol, The creative destruction of medicine, New York: basic books, 2013.

[29] Chen, J.C., Collins, and T.J.: Creation of a RFID Based Real Time Tracking (R-RTT) System for Small Healthcare Clinics. Journal of Medical Systems 36, 3851–3860 (2012)

[30]2018. [Online]. Available: https://online.king.edu/healthcare/digitizing-healthcare-how-technology-is-improving-medical-care/. [Accessed: 24- Jul- 2018].

[31] Digitizing Care, “King University,” [Online]. Available: http://online.king.edu/healthcare/digitizing-healthcare-how-technology-is-improving-medical-care/. [Accessed 06 september 2017].

[32] S. Yau and F. Karim, "An Adaptive Middleware for Context-Sensitive Communications for Real-Time Applications in Ubiquitous Computing Environments", Real-Time Systems, vol. 26, no. 1, pp. 29-61, 2004. Available: 10.1023/b:time.0000009305.62647.ee.

[33] D. Trček, "Wireless Sensors Grouping Proofs for Medical Care and Ambient Assisted-Living Deployment", Sensors, vol. 16, no. 1, p. 33, 2016. Available: 10.3390/s16010033.

[34] C. Höfer and G. Karagiannis, "Cloud computing services: taxonomy and comparison", Journal of Internet Services and Applications, vol. 2, no. 2, pp. 81-94, 2011. Available: 10.1007/s13174-011-0027-x.

[35] J. Stankovic, "Research Directions for the Internet of Things", IEEE Internet of Things Journal, vol. 1, no. 1, pp. 3-9, 2014. Available: 10.1109/jiot.2014.2312291.

[36] I. Mashal, O. Alsaryrah, T. Chung, C. Yang, W. Kuo and D. Agrawal, "Choices for interaction with things on Internet and underlying issues", Ad Hoc Networks, vol. 28, pp. 68-90, 2015. Available: 10.1016/j.adhoc.2014.12.006.

[37] H. Ning and Z. Wang, "Future Internet of Things Architecture: Like Mankind Neural System or Social Organization Framework?", IEEE Communications Letters, vol. 15, no. 4, pp. 461-463, 2011. Available: 10.1109/lcomm.2011.022411.110120.

[38] C. Chang, S. Narayana Srirama and R. Buyya, "Indie Fog: An Efficient Fog-Computing Infrastructure for the Internet of Things", Computer, vol. 50, no. 9, pp. 92-98, 2017. Available: 10.1109/mc.2017.3571049.

[39] W. Mutale *et al.*, “Assessing capacity and readiness to manage NCDs in primary care setting: Gaps and opportunities based on adapted WHO PEN tool in Zambia,” *PLoS One*, vol. 13, no. 8, pp. 1–10, 2018.

[40] Ministry of Health, "e-Health strategy", ministry of health, Lusaka, 2017.

[41] H. Situation and H. Policies, “WHO Zambia Report,” pp. 2–3, 2018.

[42] Gumede-Moyo S, Todd J, Bond V, Mee P, Filteau S. A qualitative inquiry into implementing an electronic health record system (SmartCare) for prevention of mother-to-child transmission data in Zambia: a retrospective study. *BMJ Open*. 2019;9(9):e030428. Published 2019 Sep 6. doi:10.1136/bmjopen-2019-030428

[43] Z. M. K., “a Review Paper on Smart Health Care System Using Internet of Things,” *Int. J. Res. Eng. Technol.*, vol. 05, no. 03, pp. 80–84, 2016.

[44] Clarke KEN, Phiri Chibawe C, Essiet-Gibson I, et al. Strengths, pitfalls, and lessons learned in implementing electronic collection of childhood vaccination data in Zambia: The SmartCare experience. *Int J Med Inform*. 2019;129:146-153. doi:10.1016/j.ijmedinf.2019.06.006

[45] F. Chiumya, S. Tembo, F. Chiumya and S. Tembo, "Design of an Affordable Body Sensor Network for Prevention of Non Communicable Diseases", Article.sapub.org, 2017. [Online]. Available: http://article.sapub.org/10.5923.j.ijpt.20160503.01.html. [Accessed: 29- Oct- 2017].

[46] D. NAWA, 2018. [Online]. Available: http://www.daily-mail.co.zm/uth-medical-records-earmarked-to-enter-digital-era/. [Accessed: 13- Nov- 2018].

[47] Z. Pang, L. Zheng, J. Tian, S. Kao-Walter, E. Dubrova and Q. Chen, "Design of a terminal solution for integration of in-home health care devices and services towards the Internet-of-Things", Enterprise Information Systems, vol. 9, no. 1, pp. 86-116, 2013. Available: 10.1080/17517575.2013.776118.

[48] P. M. ELLWOOD, HEALTH INFORMATION MANAGMENT: INTERGRATING INFORMATION TECHNOLOGY, NEW YORK, 1995.

[49] G. Marques and R. Pitarma, "An Indoor Monitoring System for Ambient Assisted Living Based on Internet of Things Architecture", International Journal of Environmental Research and Public Health, vol. 13, no. 11, p. 1152, 2016. Available: 10.3390/ijerph13111152.

[50] L. GAO, "Building of Smart Home Medical System Based on Internet of Things", Internet of Things and Cloud Computing, vol. 4, no. 3, p. 34, 2016. Available: 10.11648/j.iotcc.20160403.14.

[51] D. Wasankar, D. Gulhane and G. L. K., "Application of Internet of Things in the Field of Medical and Smart Health Care: A Review", IARJSET, vol. 4, no. 4, pp. 52-56, 2017. Available: 10.17148/iarjset.2017.4410.

[52]Ijircce.com, 2018. [Online]. Available: http://www.ijircce.com/upload/2016/december/45_Health_IEEE.pdf. [Accessed: 19-Jul- 2018].

[53]2017. [Online]. Available: http://www.ermt.net/docs/papers/Volume_6/8_August2017/V6N7-101.pdf. [Accessed: 27-Aug-2018].

[54] Chen, J.C., Collins, T.J.: Creation of a RFID Based Real Time Tracking (R-RTT) System for Small Healthcare Clinics. Journal of Medical Systems 36, 3851–3860 (2012)

[55]"The Computer-Based Patient Record", 2018. .

[56] M. Amatayakul and A. Sattler. "The Computer-Based Patient Record", 2018.

[57] K. Bisht, 2018. [Online]. Available: https://www.ti.com/store/ti/en/p/product/?p=LM35CAH/NOPB. [Accessed: 18- Dec-2018].

[58] M. Blake, "An Internet of Things for Healthcare", IEEE Internet Computing, vol. 19, no. 4, pp. 4-6, 2015. Available: 10.1109/mic.2015.89. [80]D. Care, "How Technology is Improving Medical Care", King University, 2018. [Online]. Available: https://online.king.edu/healthcare/digitizing-healthcare-how-technology-is-improving-medical-care/. [Accessed: 24- Jul- 2018].

[59] A. Whitmore, A. Agarwal and L. Da Xu, "The Internet of Things—A survey of topics and trends", Information Systems Frontiers, vol. 17, no. 2, pp. 261-274, 2014. Available: 10.1007/s10796-014-9489-2.

[60] Soma Bandyopadhyay, Munmun Sengupta, Souvik Maiti and Subhajit Dutta, "Role Of Middleware For Internet Of Things: A Study", International Journal of Computer Science & Engineering Survey, vol. 2, no. 3, pp. 94-105, 2011. Available: 10.5121/ijcses.2011.2307.

[61] J. Bhagat, "Technology@health: A click that keeps you healthy - PCQuest", PCQuest, 2018. [Online]. Available: https://www.pcquest.com/tech-health-keeps-healthy-click/. [Accessed: 24- Jul- 2018].

[62] S. Kwon et al., "Sinabro: A Smartphone-Integrated Opportunistic Electrocardiogram Monitoring System", Sensors, vol. 16, no. 3, p. 361, 2016. Available: 10.3390/s16030361.

[63]"IEEE Radio Frequency Integrated Circuits (RFIC) Symposium 2005", IEEE Journal of Solid-State Circuits, vol. 40, no. 5, pp. 1208-1208, 2005. Available: 10.1109/jssc.2005.848424.

[64] Tuck et al, "MFRC522 RFID Module [EF03041] - $22.80: ElecFreaks Store", Elecfreaks.com, 2017. [Online]. Available: http://www.elecfreaks.com/store/mfrc522-rfid-module-p-721.html. [Accessed: 27- Sep- 2017].

[65] "Radio-frequency identification (RFID)/sta je rfid chip", YouTube, 2017. [Online]. Available: https://www.youtube.com/watch?v=rB1Ptj3233E. [Accessed: 27- Sep- 2017].

[66] Aqeel-ur-Rehman, S. U. Rehman, I. U. Khan, M. Moiz, and S. Hasan, “Security and privacy issues in IoT and RFID,” *Int. J. Commun. Networks Inf. Secur.*, vol. 8, no. 3, pp. 147–157, 2016.

[67] "RFID Applications in Supply Chain Management - Vizinex RFID", Vizinex RFID, 2017. [Online]. Available: https://www.vizinexrfid.com/rfid-applications-in-supply-chain-management/. [Accessed: 27- Sep- 2017].

[68] "Radio-frequency identification", En.wikipedia.org, 2017. [Online]. Available: https://en.wikipedia.org/wiki/Radio-frequency_identification. [Accessed: 27- Sep- 2017].

[69] "Modern RFID Readers", Microwavejournal.com, 2017. [Online]. Available: http://www.microwavejournal.com/articles/5271-modern-rfid-readers. [Accessed: 27- Sep- 2017].

[70] EPCGlobal, EPC Radio-Frequency Identity Protocols,Class-1 Generation-2 UHF RFID Protocol for Communications at 860MHz-960MHz Version 1.2.0 (2008)

[71] W. Wen, L. Wang and L. Cao, "Research on the Coding and Decoding Technology in ISO/IEC 14443 TYPEA of RFID", Applied Mechanics and Materials, vol. 263-266, pp. 2885-2889, 2012. Available: 10.4028/www.scientific.net/amm.263-266.2885.

[72] Nxp.com, 2018. [Online]. Available: https://www.nxp.com/docs/en/data-sheet/MFRC523.pdf. [Accessed: 19- Dec- 2018].

[73] S. Sundaresan, R. Doss, and W. Zhou, "RFID in Healthcare -- Current Trends and the Future," in *Mobile Health: A Technology Road Map*, S. Adibi, Ed. Cham: Springer International Publishing, 2015, pp. 839–870

[74] R. Want, "An introduction to RFID technology," *IEEE Pervasive Comput.*, vol. 5, no. 1, pp. 25–33, 2006.

[75] E. Lutton, B. Regan, and G. Skinner, "Patient Identification within a Healthcare System: The Role of Radio Frequency Identification and Bar Code Technologies," pp. 264–269, 2009.

[76] S. Zeibig, "Radio Frequency Identification (RFID)," Controlling, vol. 18, no. 1, pp. 51-52, 2006.

[77] M. A. Khan, M. Sharma and Prabhu, "A Survey of RFID tags," International Journal of Recent Trends in Engineering, vol. 1, no. 4, pp. 68-72, 2009

[78]2017.[Online]. Available: http://www.ermt.net/docs/papers/Volume_6/8_August2017/V6N7-101.pdf. [Accessed: 27- Sep- 2017].

[79] "NHS barcode project aimed at improving patient safety | Digital Health", Digital Health, 2019. [Online]. Available: https://www.digitalhealth.net/2017/01/nhs-barcode-project-aimed-at-improving-patient-safety/. [Accessed: 02- Jan- 2019].

[80] J. Best, "RFID comes to European Hospitals," 2005.

[81] W. Wen, L. Wang and L. Cao, "Research on the Coding and Decoding Technology in ISO/IEC 14443 TYPEA of RFID", Applied Mechanics and Materials, vol. 263-266, pp. 2885-2889, 2012. Available: 10.4028/www.scientific.net/amm.263-266.2885.

[82] Nxp.com, 2018. [Online]. Available: https://www.nxp.com/docs/en/data-sheet/MFRC523.pdf. [Accessed: 19- Dec- 2018

[83] H. Boyes, B. Hallaq, J. Cunningham, and T. Watson, "The industrial internet of things (IIoT): An analysis framework," *Comput. Ind.*, vol. 101, no. December 2017, pp. 1–12, 2018.

[84] J. Stankovic, "Research Directions for the Internet of Things", IEEE Internet of Things Journal, vol. 1, no. 1, pp. 3-9, 2014. Available: 10.1109/jiot.2014.2312291.

[85] S. Yau and F. Karim, "An Adaptive Middleware for Context-Sensitive Communications for Real-Time Applications in Ubiquitous Computing Environments", Real-Time Systems, vol. 26, no. 1, pp. 29-61, 2004. Available: 10.1023/b:time.0000009305.62647.ee.

[86] S. Abughazalah, K. Markantonakis and K. Mayes, "A Formally Verified Mutual Authentication Protocol for Low-Cost RFID Tags", International Journal of RFID Security and Cryptography, vol. 3, no. 2, pp. 156-169, 2014. Available: 10.20533/ijrfidsc.2046.3715.2014.0018.

[87] J. LUO, "Research on cryptology mechanism of trusted computing platform module", Journal of Computer Applications, vol. 28, no. 8, pp. 1907-1911, 2008. Available: 10.3724/sp.j.1087.2008.01907.

[88] O. Bello, S. Zeadally and M. Badra, "Network layer inter-operation of Device-to-Device communication technologies in Internet of Things (IoT)", Ad Hoc Networks, vol. 57, pp. 52-62, 2017. Available: 10.1016/j.adhoc.2016.06.010.

[89] W. Neil, “Automation of a Beckman liquid scintillation counter for data capture and data-base management,” Journal of Automatic Chemistry, vol. 10, no. 2, pp. 106-109, 1988

[90] P. Sethi and . S. R. Sarangi, “Internet of Things: Architectures, Protocols, and Applications,” Journal of Electrical and Computer Engineering, vol. 2017.

[91] I. Peña-López, “ Itu Internet Report 2005,” 2005.

[92] D. Evans, “The Internet of Things,” [Online]. Available: http://blogs.cisco.com/news/the-internet-of-things-infographic. [Accessed 12 octber 2017].

[93] M. Swan, “Sensor Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0,” [Online]. Available: http://www.mdpi.com/2224-2708/1/3/217/htm. [Accessed 12 october 2017].

[94] L. Patrono, “Integrating Passive UHF RFID Tags with WSN Nodes: Challenges and Opportunities,” Journal of Communications Software and Systems, vol. 2, no. 10, p. 99, 2014.

[95] M. Mubarak and. J.-l. A. Manan, “A Critical Review on RFID System towards Security, Trust, and Privacy (STP),” in IEEE 7th International Colloquium on Signal Processing and its Applications, 2011

[96] N. Lane, E. Miluzzo, H. Lu, D. Peebles, T. Choudhury and A. Campbell, "A survey of mobile phone sensing", IEEE Communications Magazine, vol. 48, no. 9, pp. 140-150, 2010.

[97] A. Rica and L. Gan, "The Internet of Things—A survey of trends", Information Systems Frontiers, vol. 18, no. 4, pp. 100-216, 2018.

[98] Aqeel-ur-Rehman, S. U. Rehman, I. U. Khan, M. Moiz, and S. Hasan, “Security and privacy issues in IoT,” *Int. J. Commun. Networks Inf. Secur.*, vol. 8, no. 3, pp. 147–157, 2016.

[99] Who.int, 2018. [Online]. Available: http://www.who.int/goe/policies/countries/zwe_ehealth.pdf. [Accessed: 02- Nov-2018].

[100] A. Kanungo, Hst.org.za, 2018. [Online]. Available: http://www.hst.org.za/publications/NonHST%20Publications/eHealth_Strategy_South_Africa_2012-2016.pdf. [Accessed: 02- Nov- 2018].

[101] M. Matsoso, Hst.org.za, 2018. [Online]. Available: http://www.hst.org.za/publications/NonHST%20Publications/eHealth_Strategy_South_Africa_2012-2016.pdf. [Accessed: 02- Nov- 2018].

[102] Repository.up.ac.za, 2018. [Online]. Available: https://repository.up.ac.za/bitstream/handle/2263/20648/Weeks_Healthcare (2012).pdf?sequence=1. [Accessed: 02- Nov- 2018].

[103] J. Mulwanda, Nationalplanningcycles.org, 2018. [Online]. Available: http://www.nationalplanningcycles.org/sites/default/files/planning_cycle_repository/zambia/zambia_ehealth2017.pdf. [Accessed: 02- Nov- 2018].

[104] R. Mehta, "Latest Healthcare Technology Systems Today help Boost Patient Care", Health Works Collective, 2018. [Online]. Available: https://www.healthworkscollective.com/latest-healthcare-technology-systems-today-help-boost-patient-care/. [Accessed: 02- Nov- 2018].

[105] S. Amendola, R. Lodato, S. Manzari and C. Occhiuzzi, "RFID Technology for IoT-Based Personal Healthcare in Smart Spaces - IEEE Journals & Magazine", Ieeexplore.ieee.org, 2018. [Online]. Available: https://ieeexplore.ieee.org/iel7/6488907/6702522/06780609.pdf. [Accessed: 06- Nov- 2018].

[106] N. Karmakar, Handbook of smart antennas for RFID systems. Hoboken, N.J.: Wiley, 2010.

[107] F. Mattern, Rfid Handbook. John Wiley & Sons, 2010.

[108] S. Preradovic and N. Karmakar, "Modern RFID Readers", Microwavejournal.com, 2018. [Online]. Available: http://www.microwavejournal.com/articles/5271-modern-rfid-readers. [Accessed: 09- Nov- 2018] [110]W. Wen, L. Wang and L. Cao, "Research on the Coding and Decoding Technology in ISO/IEC 14443 TYPEA of RFID", Applied Mechanics and

Materials, vol. 263-266, pp. 2890-2899, 2012. Available: 10.4028/www.scientific.net/amm.263-266.2885

[109] S. Preradovic, “ Chipless RFID: Bar Code of the Future,” IEEE Microwave Magazine, Vols. 787-97, no. 11, 2010.

[110] A. Microcontroller, "ATMEGA328P-PU Atmel 8 Bit 32K AVR Microcontroller - Protostack", Protostack, 2018. [Online]. Available: https://protostack.com.au/shop/microcontrollers/atmega328p-pu-atmel-8-bit-32k-avr-microcontroller/. [Accessed: 27- Dec- 2018].

[111]2018. [Online]. Available: https://www.newark.com/c/semiconductors-ics/ic-sensors/ic-temperature-sensors?sensing-accuracy-range=posneg-0.4degf. [Accessed: 18- Dec- 2018].

[112] A. Rghioui, A. L’Aarje, F. Elouaai, and M. Bouhorma, “The Internet of Things for healthcare monitoring: Security review and proposed solution,” *Colloq. Inf. Sci. Technol. Cist*, vol. 2015-January, no. January, pp. 384–389, 2015.

[113] S. K. Yeung, Kwok1 and. H. C. Mui, “International Journal of Engineering Business Management,” An Investigation of an RFID-based Patient-tracking and Mobile Alert System.

“INTERNATIONAL STANDARD ISO / IEC Information technology — Automatic identification and data capture,” vol. 2011, 2011.

[114] A. McEwen and H. Cassimally, “The Internet of Things: An Overview,” *Des. Internet Things*, no. October, p. 8, 2013.

[115] Ni L.M., Liu Y., Lau Y.C., Patil A.P. LANDMARC: Indoor location sensing using active RFID; Proceedings of the First IEEE International Conference on Pervasive Computing and Communications, 2003. (PerCom 2003); Fort Worth, TX, USA. 26–26 March 2003; pp. 407–415

[116] V. Mishra, “Use of Wireless Devices and Iot in management of Diabetes,” no. November 2017, 2019.

[117]"ESP8266 WiFi Module make smart plug Internet of Things Application. | Arduino | Pinterest | Wifi, Projects and Arduino", Pinterest, 2018. [Online]. Available: https://www.pinterest.com/pin/695946948638294119/. [Accessed: 18- Dec- 2018].

[118]"Timers & Controllers Archives - Circuit Ideas I Projects I Schematics I Robotics", Circuit Ideas I Projects I Schematics I Robotics, 2018. [Online]. Available: http://www.twovolt.com/category/timer-controllers/. [Accessed: 18- Dec- 2018].

[119] P. Satyavolu, B. Setlur, P. Thomas, and G. Iyer, "Designing for Manufacturing's 'Internet of Things,'" *Technol. Solut. Cogniz.*, pp. 4–14, 2015.

[120] E. Wamicha, Study.com, 2018. [Online]. Available: https://study.com/academy/lesson/what-is-object-oriented-analysis-design.html. [Accessed: 19- Dec- 2018].

[121] 2018. [Online]. Available: https://www.researchgate.net/post/What_are_the_advantages_and_disadvantages_of_mix_method_research. [Accessed: 03- May- 2018].

[122] R. Timans, P. Wouters, and J. Heilbron, "Mixed methods research: what it is and what it could be," *Theory Soc.*, vol. 48, no. 2, pp. 193–216, 2019.

[123]2018. [Online]. Available: https://www.researchgate.net/post/What_is_triangulation_of_data_in_qualitative_research_Is_it_a_method_of_validating_the_information_collected_through_various_methods. [Accessed: 19- Dec- 2018].

[124] D. Bell, "The Sage Encyclopedia of Qualitative Research Methods2009365Lisa M. Given. The Sage Encyclopedia of Qualitative Research Methods. Thousand Oaks, CA: Sage Publications 2008. , ISBN: 978 1 4129 6390 9 £240/$435 Last visited May 2009 URL: http://SAGE-ereference.com/research/ Also available as a 2 vol. printed set (ISBN 978 1 4219 4163; £215/$350)", Reference Reviews, vol. 23, no. 8, pp. 24-25, 2009. Available: 10.1108/09504120911003302.

[125]"Purposive sampling | Lærd Dissertation", Dissertation.laerd.com, 2018. [Online]. Available: http://dissertation.laerd.com/purposive-sampling.php. [Accessed: 03- May- 2018]

[126] P. Johannesson, Introduction to design science. Cham: Springer, 2014.

[127] H. Phtiaka, "Book Review: MICHAEL BLOOR and FIONA WOOD, Keywords in Qualitative Methods: A Vocabulary of Research Concepts. London: Sage, 2006", Qualitative Research, vol. 10, no. 3, pp. 389-390, 2010. Available: 10.1177/14687941100100030607.

[128] A. DRESCH, DESIGN SCIENCE RESEARCH. [S.l.]: SPRINGER INTERNATIONAL PU, 2016.

[129] C. Lougen, "Sources: The Sage Encyclopedia of Qualitative Research Methods", Reference & User Services Quarterly, vol. 49, no. 1, pp. 101-102, 2009. Available: 10.5860/rusq.49n1.101.

[130]] Ijritcc.org, 2018. [Online]. Available: http://www.ijritcc.org/download/browse/Volume_5_Issues/January_17_Volume_5_Issue_1/1486109693_03-02-2017.pdf. [Accessed: 27- Dec- 2018].

[131]2017. [Online]. Available: https://www.researchgate.net/publication/232206641_Problem_Statement_Conceptual_Framework_and_Research_Question. [Accessed: 03- Nov- 2017]. [53]Pandey, "Conceptual framework", Slideshare.net, 2017. [Online]. Available: https://www.slideshare.net/achyutrajpandey/conceptual-framework-78233740. [Accessed: 03- Nov- 2017].

[132] Pandey, "Conceptual framework", Slideshare.net, 2017. [Online]. Available: https://www.slideshare.net/achyutrajpandey/conceptual-framework-78233740. [Accessed: 03- Nov- 2017

[133] H. Sensor, "Buy Heart Beat Sensor online in India at low price from DNA Technology, Nashik", Dnatechindia.com, 2018. [Online]. Available: http://www.dnatechindia.com/Heart_Beat_Sensor.html. [Accessed: 27- Dec- 2018].

[134] "Thumb Heart Beart Sensor", Nskelectronics.com, 2018. [Online]. Available: http://www.nskelectronics.com/thumb_heart_beart_sensor.html. [Accessed: 27- Dec- 2018].

[135] "Movable patient health monitoring using GPS - IET Conference Publication", Ieeexplore.ieee.org, 2018. [Online]. Available: https://ieeexplore.ieee.org/document/6193559/. [Accessed: 27- Dec- 2018].

[136] "How to Use an RFID RC522 on Raspberry Pi - Wiki", Wiki.sunfounder.cc, 2018. [Online]. Available: http://wiki.sunfounder.cc/index.php?title=How_to_Use_an_RFID_RC522_on_Raspberry_Pi. [Accessed: 27- Dec- 2018].

[137] "Avnet: Quality Electronic Components & Services", Avnet.com, 2018. [Online]. Available: https://www.avnet.com/shop/emea/products/nxp/mfrc52202hn1-151-3074457345634452275/. [Accessed: 27- Dec- 2018].

[138] "The MFRC522 is a highly integrated reader/writer IC for contactless communication at 13.56 MHz. The MFRC522 reader supports ISO/IEC 1444… | Electronics | Pinterest | Rfid arduino, Arduino and Electronics", Pinterest, 2018. [Online]. Available: https://www.pinterest.com/pin/311452130464589841/. [Accessed: 27- Dec- 2018].

[139] A. Microcontroller, "ATMEGA328P-PU Atmel 8 Bit 32K AVR Microcontroller - Protostack", Protostack, 2018. [Online]. Available: https://protostack.com.au/shop/microcontrollers/atmega328p-pu-atmel-8-bit-32k-avr-microcontroller/. [Accessed: 27- Dec- 2018

[140] "Arduino - ScanAndMake", ScanAndMake, 2018. [Online]. Available: https://scanandmake.com/arduino/. [Accessed: 18- Dec- 2018].

[141] O. Gabry, "Object-Oriented Analysis And Design — Introduction (Part 1)", Medium, 2018. [Online]. Available: https://medium.com/omarelgabrys-blog/object-oriented-analysis-and design-introduction-part-1-a93b0ca69d36. [Accessed: 19- Dec- 2018].

[142] U. Erickson, Reqtest.com, 2018. [Online]. Available: https://reqtest.com/requirements-blog/functional-vs-non-functional-requirements/. [Accessed: 19- Dec- 2018].

[143] B. Padmanabhan, "Unified Modeling Language (UML) Overview," *Princ. Softw. Eng.*, pp. 1–20, 2012.

[144] "Open Source IOT Development Platform | IOTGecko", Iotgecko.com, 2018. [Online]. Available: http://iotgecko.com/NewRequirement.aspx. [Accessed: 19- Dec- 2018].

[145] "PHP Mock Test TutorialsPoint", www.tutorialspoint.com, 2018. [Online]. Available: https://www.tutorialspoint.com/php/php_mock_test.htm. [Accessed: 19- Dec- 2018].

[146] "Apache Web Host Service | Department of Mathematics | NC State University", Math.sciences.ncsu.edu, 2018. [Online]. Available: https://math.sciences.ncsu.edu/faculty-and-staff-resources/informationtechnology/apache-web-hosting-service/. [Accessed: 19- Dec- 2018].

APPENDIX

Appendix A: Data collection questionnaire

THE UNIVERSITY OF ZAMBIA

QUESTIONNAIRE

Dear Respondent,

I am a student at the University of Zambia pursuing a Master of Engineering in information Communications. As partial fulfilment for the award of a Master of Science degree, I am carrying out a study on**:**
You are one of those who have been selected to participate in this study. This study is strictly for academic purposes and your responses will be treated with strictest confidentiality.

Section A: Personal Demographic Data

1. What is your sex

a) Male

b) Female

2. How old were you on your last birthday?

3. What is your level of education?

a) Certificate

b) Diploma

c) Degree

d) Master Degree

e) Doctorate

f) Others specify

………………………………………………………………………….

4. What is your occupation (Applies only to Hospital staff only)?

a) Doctor

b) Nurse

c) Administrative officer

d) Registry clerk

e) Others

…………………………………………………………………

5. What is your level of income?

a) Between K 500 – K 2500

b) Between K 2500- K 5000

c) Between K 5000- K 7500

d) Above K7500

e) Others specify …………………………………………………….

Section B: Challenges with the current registration system at the Hospital

Part A

1. Kindly describe the process of registration at the Hospital at your first visit.

…………………………………………………………………………………

………………………………..

2. What is your experience with the registration process at the Hospital?

…………………………………………………………………………………

…………………………………..

3. What challenges have you had at the hospital

…………………………………………………………………………………

………………………………..

4. Have you had your medical files misplaced, lost or ruined at the hospital

Yes ☐ No ☐

5. Have you ever been given another patients medical files or miss-identified by a doctor or nurse?

Yes ☐ No ☐

6. Have you ever been given wrong medication before?

Yes ☐ No ☐

7. What are some of the possible solutions to the challenges stated?

…………………………………………………………………………

………………………………..

8. On average how long does it take to have your vitals taken and recorded?

…………………………………………………………………………

…………………………………..

9. Do you recommend a that Remote monitoring and Tracking system is required at the hospital?

If yes, why recommend the Remote Monitoring and Tracking system at the Hospital

…………………………………………………………………………

…………………………………..

If No, why not recommend the Remote Monitoring and Tracking system at

at the Hospital

……………………………………………………………………………
……………………………………...

10. Lastly recommend what improvements you would want to see from current system

……………………………………………………………………………
……………………………………

Section C: Access to the internet

1. Do you have a mobile phone?

Yes ☐ No ☐

2. Is your phone a smart phone?

Yes ☐ No ☐

3. Do you have access to the internet?

Yes ☐ No ☐

4. How do you access the internet?

Personal Mobile Devices (e.g. Phones, Tablets, Dongles) ☐

Through place of work (internet or employer) ☐

Public Wi-Fi (e.g. internet café) ☐

5. How easily accessible and affordable is internet in your area

Yes ☐ No ☐

6. Which internet provider is available in your area

Section D: System challenges [Hospital Staff Only]

1. What challenges have you had with the current Manuel system

……………………………………………………………………………

…………………………………..

2. Have you had experience with losing a patient's medical files

....

3. Have you ever miss-identified a patient due to wrong information on their medical files?

……………………………………………………………………………

…………………………………..

4. What are some of the possible solutions to the challenges started?

……………………………………………………………………………

…………………………………..

Section E: Developing of the IoT-RFID Tracking and Monitoring System

1. Do you think introduction of the IoT-RFID system would improve the services and conditions at the hospital?

Yes ☐ No ☐ Not Sure ☐

2. Would you recommend using IoT-RFID system for tracking and monitoring at the Hospital?

Yes ☐ No ☐ Not Sure ☐

Appendix B: Source code for the IoT monitoring

```
#include <LiquidCrystal.h>


/////constants//////

int update_st = 0;

int cmd=1; int i = 0;

int reset=0;

int last_beats=0;

String str;

String str1="GET /IOTheart.aspx?id=ag19952@gmail.com&pass=7966&rate=";

String str2="&tmp=";

String str3=" HTTP/1.1\r\nHost: www.iotgecko.com";

String inputString="";


long time1;

long time2;

int beats=0,last_rate;

float temp = 0;

//////pins//////

const int HR_RX = 6;

const int lm35 = A0;


SoftwareSerial esp8266(A4,A5); // make RX Arduino line is pin 2, make TX Arduino line is pin 3.
```

```
// This means that you need to connect the TX line from the esp to the Arduino's pin 2
                              // and the RX line from the esp to the Arduino's pin 3
LiquidCrystal lcd(7,13,9,10,11,12);


void setup()
{
  Serial.begin(9600);
  lcd.begin(16, 2);
  pinMode(HR_RX,INPUT);
  lcd.clear();
  lcd.print("  IOT Patient  ");
  lcd.setCursor(0, 1);
  lcd.print(" Health monitor ");
  delay(2000);
  lcd.clear();
  lcd.print("Connecting Wifi");
  esp8266.begin(9600)// your esp's baud rate might be different
  sendData("AT+CWAUTOCONN=0\r\n","OK",2000,1);
  sendData("ATE0\r\n","OK",1000,1);
  sendData("AT+CIPMUX=1\r\n","OK",2000,1);    //    configure    for    multiple
connections
  sendData("AT+CWMODE=3\r\n","OK",2000,1); // configure as access point
  sendData("AT+CWJAP=\"iotpatient\",\"project1234\"\r\n","OK",10000,1);
```

```
sendData("AT+CIPSTART=4,\"TCP\",\"www.iotgecko.com\",80\r\n","OK",5000,1);
  reset=0;

  lcd.clear();
  lcd.print("Connected...");
  delay(1000);
  lcd.clear();
  lcd.print("Beats/minute:");
  lcd.print(beats);
  lcd.setCursor(0,1);
  lcd.print("Temp:");
  lcd.print(temp);
  lcd.print(F("\337C"));
  reset=0;
}

void loop()
{
  if(reset==1)
  {
    lcd.clear();
    lcd.print("connection lost..");
```

```
delay(1500);
lcd.clear();
lcd.print("Trying to ");
lcd.setCursor(0,1);
lcd.print("reconnect...");
sendData("AT+CIPCLOSE=4\r\n\r\n","OK",1000,1);
sendData("AT+CIPMUX=1\r\n","OK",1000,1); // configure for multiple connections
sendData("AT+CWMODE=3\r\n","OK",1000,1); // configure as access point
sendData("AT+CWJAP=\"iotpatient\",\"project1234\"\r\n","OK",10000,1);
sendData("AT+CIFSR\r\n","OK",1000,1); // get ip address

sendData("AT+CIPSTART=4,\"TCP\",\"www.iotgecko.com\",80\r\n","OK",5000,1);
reset=0;
lcd.clear();
lcd.print("Connected....");
delay(1500);
lcd.clear();
lcd.print("Beats/minute:");
lcd.print(beats);
lcd.setCursor(0,1);
lcd.print("Temp:");
lcd.print(temp);
lcd.print(F("\337C"));
```

```
}
else
{
  hbt();
  temperature();
  lcd.clear();
  lcd.print("Beats/minute:");
  lcd.print(beats);
  lcd.setCursor(0,1);
  lcd.print("Temp:");
  lcd.print(temp);
  lcd.print(F("\337C"));

  str="";
  str +=str1;
  str += (String)beats ;
  str += str2;
  str += (String)temp;
  str += str3;

  String len=String(str.length()) + "\r\n" ;
  sendData("AT+CIPSEND=4,",">",100,0);
  sendData(len,">",2000,1);
```

```
    sendData(str,"</html>",10000,1);
  }

}

void hbt()
{
  int k=0;
  long t_out1 = millis();
  bool zero = false;
  while(k<15)
  {
   if(digitalRead(HR_RX))
   {
    t_out1 = millis();
    if(k==0)
    time1=millis();
    k++;
   }
    if(millis() - t_out1 > 2000)
    {
      zero = true;
      break;
```

```
    }
  }
  if(!zero)
  {
    time2=millis();
    beats=time2-time1;
    beats=beats/15;
    beats=60000/beats;
  }
}
void temperature()
{
  temp = analogRead(lm35)/2;
}

void sendData(String cmd,String response,int timeout,int debug)
{
  esp8266.print(cmd);
  if(debug==1)
  {
    long current_time=millis();
```

```
  while((inputString.endsWith(response)==false)&&((current_time+timeout)>millis(
  )))
   {
     inputString="";
     while(esp8266.available()>0)
     {
       char inChar = (char)esp8266.read();
   inputString += inChar;
     }
     if(inputString.indexOf("ERROR")>=0)
     {
       reset=1;
     }
   }
  }
}
```