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Near-Field Communication Based-Model for Health Information Portability



Master of Science in Computer-Based Information Systems

2016

Near-Field Communication Based-Model for Health Information Portability

Paul Morumbwa Onyancha

**Submitted In Partial Fulfillment of the Requirements for the Degree of Master of Science
in Computer-Based Information Systems at Strathmore University**

Faculty of Information Technology

Strathmore University

Nairobi, Kenya

June, 2016

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Abstract

Health Information Portability is an important concept in the healthcare sector because of the patient's ability to carry their medical data when visiting a health care center. Data that can be stored in hitherto time-honored systems such as Health Information Systems and Electronic Medical Record (EMR) systems is diverse and hence a need for a focused approach on the data to be stored and retrieved securely when needed. Empirical evidence shows a lack of clear technological solution for Health Information Portability in the era of efficiency of mobile devices accessing stored EMRs. Near Field Communication (NFC) technology presents a new dimension for enterprises such that with NFC tags, any object can be turned into a digital data point that can transfer information to NFC-enabled mobile devices using short range radio waves. In this research, agile development methodology was used and different systems, models and prototypes incorporating NFC tags, NFC readers, mobile application, encryption and decryption studied and their beneficial aspects borrowed to create a novel application that runs on the doctor's NFC-enabled phone that can read and write into a patient's NFC-enabled medical card. Security features such as password, decryption and encryption of data on the NFC card and the vital EMR data necessary as per doctor's recommendations, which included patient's name, allergies and blood group, were incorporated. A model developed showing communication from a host PC and a mobile phone client demonstrated the machine-to-machine communication NFC concept. Authentication, data capture and deploy, data view and edit, mobile to host PC connection were tested and all showed a pass. This system will help reduce incidences of duplication of medical tests leading to reduction in medical costs for patients, assist doctors in making quick clinical decisions and also form the basis for future research on NFC in healthcare.

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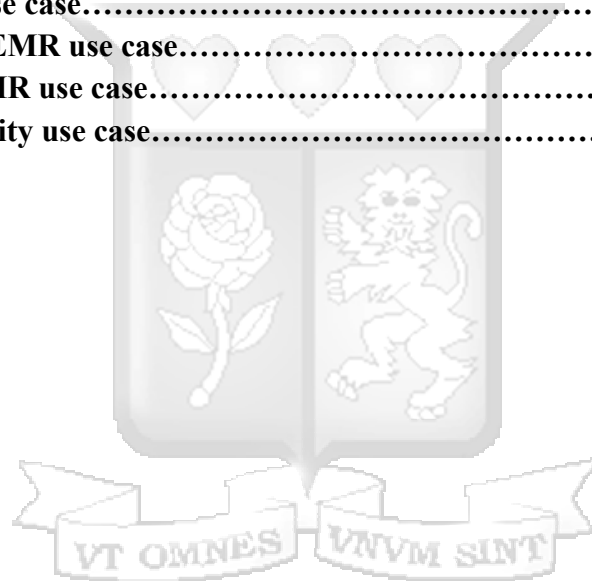
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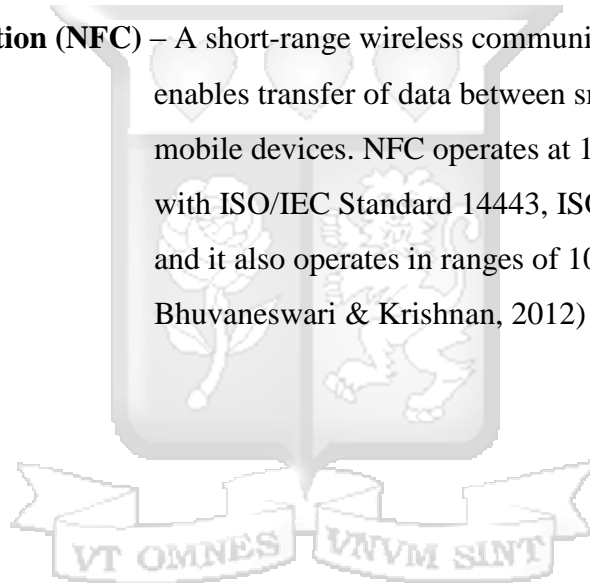
Abbreviations/Acronyms

AIDE	- Android Integrated Development Environment
API	- Application Programming Interface
CDMA	- Code Division Multiple Access
DB	- Database
EHR	- Electronic health record
EMR	-Electronic medical record
GSM	-Global System for Mobile
HIE	- Health Information Exchange
HIPAA	- Health Insurance Portability and Accountability Act
HTML	- Hypertext Markup Language
M2M	- Machine to Machine communication
MTP	- Media Transfer protocol
IDE	- Integrated Development Environment
NFC	- Near Field Communication
OEM	- Original Equipment Manufacturer
PC	- Personal Computer
PHI	- Protected Health Information
RFID	- Radio-Frequency identification
SDK	- Software Development Kit
UI	- User Interface

Definition of Terms

Health Information Portability- The ability of health information to be stored in a medium and this information can move as defined by the 1996 The Health Insurance Portability and Accountability Act (HIPAA) that was designed to protect health information. (Cuper, 2012)

Near Field Communication (NFC) – A short-range wireless communication technology that enables transfer of data between smartphones and similar mobile devices. NFC operates at 13.56 MHz and complies with ISO/IEC Standard 14443, ISO/IEC Standard 18092 and it also operates in ranges of 10 cm or less. (Devendran, Bhuvaneshwari & Krishnan, 2012)



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Dedication

I would like to dedicate this research work to my lecturers at the faculty of Information Technology and Professor Ismail Ateya Lukandu for his guidance during the class seminars.

To my family members- My father Benson Morumbwa, mother Annastancia Bwari, Aspenas, Dolphine, Richard, Brenda, Treezer, Conrad, Florence, Dr Evans Atera, Zipporah, Duncan, Grace, George, Enoch and Sylvia for your moral support. This research is for all of you who told encouraged me and stood by me every step of the way.



CHAPTER 1: INTRODUCTION

1.1 Background of Study

Health data portability has been defined as the ability of health information to be stored in a medium and this information can move as defined by the 1996 Health Insurance Portability and Accountability Act (HIPAA) that was designed to protect health information. (Cuper, 2012)

Health information portability has been described by scholars as a crucial concept in the health sector as elaborated by the need to have patient data available to healthcare personnel in times of emergency where availability of patient's critical data such as blood group type, past medical history, allergies to drugs can save lives. (Dünnebeil, Köbler, Koene, Leimeister & Krcmar, 2011) The biggest question in this case is not just why we need to have patients move with their data from one healthcare center to the next but also to research on the medium on which this data can be stored.

In the development of applications that store and manage patient's data, a great number of operational, security and cost issues are raised and recent research has shown that in a health care milieu when Near Field Communication (NFC) technology is employed, there is a marked reduction in health care costs. NFC technology also facilitates automating and streamlining of patient identification processes in hospitals and there is a great need to incorporate mobile phone applications to achieve health information portability. (Krishna, Sreevardhan, Karun, & Kumar, 2013)

Devendran et al. (2012) points out that even though primary care physicians are open to the idea of adoption of electronic medical record (EMR) systems, a very few of them use such systems in their clinical practice. Devendran et al. (2012) offers an insight into a new paradigm whereby mobile devices are currently offering new ways for users to access medical care data and services in a secure and user-friendly environment. The usage of mobile healthcare technology is therefore regarded as one of the solutions to healthcare costs without reducing the quality of patient care. This research will attempt to highlight the key areas in the mobile phone software technology especially with the development of an application that can be used with the NFC technology.

Health information portability and indeed its usage in the healthcare sector to aid in diagnosis and patient management cannot be evaluated without highlighting the critical security aspects that it should come with and as Dünnebeil et al. (2011) argues, the health data is confidential information that must not openly be available to anyone with physical access to the storage media. Consequently, this puts emphasis on the need for a secure medium that can hold the patient's health data. This research explored four key areas that are crucial for development of an application that ensures that health information portability: content of the health data, structure of the data including data type and schemas, organization of this data and the technology to be used for storage and reading of the data.

1.2 Problem Statement

There is lack of clear technological solution for health information portability even though there is evidence of mobile devices offering ways for users to access EMR data and related services in an efficient way. (Devendran et al., 2012)

The solution is to have a NFC card that the patient carries and this card contains patient's vital health data which then can be read and written from a mobile application. As a proof of concept, there will be development of a model that ensures that the EMR is stored in a database and this data can also be accessed and manipulated.

1.3 Research Objectives

- i) To review the challenges in health information records and portability technologies.
- ii) To review the data on Near-Field Communication health card technology and EMR systems.
- iii) To review the architectures, models and prototypes in health information records and portability technologies.
- iv) To develop a model for NFC health information portability.
- v) To test the model.

1.4 Research Questions

- i) What are the challenges in health information records and portability technologies?
- ii) Which data is available on NFC health card technology and EMR systems?
- iii) What are the architectures, models and prototypes in health information records and portability technologies?
- iv) How will the model be developed?
- v) How will the model be tested?

1.5 Justification

There is a great need for an Information Technology concept designed for the healthcare sector that incorporates all the crucial medical data regarding a patient which ensures that any authorized doctor can access patient's information anywhere and this will improve the healthcare delivery. Radhakrishna, Goud, Kasthuri, Waghmare, and Raj (2014) observe that with the inception of EHR technology, there has been a marked improvement in both the quality and cost of healthcare in developed countries. Lastly, with the ubiquitous nature of mobile phones, there is a great opportunity for the health sector to benefit from it. There will be an exploration of how mobile phone technology, NFC and portable health cards can benefit the health sector and it is on this premise that this research is based.

1.6 Scope

The limitations and the delimitations of this research were based on budgetary, time and technical factors. Dünnebeil et al. (2011) point out that during the development of Encrypted NFC emergency tags based on the German Telematics Infrastructure, passive NFC tags do not provide adequate storage capacity for storage of comprehensive sets of emergency data and encrypted keys at the same time.

Based on that information it is imperative to note that due to the limited holding capacity of the tag, the amount of data to be stored was narrowed down to only the most crucial data that the doctor will need in order to make clinical judgment and offer better healthcare. This was

exemplified by the fact that during the development of the model, the patient's data was limited to patient's name, allergy, medical history, blood group, medical insurance and date when the information on the patient's card was updated. The delimitations were chosen based on objectives, variables, research question and methods of data analysis.

1.7 Limitations

The assumption made is that the data entered into the patient's database by the health care provider at the initial visit by the patient is accurate. Any inaccuracies and omissions of crucial patient's will have an effect in terms of future patient management and this study acknowledged that this was a limitation. Further, this study did not cover all aspects of patient's data because of the consideration that there is limited capacity on the NFC tag and as a result it influenced the amount of EMR data considered for the development of the model .

1.8 Assumptions

The assumptions listed below were made regarding this research:

- a) Data collected in Nairobi West Hospital and the model developed provided the blueprint for the concept of Health Information Portability.
- b) The health practitioners have a standardized health data input method.



CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This section will be divided into different themes to reflect the research objectives and research questions outlined on section 1.3 and 1.4 respectively. This chapter will explore electronic health strategies in Kenya and challenges with the broader issue of electronic medical record technology in the health sector. It will delve into the pertinent areas of NFC technology and the challenges that come with the adoption of this technology with respect to the development of the application under study. This section will further address the various architectures and models in NFC and EMR and offer a critique on their merits and demerits. These considerations formed the building blocks for the development of the application and model.

2.2 Africa's barriers to technology adoption in the healthcare sector

A report on the 2nd global survey on e-health by World Health Organization (WHO) argues that contemporary ICT technologies such as The Internet, cell phones and computers have revolutionized how people communicate and exchange information. Global health problems can therefore be addressed adequately when these ICT tools are employed (WHO, 2010)

Health information portability enables health data to be shared across the health sector and this report outlines four major barriers to its adoption- cost, infrastructure, culture and policy.

Figure 2.1 illustrates those technological barriers in Africa compared to the global prevalence of that barrier. What can be deduced here is that even though the graph indicates that Africa does poorly when compared to its global counterparts, the difference is statistically insignificant. The overall benefit accrued from analysis of the chart on Figure 2.1 is to help this research on the areas which needs to be prioritized if technology in healthcare is to be adopted. In this context, a Pareto Analysis was compared against it and this is further discussed in Chapter 4.

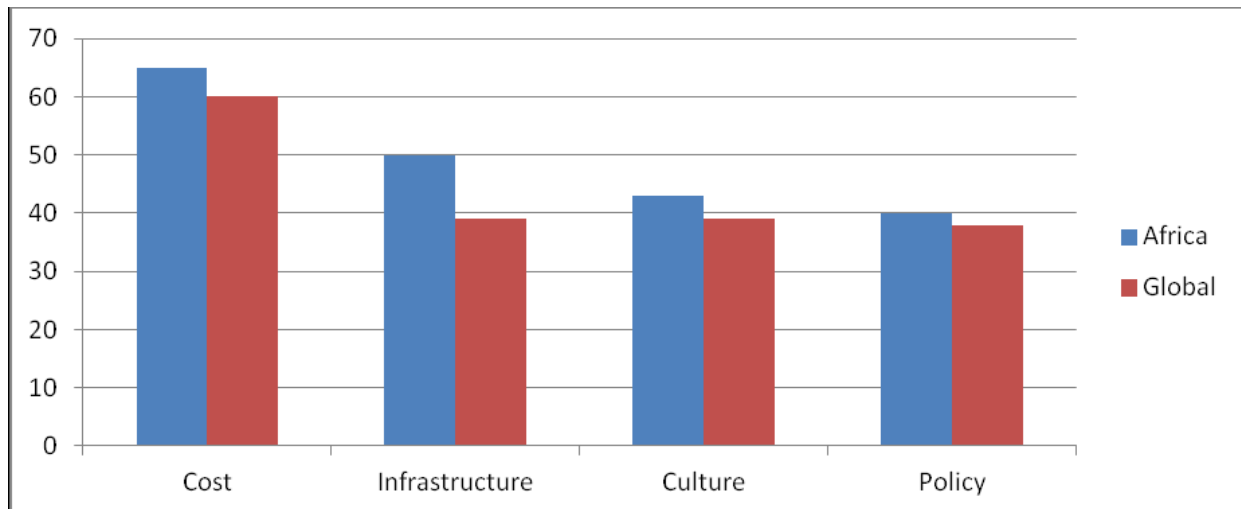


Figure 2.1 Comparative analysis of barriers to adoption of technology in healthcare (World Health Organization, 2010)

2.3 Electronic medical record (EMR) storage

According to Kenya National e- Health Strategy 2011-2017 (2011), there is a great need for an e-health strategy in Kenya anchored on Vision 2030 that aims at harnessing Information Communication and Technology (ICT) to ensure that healthcare delivery is improved. This includes having a paradigm shift on how information is accessed and shared across the healthcare sector.

A grim picture of Kenya's health sector is painted and as Kenya National e- Health Strategy 2011-2017 (2011) argues, only 80% of the clinicians serve 20% of the population. There is an urban-rural digital divide, lack of investment and a shortage of personnel. Table 2.1 shows a breakdown of the various carders in the health sector and their corresponding numbers and the inference from this table is that there is a shortage of health personnel in Kenya. Consequently, it calls for a great need for new technological solutions to assist in better healthcare delivery. EMR and NFC technology adoption can be of immense benefit when adopted and applied in the health sector.

Table 2.1 Data on number of health personnel in Kenya. (Kenya National e-Health Strategy 2011-2017, (2011))

Personnel in health sector	Number	Approximate ratio (Personnel per)
Doctors	1,513	1:26,438
Pharmacists	283	1:141,343
Dentists	169	1:236,686
Clinical Officers	2,104	1:19,011
Nurses	16,227	1:2,465
Other health personnel	9,720	1:4,115
Non health personnel	5,615	1:7,124
Total	35,631	

The research paper goes further to outline the strategic areas of intervention that forms the pillars of the e-health strategy as mobile health (M-Health), E-Learning, Telemedicine, Health Information Systems and Information for Citizens (Kenya National e- Health Strategy 2011-2017, 2011)

2.4 Problems with traditional health data storage techniques

Oltean (2011) argues that there is a greater need for replacement of traditional, existing data storage techniques in the healthcare industry. Therefore the novel NFC technology that allows patients to store their health data and doctors to retrieve it in a clinical setup can replace the conventional way of how health data is handled. This will then lead to lower costs and has an improved net effect on healthcare delivery.

One of the fundamental requirements in the healthcare sector is security, authenticity and confidentiality of medical records. With the old paper-based system, studies show that the patient's health data is not encrypted and therefore compromises on the confidentiality of this data as anyone who can access these medical records is able to access and see this private data. Additionally, the doctor's signature and seal are not a good security features as they are prone to forgery and other security breaches. The application being developed will have security features

that will ensure that data is not accessed by unwarranted persons. Encrypting the data ensures confidentiality, and usage of electronic signatures ensures that authenticity and integrity are achieved. Lastly, data access management is enabled by introduction of access rights policy. (Oltean, 2011)

2.5 Electronic medical record systems (EMR) versus Electronic Health Records (EHR)

Parks (2012) defines EMR's as electronic patient records that are created and also maintained by one care delivery organization (CDO). These records include clinical documentation, the medical history of the patient, laboratory and radiological tests and medication. Parks (2012) further elaborates on the distinction between EMR and electronic health record (EHR) and argues that EMR is a patient record that electronically resides in a system that is designed to support users through availability of complete and accurate data, clinical Decision Support Systems (DSS), reminders and alerts, linkages to bodies of medical knowledge and other aids. EHRs, on the other hand, are geared towards capturing the patient's information in a digital format and make information available to other stakeholders in the healthcare sector.

2.6 Health Data Classification

Health data, which is the premise of this research, is important. There is need to classify this data for ease of interpretation and application and due to its diverse nature, attempts have been made through research to give a general classification of this data into patient demographics, the date the information was updated, the type of allergies the patient may be having, the medications the patient is currently on, the surgical procedures that have been done and so on. (Smart Card Alliance, 2012)

The model developed then used this classification to narrow down on the patient's vital data that should be included in the model as the EMR. As pointed out earlier, this data was limited to patient's name, allergy, medical history, blood group, medical insurance and date when the information on the patient's card was updated.

2.7 NFC technology and review of other communication techniques

The focus now shifts to how communication between electronic devices is achieved and Near-field communication (NFC) is one way this is achieved and NFC is described as a new

short-range wireless technology which was developed by Sony and Phillips in 2002 that operates as a combination of Radio-Frequency Identification (RFID) and interconnection technologies that allows devices communicate when in close proximity and a reach of 10cm. (Mulevu, 2012)

Mulevu (2012) states that NFC is based on RFID technology and uses the same working principles. The paper further states that NFC is an interface technology for short range data communication working in the frequency band of 13.56 MHz's and that NFC is standardized in ISO/IEC 18092 and is compatible to ISO/IEC standards 14443 (proximity cards) and 15693 (vicinity cards) and to Sony's Felica contactless smart card system. Consequently, NFC is able to be used in existing infrastructures based on the aforementioned standards, eliminating the need for a separate NFC infrastructure.

Smart Card Alliance White Paper (2015) states that NFC technology is found in a variety of devices running a number of operating systems (OS) which includes Android, iOS for Apple products, Blackberry and Windows. It is also imperative to note that NFC is also supported in over 330 phone models, tablets, and other mobile devices, with one billion in market now and over two billion estimated to be in market by the end of 2016.

Mulevu (2012) classifies mobile phones under regular phones and NFC-enabled smart phones, whereby regular phones being mobile phones that do not have inherent NFC capability but have the basic cellular communication channels (CDMA or GSM) for messaging. On the other hand, NFC-enabled smart phones have in-built readers that are able to capture data from or store data onto external tags. The paper further states that some models of the NFC-enabled phones also have in-built tags that can be used to store user's data, such as a phone number. These phones can be able to be programmable and support regular cellular communication.

2.7.1 Operating modes of NFC devices

There are three operating modes of devices as illustrated by Figure 2.2. The first is Reader/Writer mode where the NFC-enabled device reads NFC forum mandated tag types. The other is Peer-to-Peer mode where two NFC-enabled devices are able to exchange information. Lastly, there is the Card Emulation mode where the NFC-enabled device appears to an external reader same as a traditional contactless smart card. This allows contactless transfer and manipulation of data by NFC devices without changing the existing infrastructure. The NFC

specifications do not dictate a security approach for any of the three modes. How security is implemented depends on the mode and the app's requirements. (Smart card alliance 2015)

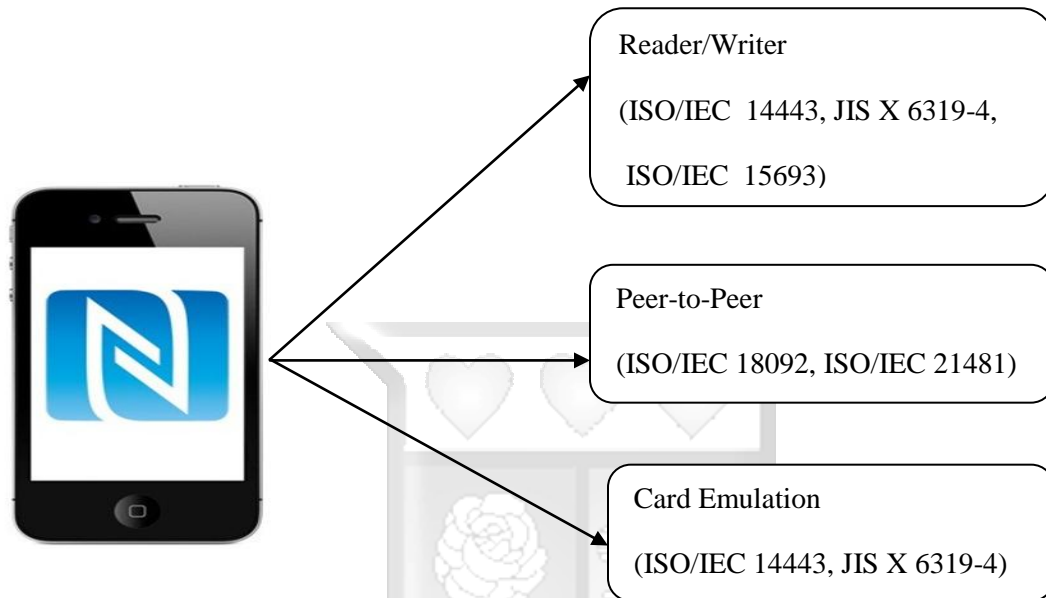


Figure 2.2 NFC Operating modes (Smartcard Alliance, 2015)

2.7.2 Applications of NFC technology in the industry

Smart card alliance (2015) elaborates that in conjunction with an application, NFC can be used for a variety of purposes which includes making payments by tapping the phone on a contactless card reader, reading information and picking up special offers and discounts from smart posters, storing loyalty program information and rewards for use at retail locations, storing tickets that open transportation gates or access parking garages or events and delivering file/product updates to read/write physical contactless or dual-interface smart cards.

Other applications include storing user information that allows secure building access, transferring a picture to an NFC-enabled printer or monitor and sharing business cards with other NFC-enabled phones.

2.7.3 Comparison between NFC and other communication techniques

a) NFC versus QR Code

Masud, Fatima, Iqbal and Ahmad (2014) points out that despite the fact that QR codes offers a fast and efficient information storage and retrieval, they are not reliable as they are prone to damage which renders them inoperable. NFC on the other hand optimizes ease of use as information is transferred by simply bringing the mobile phone in close proximity to the NFC tag.

The QR codes require two things for data transfer to take place. First is pre-processing and secondly, an active application. QR codes cannot be modified once printed. This is different from NFC tag whereby information written on it can be changed at will.

b) NFC versus Barcode

Masud et al. (2014) argues that barcode-based application require consistent power to operate whereas NFC tags do not depend entirely on power. NFC incorporates RFID technology whereby data is transferred from a passive tag to an NFC-enabled device through radio waves. The major advantage of the RFID tag is the reader can operate at a relatively large distance from the tag and even when the reader is out of direct line of sight.

2.7.4 NFC incorporation in mobile phones

Mobile phone manufacturers have produced smart phone with NFC capabilities and the trend seems to rise by end of 2015 (Mulevu, 2012) This is a positive trend because it gives this research the necessary impetus and argument that since NFC adoption is set to increase, there will be need to incorporate it in the healthcare sector. Figure 2.3 and Figure 2.4 shows the total NFC-Enabled Device and chipset shipments world market forecast and NFC enabled mobile phone shipped respectively which is an indication that in future there will be an increase in NFC technology in the market.

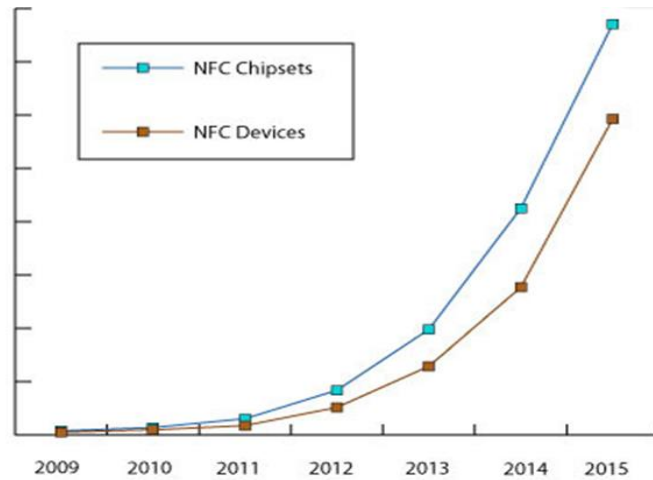


Figure 2.3 Total NFC-enabled device and chipset shipments world market, forecast: 2009-2015 (Mulevu, 2012)

A study that examines the shipment of NFC-enabled mobile phones and concludes that NFC will be included in 64% of the mobile phones shipped in 2018, up from 18.2% in 2013, according to a new forecast from IHS Technology. Global shipments of NFC-enabled mobile phones will be more than four times higher in 2018 than in 2013, the researchers add, with annual shipments increasing from 275m units in 2013 to 1.2 billion units in 2018. Figure 2.4 shows NFC enabled mobile phone shipped from 2013 to 2018 (Clark, 2014)

This adds to the assertion that there will be a tremendous uptake of NFC technology and the health sector can also benefit from it.

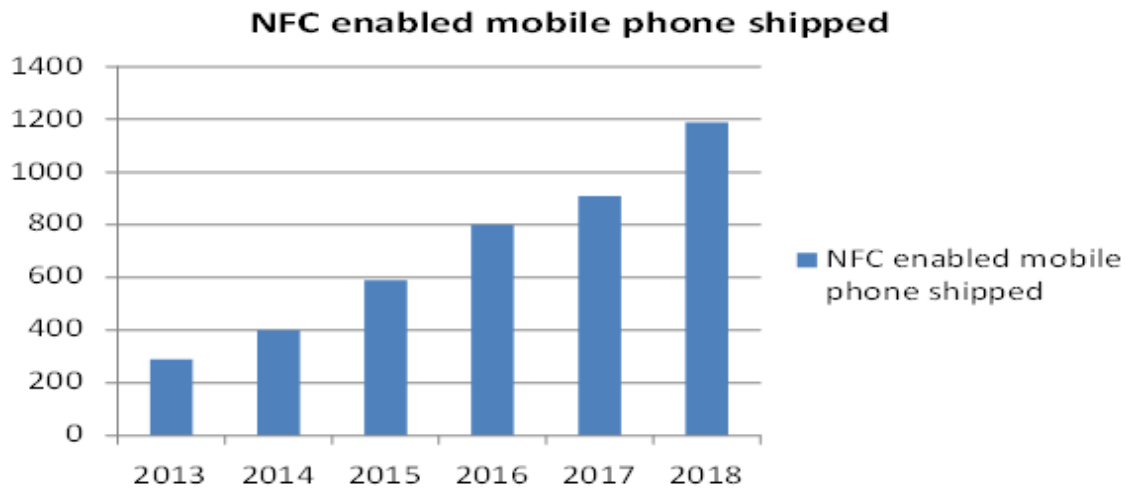


Figure 2.4 NFC enabled mobile phone shipped (Clark, 2014)

2.8 Review of related NFC-based medical applications

This section will review the different models, architectures and prototypes that are relevant to this study in order to gain deep understanding how NFC technology can be used for medical applications.

2.8.1 NFC Tags-Based Notification System for Medical Appointments

Masud et al. (2014) proposes a system whereby NFC technology is used for notifying and scheduling medical appointments. The proposed system uses passive NFC tags that automatically set appointment alerts on the smart phone of the patient and what can be concluded in this case is that the system enables an effective and reliable storage of appointment information.

Figure 2.5 illustrates the NFC-tag based alarm activation for medical appointment

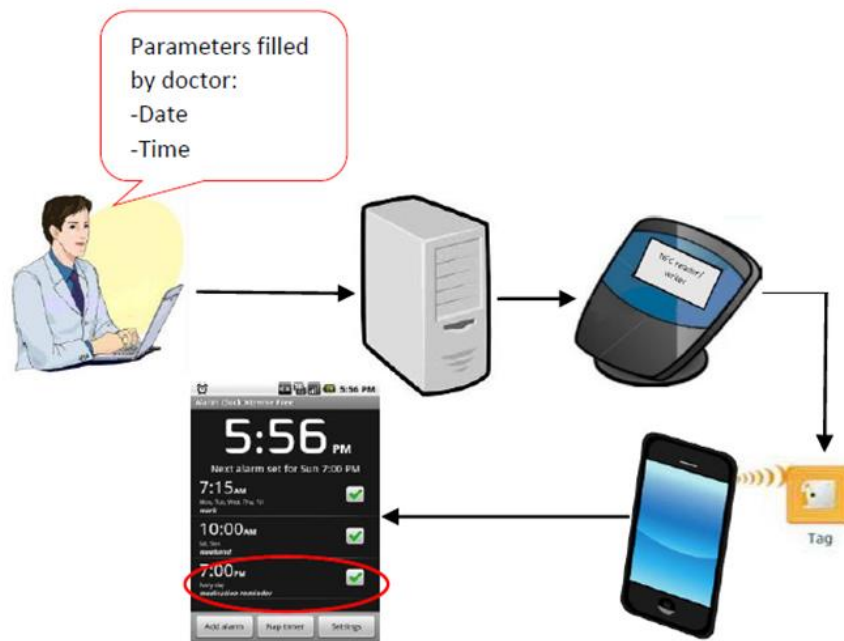


Figure 2.5 NFC-tag based alarm activation for medical appointment (Masud et al., 2014)

The NFC-tag based alarm activation for medical appointment system offers a provision for entry of information regarding time and date of the appointment follow-up by the doctor. This information is passed to a fixed NFC passive tag at the reception desk via the NFC read/write device. The patient then taps their mobile phone on the NFC read/write device in order to automatically set an alert in the patient's calendar. The benefit of this system is that it frees the patient from actively tracking future appointments.

Figure 2.6 shows the Flow Diagram for writing information to the NFC tag.

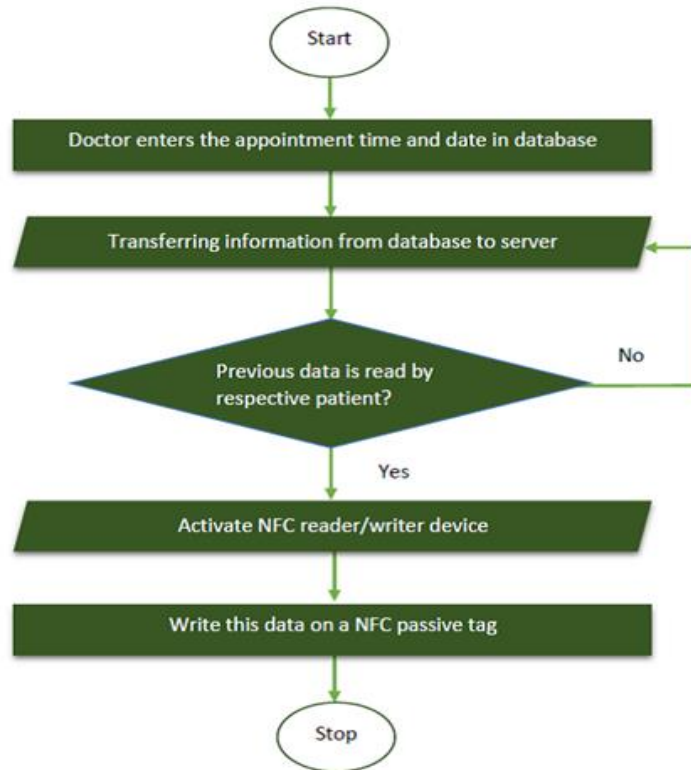


Figure 2.6 Flow Diagram for writing information to the NFC tag (Masud et al., 2014)

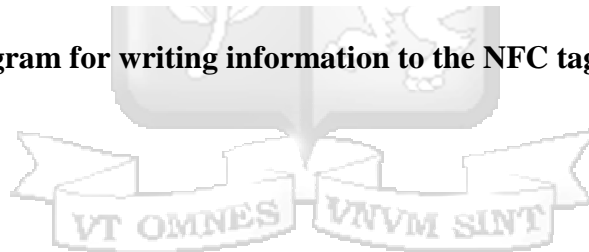


Figure 2.7 illustrates the Flow Diagram for information retrieval from the NFC tag and alert setting.

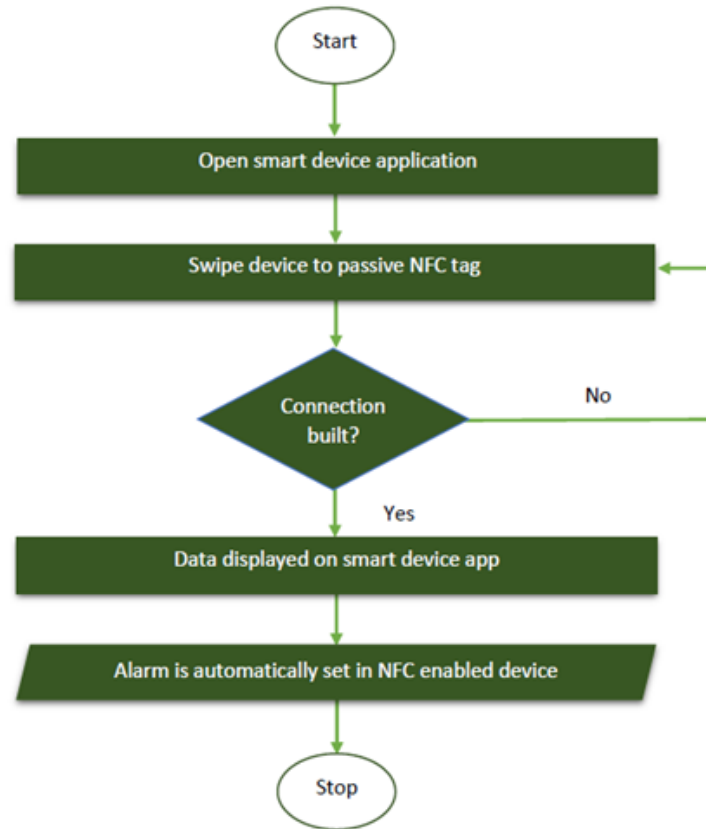


Figure 2.7 Flow Diagram for information retrieval from the NFC tag and alert setting.
(Masud et al., 2014)

The interface of the Android application is shown in Figure 2.8. This information that is displayed is read from a passive tag and then stored in the patient's internal memory for later use. This illustration also shows how the application arranges periodic notifications of the appointment.

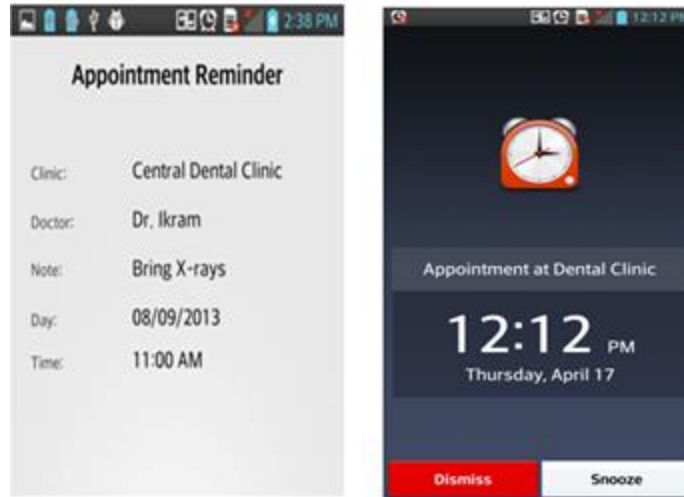


Figure 2.8 Appointment reminder app for Android device (Masud et al., 2014)

Masud et al. (2014) points out that there are different types of NFC tags that are available and the solution proposed was developed using NFC tags with internal storage of 128 bytes. This storage was enough to store limited data which includes doctor's name and date and time of the patient's appointment. This system guided the development of the NFC application and the model because it supports not just the objective of having only the critical medical record to be included in the NFC card, but also the idea that the NFC tags are themselves smaller in terms of capacity and hence may not hold much data.

The relevance of NFC Tags-Based Notification System for Medical Appointments can be looked at in three aspects. First is the health information entry into a database by the doctor which is followed by establishment of a connection from the host device to a mobile client for viewing of the data and lastly the inclusion of NFC read/write device. These factors are important in the development of an NFC based application for health information portability as they provide the tools necessary to ensure that there is provision for health database, enabling a machine-to-machine (M2M) communication and allowing for patient's data to be read and written.

2.8.2 NFC Emergency Hospital Patient Management architecture

Krishna, Sreevardhan, Karun and Kumar (2013) researches on the latest versions of the Hospital Patient Management Systems (HPMS) that can be implemented in different departments namely medicine and surgeries. The main focus of the study is the emergency

department that handles emergency cases. Krishna et al. (2013) argues that the HPMS needs to be first implemented in the emergency department because in such an environment it is highly useful to obtaining health data without disturbing the patient. Krishna et al. (2013) proposes that the NFC reader be placed on the door and should be uplinked to the database so that every time it receives data it should be updated immediately.

Therefore by achieving this, the NFC can be used for time stamping as well just like the RFID tags that is currently being used in our daily lives. The NFC reader is placed on a door to aid in collecting data of patients entering the hospital or the doctor's consultation room. (Krishna et al., 2013)

A critical analysis of this research shows that it is an important study as it underscores the importance of automation of medical data, using NFC technology, for efficiency in handling emergency cases. However, its major drawback is that the technology used in this case is only limited to emergency department. It overlooks the fact that there are many departments in the hospital that may need this technology. We will describe in subsequent chapters the relevance of the NFC application in all hospital departments and the logistics that come with it especially when it is implemented in Intensive Care Unit (ICU) where patients may not be able to offer passwords and username to doctors.

2.8.3 SEMTAG prototype

Dünnebeil et al. (2011) proposes a prototype that consist of a web application that uses a Connector and a smart card reader to access the public and private keys of doctors and the patients. The local Connector is a component that encapsulates all local services as encryption or card access. This Connector establishes a secure virtual private network (VPN) connection to the central servers when needed. The Connector is connected to smart card readers and it allows access to the electronic health card.

Dünnebeil et al. (2011) acknowledges that the merit of this prototype is the encryption of the data ensures health data security. The demerits include the fact that the NFC tags do not yet provide enough storage capacity to store comprehensive sets of emergency data and several encrypted keys at the same time and centralized electronic health records are not a feasible method for cooperation of caregivers in case of emergencies.

SEMTAG process routine as outlined by Dünnebeil et al. (2011) has been described as the process that enables the secure exchange of emergency data between patients, doctors and emergency caregivers. The process is shown in Figure 2.9 and the explanation of the various steps follows.

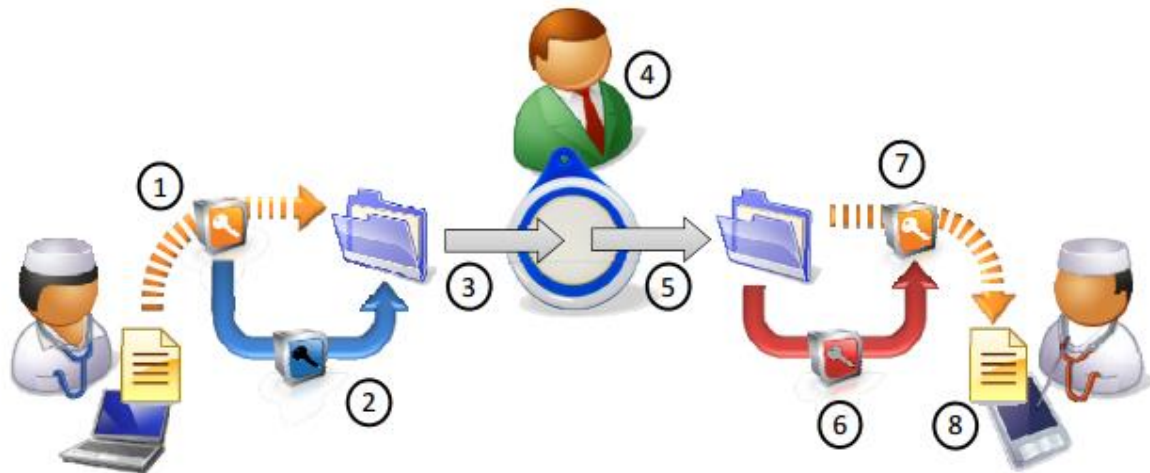


Figure 2.9 SEMTAG process (Dünnebeil et al., 2011)

- i) Connector provides a symmetric key to encrypt emergency EMR.
- ii) Decryption key given to only the specific people who are required to access the patient's data such as name, allergy, medical history, blood group, medical insurance and date when the information on the patient's card was updated access the EMR.
- iii) The encrypted keys and encrypted data are then stored in the SEMTAG NFC tags.
- iv) Tags placed where they can easily be accessed and carried by the patient.
- v) A device used by doctors embedded with a smartcard reader is used to read and decrypt the medical data in the NFC tag.
- vi) The symmetric key is decrypted within the smart card of the doctor using the doctor's private key.
- vii) The SEMTAG software component in addition to the Connector helps facilitate the decryption of the medical data

viii) The mobile device then displays the emergency data.

The relevance of this study is the security provisions that come with the SEMTAG prototype. The system developed allows for decryption of patients data and encryption of this data after it has been written on the NFC card. A look at the NFC based application for health portability illustrated on the flowchart in Chapter 5 (Systems Design and Architecture) shows the inclusion of encryption and decryption functionalities.

2.8.4 Models in Electronic Health Record (EHR) applications

Health record keeping has been a vital component of the health care system as it ensures that medical data is stored in a repository for use by the clinician for diagnosis and formulation of treatment plan (Latha, Murthy & Sunitha, 2012)

2.8.4.1 Smart Card Based Integrated EHR System (IEHRS) For Clinical Practice

Latha et al. (2012) argues that by automating the systems in hospitals, there is a net benefit of ensuring that there is efficiency in the working environment for doctors and other healthcare givers. The model proposed here ensures that there is access to accurate medical data. Latha et al. (2012) compares the differences that exist between an EMR and paper-based system and argues that when health data is stored in paper-based system, it is difficult to access, insecure, not easy to update and not easy to share and maintain for a long time.

The system proposed here is one in which patient carries their own card. This card contains the patient's medical data and the reasons given for the preference of the medical card is that it is cheap, easy to use and update and doesn't get damaged easily.

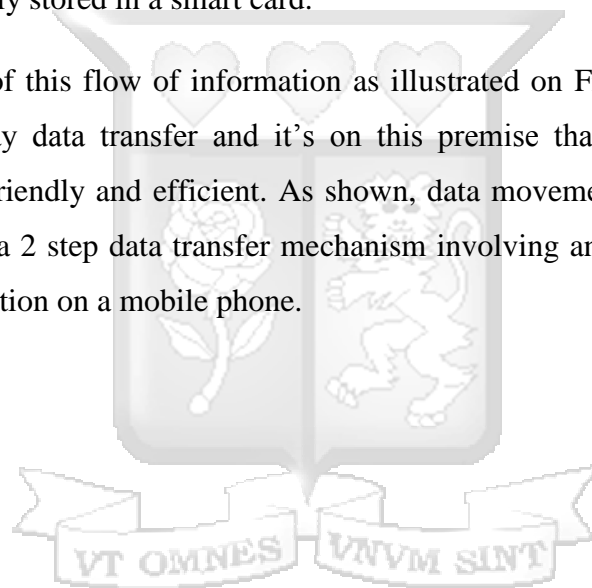
In this Integrated Electronic Health Record System (IEHRS), each computer has a connected card acceptance devices (CAD) and they can connect to databases. Doctors use these cards to access medical data from the database. Smart cards are used as a mobile medical data carrier.

The merits of this approach is the doctor is able to update the patient's health data and also that it allows for easy integration of the current health information systems so that the users of the old systems are able to adapt to the new system without major problems.

The demerits of the IEHRS are that there are inherent flaws in the system due to the fact that during system development, there is lack of medical store standardization as well as retrieval standardization. Latha et al. (2012) proposes a worldwide-generic coding standard for healthcare data which will ease the designing and development process of smartcard based healthcare systems.

Figure 2.10 and Figure 2.11 shows the block diagram and flowchart respectively of the IEHR. There is a general flow and communication between stage 1 and stage 2, and stage 2 and stage 3. The summary of this flow of information is that health data moves from stage 1 where there are medical equipments for collection data to a personal computer which is relayed to a smartcard reader and lastly stored in a smart card.

The complexity of this flow of information as illustrated on Figure 2.10 demands for a simpler but efficient way data transfer and it's on this premise that we will design a NFC application that is user-friendly and efficient. As shown, data movement occurs in 3 stages but this research will create a 2 step data transfer mechanism involving an NFC card which is read and written by an application on a mobile phone.



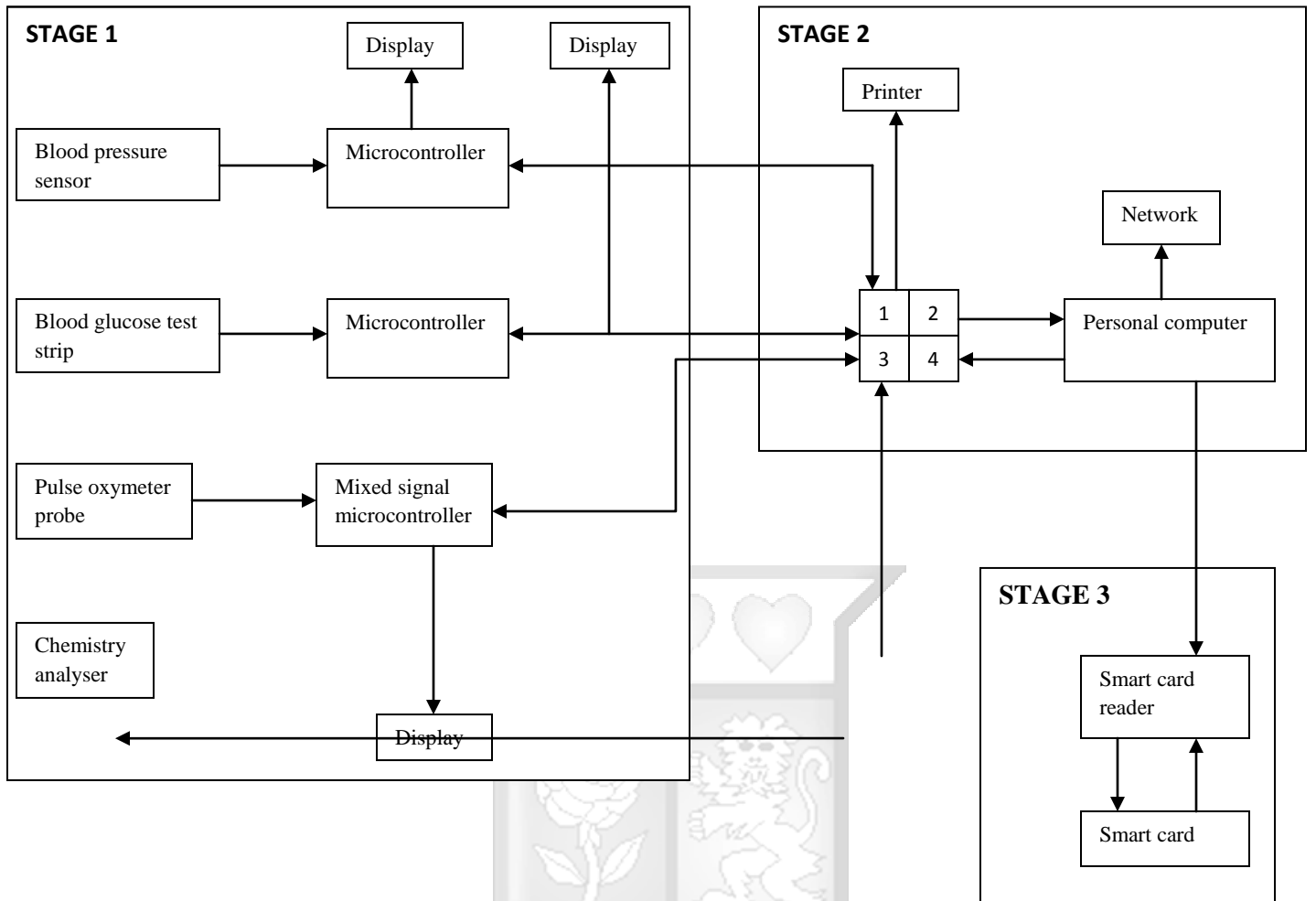
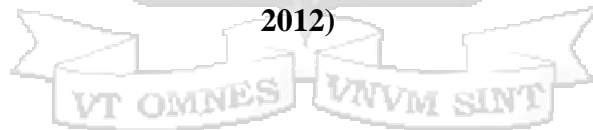


Figure 2.10 Block diagram of Integrated Electronic Health Record System (Latha et al., 2012)



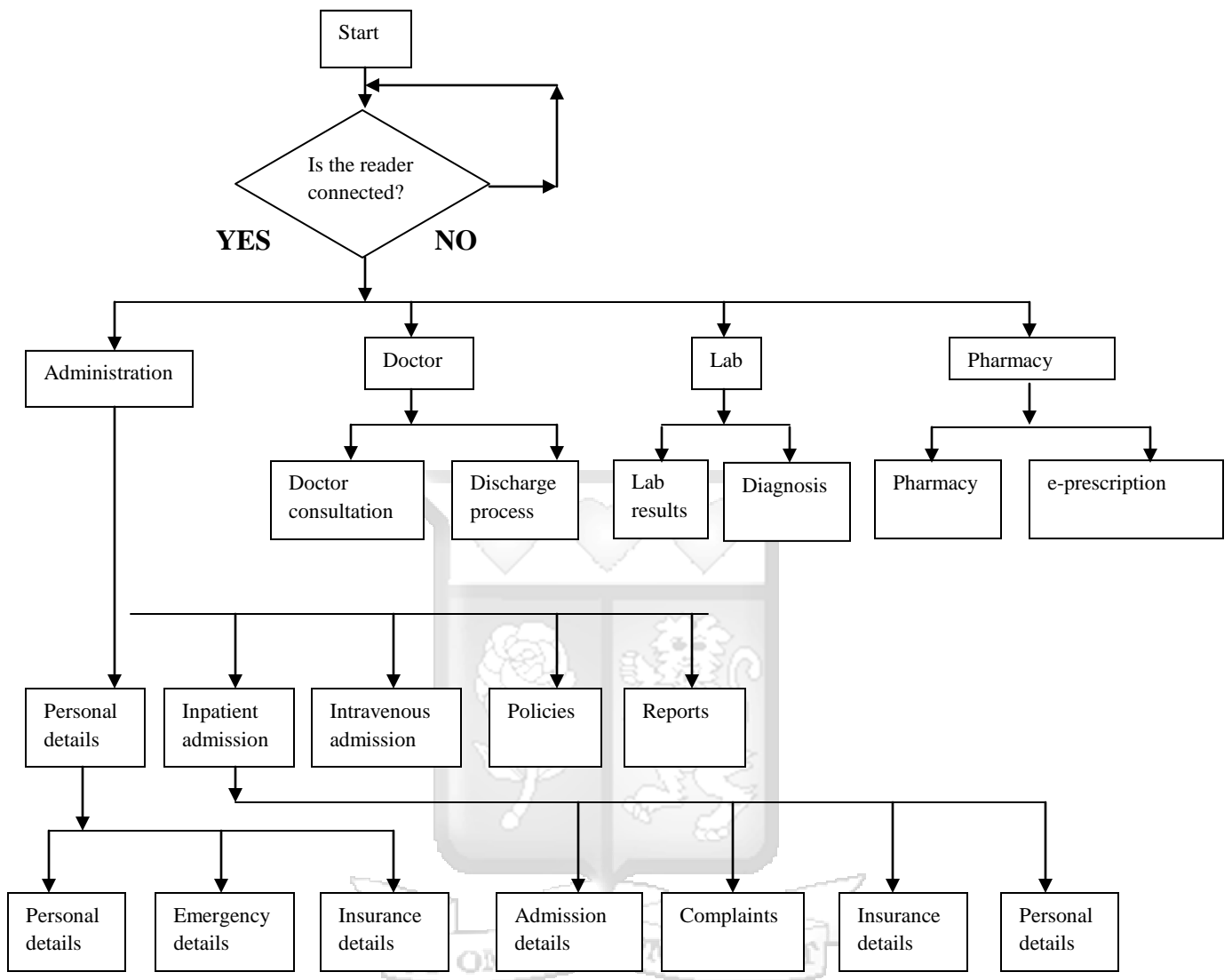


Figure 2.11 Flow chart of IEHR System (Latha et al., 2012)

2.9 Health data portability

This section will delve into the different aspect of movement of health data and its significance when addressing the concept of EMR in the healthcare sector.

2.9.1 Health portability concerns

Clouds Standards Customer Council (2012) in an analysis of health data portability in the context of cloud computing, states that there are real concerns with health data being hosted in a different place other than physical systems, services and data within the healthcare center. Secondly, if the service provider were to suspend their cloud service, the healthcare center may

be unable to provide service to their patients. Interoperability is also another issue that has been raised with regard to health data portability when the patient moves to another service vendor.

These issues were addressed in light of developing the system and later the model. To reiterate for emphasis, the patient's data is stored in a NFC card and therefore there are security and confidentiality challenges should there be an unauthorized access to the card.

2.10 Challenges and risks associated with electronic data

Clouds Standards Customer Council (2012) argues that a number of challenges exist when there is an attempt to leverage electronic health data storage for healthcare. Since cloud computing is an electronic way of data storage, the challenges listed below applies to all forms of EMR systems:

i) Privacy and Security Challenges

Health data stored in an electronic media may have private, personal or confidential health information that demands proper security to prevent any disclosure, misuse or compromise. Issues related to security, data jurisdiction, privacy and compliance impacts the adoption of EMR systems in the healthcare sector.

ii) Service Reliability

Evidence has shown that from an operational standpoint, all the EMR ecosystems do have some disruptions at some point. Mission critical health information technology applications must meet very high reliability, availability and performance standards. This is because the healthcare industry dependence on the reliability and availability of health information can be a matter of life and death.

iii) Integration and Interoperability

Reliable exchange of health data among health professionals is a crucial component to the healthcare that transcends the IT domain. Different medical specialists in the healthcare sector have different terminologies and requirements and therefore delivering an end-to-end technology that integrates the crucial patients' data requires standardization and interoperability.

2.11 Protection and management of health information privacy

Empirical research shows that organizations have to address the challenges of information privacy and the urgency and importance of this challenge is required when health data is involved. Parks (2012) attempts to classify these privacy issues into technical, policy, training and education, culture of privacy, privacy impact assessment, disciplinary measures and physical measures. Parks (2012) goes further and outlines various technologies that are crucial when addressing health information privacy threats and Table 2.2 illustrates a Mapping of Privacy Threats to Their Countermeasures.

Table 2.2 Mapping of Privacy Threats to their Countermeasures (Parks, 2012)

Privacy Threat	Technical Countermeasure
Data collection	Anonymization
Use and disclosure	Anonymization Cryptography Access Control
Unauthorized Access	Access Control Mechanism Encryption Anonymization
Secondary Use	Anonymization

So the question that needs to be asked first is whether the health practitioner is mandated to collect a patient's data. This forms an important beginning of addressing health information privacy. This research addresses the issues regarding components of systems security by incorporation of decryption, password authentication encryption of data as a foundation of health information security.

2.12 Conceptual framework

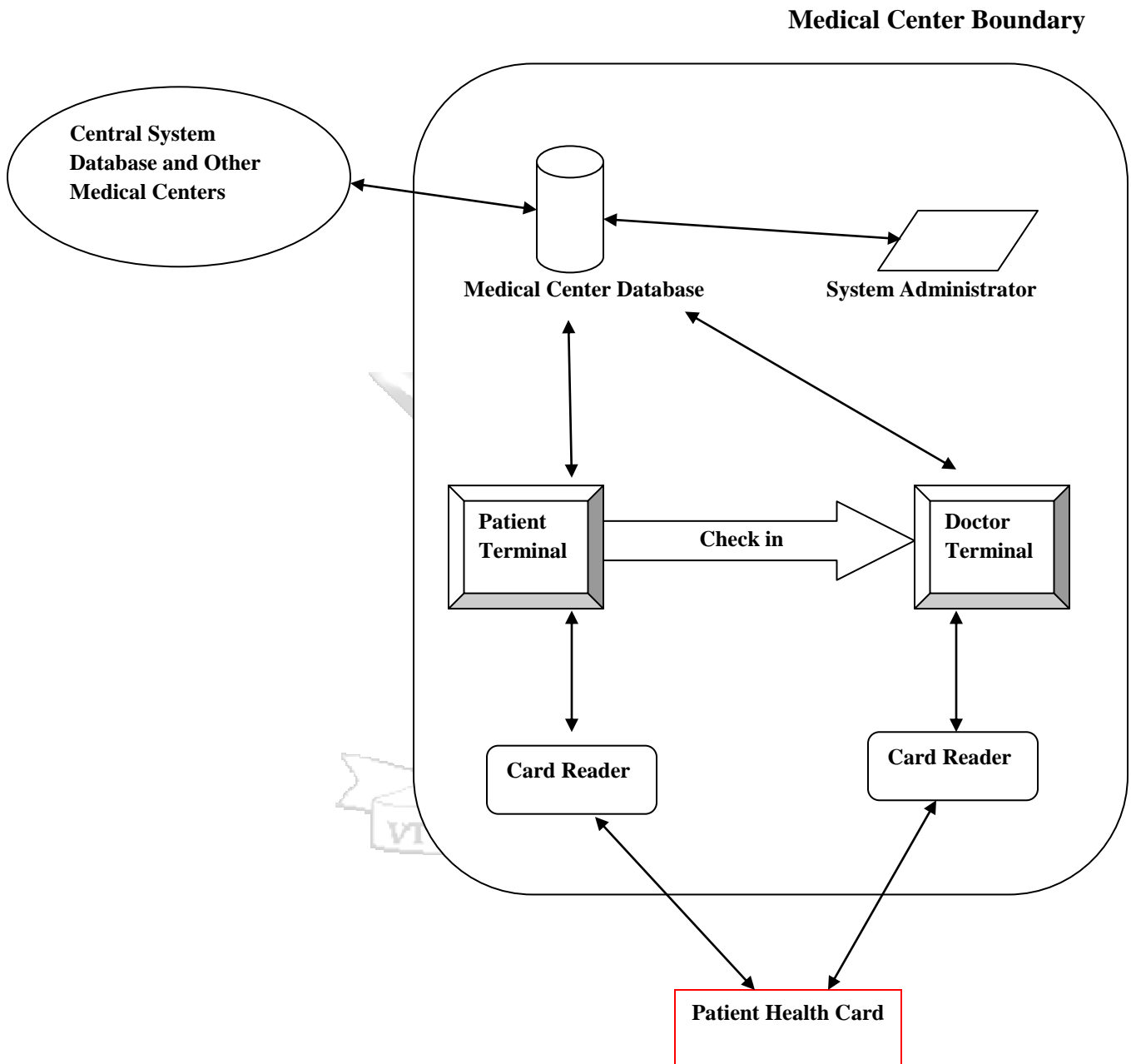


Figure 2.12 Conceptual framework (Rodrigues, 2009)

Figure 2.12 shows the conceptual framework derived from Java Modeling Language (JML) Based Formal Development of a Java Card Application for Managing Medical Appointments whereby a patient can use their smartcard in any hospital. The system architecture comprises of 2 card terminals:

- i) **The patient terminal** which has a smartcard reader which is used for appointment scheduling, modification of patient's personal data and for requests of drug prescriptions renewal.
- ii) **The doctor's terminal** has a smartcard reader and it allows the health practitioner to access the patient's health information. This terminal also allows the health practitioner to input the patient's health data into the patient's health card.

This conceptual framework also has a medical center database which provides support to the patient's health card information whereby it stores relevant health data such as drugs and vaccines, allergies and other health information. Additionally, the database offers support to the information about the doctor's available schedules. The system administrator operates and keeps the medical center updated.

This research borrowed some aspects of this framework which includes having a mobile phone and application at the doctor's terminal that acts as the NFC card reader that can read and write on the patient's NFC card. However, the medical database is stored in the patient's NFC card and not in the medical center database as shown the conceptual framework on Figure 1.2

2.13 Conceptual design

Figure 2.13 shows the conceptual design and there are three components to this design. The first is the NFC enabled phone that is stationed in the clinic and is used by the doctor to read and write contents on the patient's NFC card. This mobile phone has an NFC application that runs on its android operating system (OS). The second component is the patient's NFC card that has an NFC tag with the capability to store patient's data. Lastly is the patient database which constitutes the vital medical data.

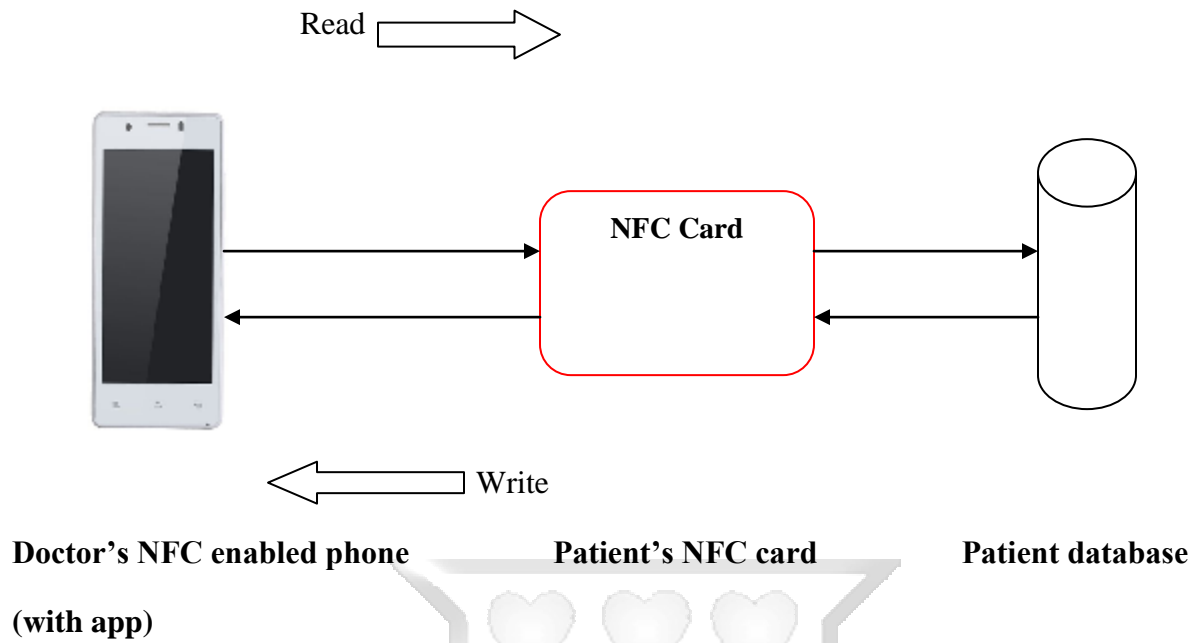
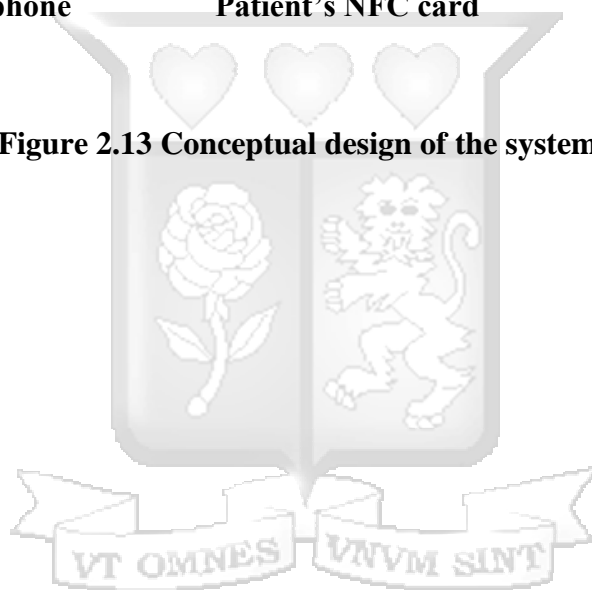


Figure 2.13 Conceptual design of the system



CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter elaborates on the study area, research design, instruments used to collect data, population and sampling methods, the methodology used, variables considered data analysis and how this data was presented. Further, the chapter describes the system design and development of the model, activities and deliverables including the model design schedule. Lastly, a discussion on the validity and reliability of the research including the ethical considerations was done. The research methodology strategy aided in the development of the system and the model.

3.2 Selection of the study area

The Nairobi West Hospital was selected for the research work. This Hospital is located in Nairobi West, Nairobi, Kenya and has health practitioners and other staff members working in various departments namely emergency and casualty, Outpatient clinic, 17 bed capacity Haemodialysis Unit, Operating theaters, Maternity Wing, Intensive Care Unit and High Dependency Unit, Private Wing wards, Dental department, Physiotherapy department. Some of the medical machines available in the hospital include: MRI Machine, Catheterization Lab, CT Scan and Neonatal Incubators.

The development of the system was tailor-made to suit the technological and clinical needs of the hospital and consideration was made to ensure that there is relevance and justification for NFC application and card. The clinical data such as allergy, blood group and medical history to be input into the system and the data was collected in The Nairobi West Hospital using the data collection instruments outlined in section 3.6

3.3 Research design

This is an applied research which seeks to find a solution to the issue of information portability and NFC technology in the healthcare sector. Mwikali (2013) describes the choice of the research methodology as one which is guided by the research objectives to allow for exploration and understanding of a particular phenomenon. The system application is in the healthcare sector and involves health data writing and reading and how communication occurs between a NFC enabled mobile phone and a patient's card.

Both qualitative and quantitative approaches were used. Quantitative because the research aims at collecting data on variables and present them on pie charts, graphs and tables. Mulevu (2012) describes the qualitative approach as one which relates to the study of things in their natural setting and making an attempt to make sense of or interpret phenomenon in terms of the meaning that people bring to them.

Qualitative approach was achieved by formulating open ended questions in the questionnaire. Among the questions designed for qualitative data that the health practitioners were meant to answer includes which other patient data portability methods do doctors recommend other than the regular insurance cards.

3.4 Population and Sample size determination

The populations that offered data relevant for the study were doctors in Nairobi West Hospital, patients who visited this health facility and those stationed at the IT department. The relevance of the population is the systems and the model developed depended on the interaction of the two sets of this population. The patients are meant to carry the NFC card and the doctors read the contents of this card using the card reader which in this case is an NFC-enabled mobile phone.

The sampling method that was used by the researcher was purposive sampling and as described by Mwikali (2013) this sampling entails sampling a particular segment of the universe for constituting a sample which represents the universe. The rationale for this is that most of the health practitioners who discharge their duties at The Nairobi West Hospital Hospital are not employed on permanent basis therefore distributing questionnaires to locum doctors can pose a challenge. However, the number of doctors working on a permanent basis which is 25, is limited therefore it was more convenient for them to fill the questionnaire and the responses therein were a representative of the views of the collective health practitioners.

Israel (2013) asserts that sampling is influenced by purpose of the study, population size, the risk of selecting a “bad” sample, the level of precision (+/- 5 percent), the level of confidence or risk, and the degree of variability in the attributes being measured. The strategies for

determining sample size include using a census for small populations, imitating a sample size of similar studies, using published tables, and applying formulas to calculate a sample size.

3.4.1 Sample size calculation

Equation 3.1 shows the equation used to calculate the sample size for patients

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

Equation 3.1 Sample size calculation for patients (Mwogi, 2014)

Where

n= sample size

z= the standard normal deviate (1.96 for a 95% confidence level)

c= level of accuracy desired, or sampling error

p= proportion of the population having the characteristic being measured

q= proportion of the population that does not have the characteristic (1-p)

$$1.96^2 * 0.7 * (1-0.7) / 0.08 * 0.08 = 126 \text{ patients}$$

A convenient sampling of health practitioners was done and 25 doctors working on permanent basis at the hospital was selected. The reasoning behind this is that due to logistical issues, it was difficult to get the doctors working on locum or temporary basis. A sample of 25 health practitioners offered statistically significant results.

Mwikali (2013) describes a great need to address privacy and security of the medical data guided by Health Insurance Portability and Accountability Act (HIPAA) when conducting a research that involves patients and this was taken into consideration.

3.5 Data sources and respondents

Onyango (2014) argues that the sources of data collection are two pronged. The first is primary and secondly, there are secondary data sources. The complete illustration of this classification is shown on Figure 3.1 Respondents who are the data sources included doctors,

patients, IT administrator and the secondary data was from online source and review of scientific journals.

The data that was needed included gender, names of the departments that the health practitioners, the health record problems within the hospital, data on NFC and other medical application in the mobile phones, recommendations on the health data portability methods and security features required the application. Additionally, the participant’s willingness to participate in the research was crucial.

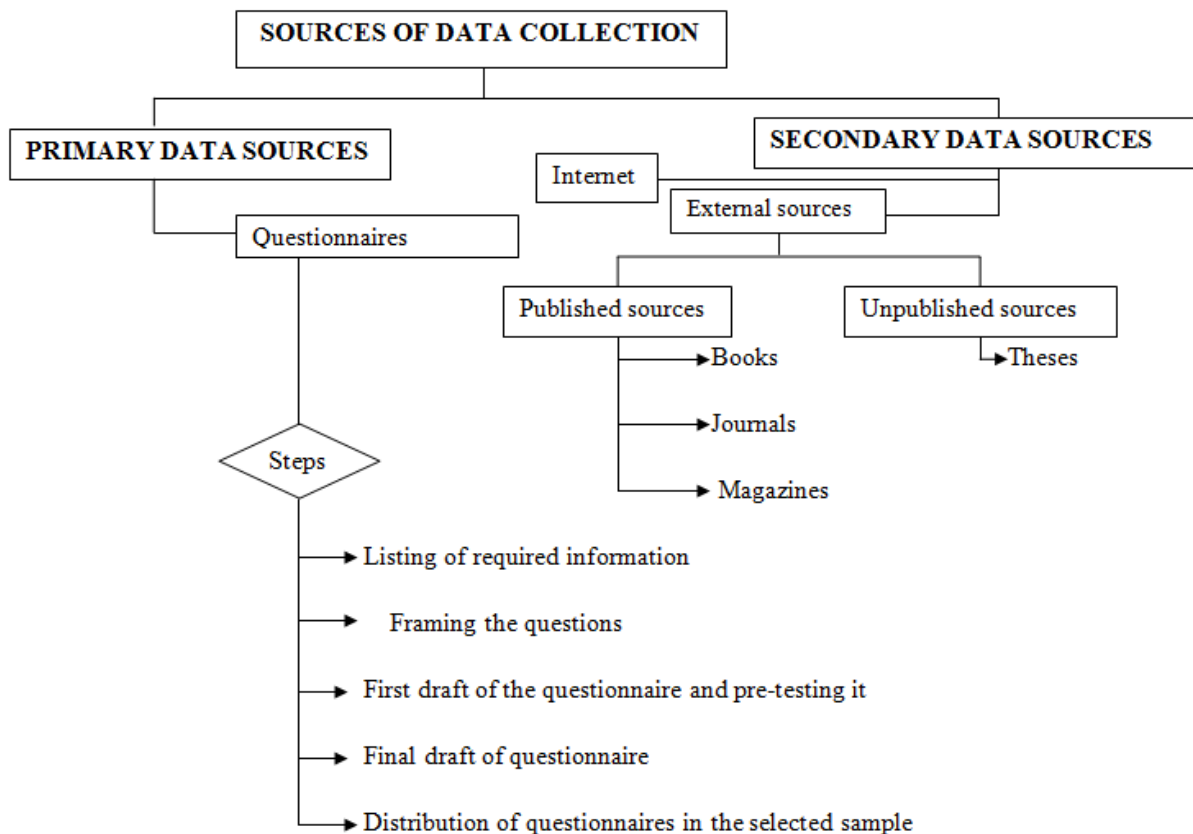


Figure 3.1 Data collection sources (Onyango, 2014)

3.6 Data collection methods

These were the tools that were employed to gather data in order to draw conclusions and make recommendations. The primary data was collected using questionnaires and interviews.

- a) Structured questionnaires for health practitioners sought to get an insight into the practitioner’s knowledge, or lack thereof, medical record management of NFC technology and views on the vital medical records that can be utilized in a clinical setup

to ensure efficiency and better healthcare to patients. The latter was aimed at gathering information on the type of data doctors would want to see implemented in the system and the model. Both open-ended and closed-ended questionnaires were employed and they were meant to capture both qualitative and quantitative data.

- b) Questionnaires for patients sought to gather data on patient's gender, whether the patient has a medical insurance card and how beneficial this card is to them. This was aimed at collecting data on the availability and usability of portable medical card among patients which then formed the basis for having an NFC card that allows patients to carry their own medical data.
- c) Review of journals and scientific materials.
- d) Interview questions for the ICT team at Nairobi West Hospital provided information on the current modes of patient data storage in the hospital, the measures taken to introduce electronic medical record in the hospital and the barriers to adoption of automation of health data in the hospital.

3.7 Variables (dependent and independent)

According to Mwikali (2013) variables can be classified into independent and dependent variables. The independent variables are the ones that can be manipulated by the researcher. On the other hand, dependent variables are a measure of effect of the independent variable. In other words, the independent variable is the cause and the dependent variable is the effect. The variables help the researcher with designing the instruments for data collection from the research respondents. For the study of Near-Field Communication Based-Model for Health Information Portability, the variables are shown on Table 3.1

Table 3.1 Dependent and independent variables (Mwikali, 2013)

Dependent variables	Independent variables
Efficiency of health data portability	Automation of health records Health data storage Robustness of the NFC card
Patient's turnaround time	Number of doctors in the hospital Type and efficiency of EMR system
Digital divide among clinicians	Usage of NFC technology among healthcare providers
Adoption of EMR system	Organizational culture Availability of technological support
Mortality rate among patients and success rate with diagnosis	Adequate/inadequate health data entry Digital divide among healthcare providers Clinical competence Health information portability
Adoption of NFC mobile app	User experience
Medical data sharing	Ability of the patient to move with their health data

3.8 System Design and Development of the model

Systems Development Life Cycle (SDLC) Phases according to Dennis, Wixom and Roth (2012) which follows the sequence of planning, analysis, design and implementation is illustrated in Table 3.2. The details of the SDLC are described in section 3.11 and 3.12 of this chapter and subsequent chapters.

Table 3.2 Systems Development Life Cycle Phases (Dennis et al., 2012)

Phase	Step	Technique	Deliverable
Planning	Identify opportunity Analyze feasibility Develop work plan	Project identification Technical feasibility PERT chart Gantt chart Scope and risk management	System request Feasibility study Project plan
Analysis	Develop analysis strategy Determine business requirements Create use cases and model processes	Business process automation, improvement and reengineering. Interview Questionnaire Observation Data flow diagramming Entity Relationship modeling Normalization	System proposal
Design	Design physical system Design architecture Design interface Design databases	Design strategy Architecture design Software and hardware selection Use scenario Interface structure ER modeling	Alternative mix System specification
Implementation	Construct system Install system Maintain system Post-implementation	Programming Software testing Performance testing Conversion strategy selection Training System maintenance Project assessment	Test plan Documentation Migration plan Support plan Post-implementation audit report

3.9 Software Development Process

Figure 3.2 shows the software development process as outlined by Rodrigues (2009) that was employed in the system and model development. Chapter 5 (System Design and Architecture) of this research is a detailed discussion of the individual steps that this process took.

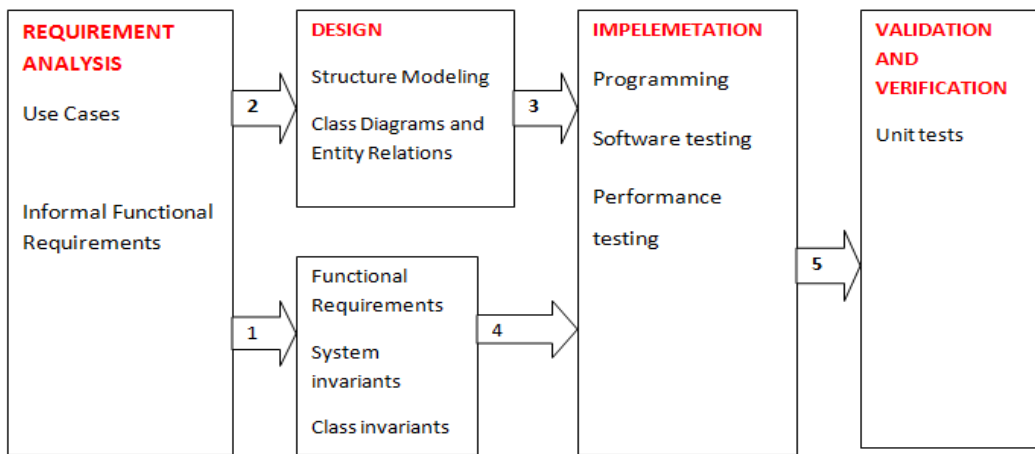


Figure 3.2 Software Development Process (Rodrigues, 2009)

3.10 Project methodology

Dennis et al. (2012) outlines project methodology options which includes Waterfall Development, Parallel Development, V-Model, Rapid Application Development (RAD), Iterative Development and Agile Development. Dennis et al (2012) outlines the different types of Agile development namely extremely programming, scrum and dynamic systems development method.

This research will use the Agile Development approach as shown on Figure 3.3 and it is defined as collection of programming-centric methodologies that geared towards streamlining Systems Development Life Cycle (SDLC) This type of methodology stresses more on simple, iterative application development whereby every iteration is a fully fledged software project. This includes planning, requirement analysis, design, coding, testing and documentation.

Agile development is best utilized when user requirements are unclear, developing systems that are reliable and systems that have a short time schedule. The demerits are Agile

development is poor in developing systems with unfamiliar technology and the ones that are complex. (Dennis et al., 2012)

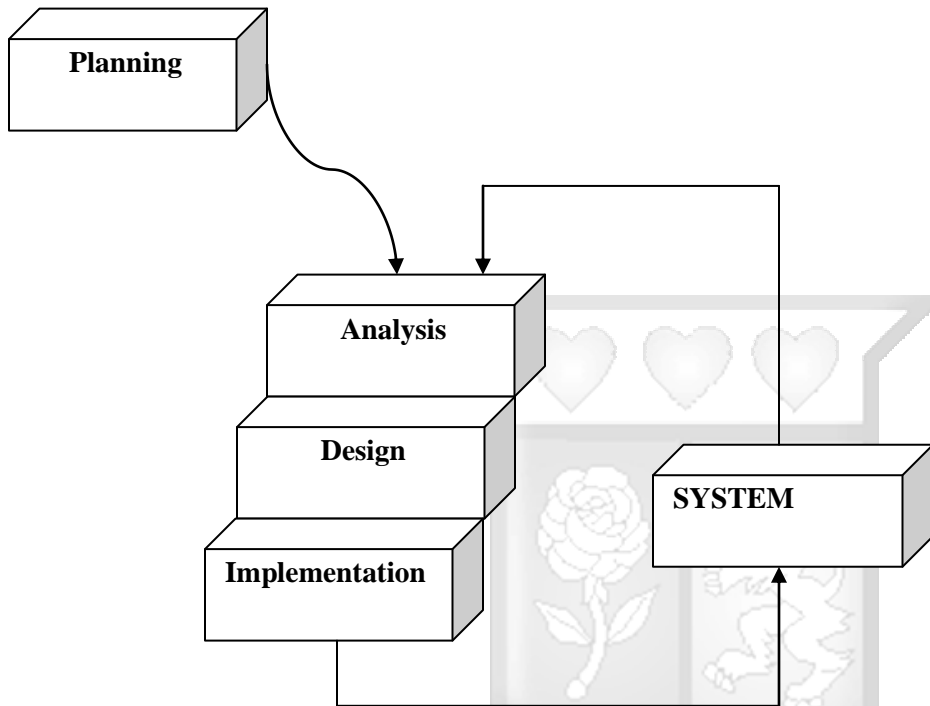


Figure 3.3 Agile development methodology (Dennis et al., 2012)

The planning stage involved thoughtful overview of the relevance of NFC application in the healthcare industry and evaluation of who the end-users of this application will be and in this case health practitioners and patients were considered. The setup for the application was a hospital setup.

The requirement analysis included functional and non-functional requirement analysis. For the system, examples of functional requirements are user authentication, user verification, user personalization, interoperability, data write, data reading and machine-to-machine connectivity. The non-functional requirements include user-friendliness, data encryption, reporting of error, availability, performance. This has been elaborated in chapter 5, section 5.4

The system requirements considered for the development of the proof of concept model is as follows:

i) Host requirements

The host is the Personal Computer that has the patients' database and which the TracerPlus Mobile Client communicates with when syncing patient's data.

ii) Mobile client

The mobile phone runs on Android version 5.0.1 and the medical data syncing with the mobile phone done using a universal serial bus cable. The model developed underwent a series of refinement and constant changes to suit the functional and nonfunctional requirements. The complete model development is discussed in subsequent chapters.

3.11 Activities and Deliverables

A model as a proof of concept was developed using TracerPlus software. This model was able to achieve the following functions: creation and storage of patient's database, connection of the host (personal computer) and data transfer to the mobile client.

3.12 Model design schedule

Duration of the study took three months from January to March 2016 during which time the research underwent different steps. The requirement analysis was done and this guided not only the formulation of the questionnaires and interview questions but also gave a blueprint for the design of the model.

The second part of this schedule focused primarily on the collection of data including a thorough assessment of the various medical insurance cards system, EMR systems, systems that support M2M communication and personnel infrastructure that handle these systems.

The researcher then strategized on the development of the model and laying out a plan on the technology to be adopted and hypothesize on the challenges that might occur during implementation stage. This step was aimed at addressing the research objectives outlined in chapter 1. The model was developed and then tested.

With respect to the model, the important factors considered prior to its development as argued by Dennis et al. (2012) included clarity of user requirements, familiarity with technology, system complexity, system reliability, short time schedules and schedule visibility. The testing phase went through the test planning and unit tests. This will be elaborated more in later chapters where the model testing and implementation have been discussed.

3.13 Data analysis and presentation

Basher and Roy (2011) asserts that data analysis as processing and analyzing using both descriptive and inferential statistical data by employing SPSS and MS Excel. The tools used for data analysis include tabular form, percentage and graphs and the purpose of data analysis is to draw inferences which are useful for the research. The tools employed include graphs, pie charts and SPSS. The data collected was presented in graphs, column charts, tables, line charts, pie charts using Microsoft Excel.

This scientific analysis was crucial in evaluation of how the data collected is useful in the development of the application. Of importance to note is that since this is an applied research and the data collected influenced how much data was to be stored in the patient's NFC card, a more targeted approach on the type and nature of questions in the questionnaire was needed. Pareto analysis was used to analyze the health record problems that lead to inefficient health care delivery and an inference made on which medical record problems within the hospital required prioritization.

3.14 Validity and reliability of the research

Reliability was done through retest method to measure the consistency of the results of data input, data output and modification of the patient's data from the database.

Validity was done using content validity method where the health practitioners were asked to identify the content of the prototype developed and verify its authenticity. The other aspect of validation was done by IT administrator who has vast experience in information systems design and implementation. The aspects that were to be validated included the technology used and its suitability and relevance. It was important to carry out this validation as

it was meant to ensure that the model developed met the requirement needed both technically and medically.

3.15 Ethics in research

Storage of electronic health information for patients presented the research with confidentiality issues hence collection and analysis of patient data needed informed consent from patients, healthcare practitioners and the hospital. The information derived from the questionnaires and interviews were kept confidential and this was communicated to the respondents both verbally and in writing.



CHAPTER 4: PRESENTATION AND ANALYSIS OF RESEARCH FINDINGS

4.1 Introduction

This chapter presents the findings of the research followed by a comprehensive analysis of those findings. The tools for collecting data were observations, structured questionnaires and interviews. The data collection instruments provided both qualitative and quantitative data and the analysis of the variables relevant to this research was done. The key aspects of data herein that guided the development of the NFC application include- The departments of the hospital in which the respondents worked and their usage of EMR System, health record problems that lead to inefficient healthcare delivery and an assessment of NFC functionality on the mobile phone including medical phone applications on the phone. Questions related to the security features in this application have been explored as well.

Patients were also asked about whether they had medical insurance cards. Interview questions for the ICT team at Nairobi West Hospital have been formulated and the researcher sought to know the current modes of patient data storage in the hospital. Further, the researcher will outline the architecture of the model that has been developed.

4.2 Background and study area

The Nairobi West Hospital whose motto is “Health Care at Its Best” is located on Gandhi Avenue, Nairobi West, Nairobi, Kenya. It’s a level IV hospital with over 30 years of service to the local and international community and is different medical and surgical departments and medical technology alluded to earlier in Chapter 3 section 3.2

Health practitioners include medical officers of health, dental surgeons, and consultant doctors and can also be categorized under those who on permanent regular basis and locum-based doctors. Patients that took part in the research were primarily from the outpatient and casualty department. This was because of the ease distribution of the questionnaires to them as they approach the hospital reception. Patient’s in the ward and ICU were neither interviewed nor provided with the questionnaires.

4.3 Data results, presentation and analysis

This section will cover the presentation the data and analysis based on the categorization of the respondents. The respondents were health practitioners, patients, ICT administrator and head of outpatient casualty department.

4.3.1 Health practitioners' profile

The following questions and respondents reported here pertained to health practitioners who participated in the research.

a) Gender

Out of 25 health practitioners, 9 were female and 16 were male. The distribution in terms of percentage is illustrated in Figure 4.1, 64% of the respondents were male as compared to 36% who were female respondents.

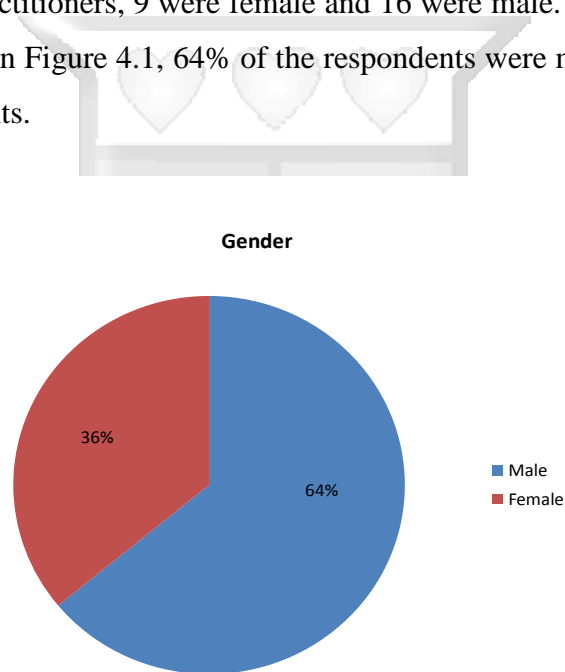


Figure 4.1 Gender analysis

b) The departments of the hospital in which the responded worked

Figure 4.2 shows the departments of the hospital in which they are stationed. It also shows the distribution of the department as responded by the health practitioners. Majority of the respondents indicated that they were stationed at the outpatient and casualty department and as a

result helped the researcher to prioritize on the department where the model and system can be tested and implemented.

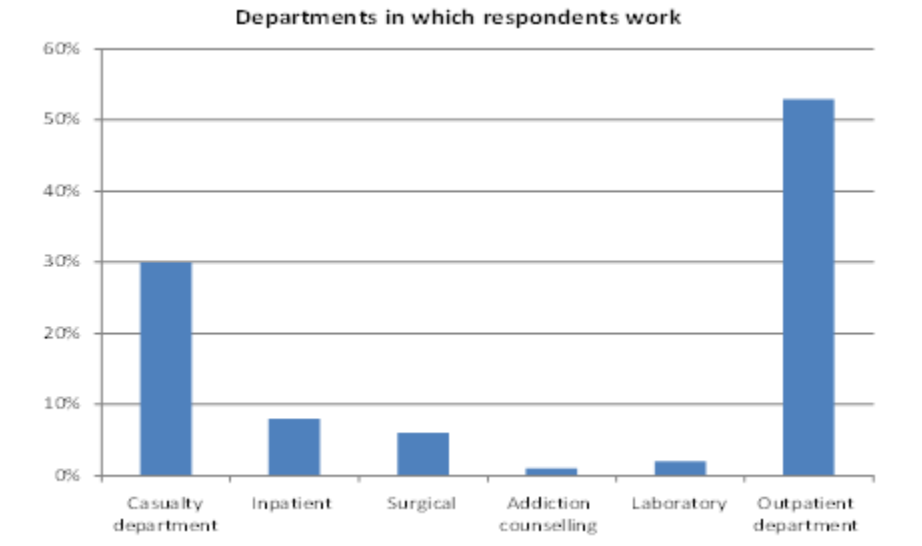


Figure 4.2 List of the department in which the practitioner is based

a) Health department’s usage of Electronic Medical Records System

The question “*Does your department use electronic medical record system*” sought to investigate the usage of technology for data storage in the hospital. The purpose of this analysis was to extrapolate on the hospital readiness to have an NFC based health record system where patients carry their own medical data which can be connected to an NFC enabled phone through an app. Figure 4.3 shows that an overwhelming majority of the respondents (98%) indicated that they have EMR system in their departments.

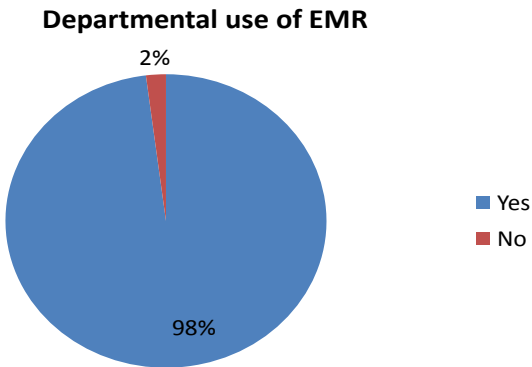


Figure 4.3 Departmental use of EMR

b) Health record problems that lead to inefficient healthcare delivery

The health practitioners were asked the question “*Which of the following health record problems lead to bad healthcare delivery?*” They responded by giving a variety of reasons and this information was collated and is shown on Table 4.1

Table 4.1 Classification of problems with health records

Health record problems	Data collated from the questionnaire
Health data portability	Lack of health data sharing among clinicians Inability of the patients to move with their health data Lack of proper medium of storage of their health data
Culture	Poor record keeping habits Lack of health data sharing among clinicians Organizational culture Problems at the hospital reception
Health data entry	Inadequate health data entry Patients providing inaccurate health data during clerking
Technological infrastructure	Lack of technological infrastructure Digital divide among clinicians Lack of proper medium of storage of health data

With this background in mind, a Pareto analysis was then done on we will show the details of this analysis in the subsequent sections of this chapter.

c) Near Field Communication (NFC) functionality on the mobile phone

25 respondents were asked to state if their mobile phone had NFC functionality. Only 2 respondents marked YES which accounts for 8% of the respondents. 92% marked NO. Figure 4.4 shows the distribution of the respondents for this question.

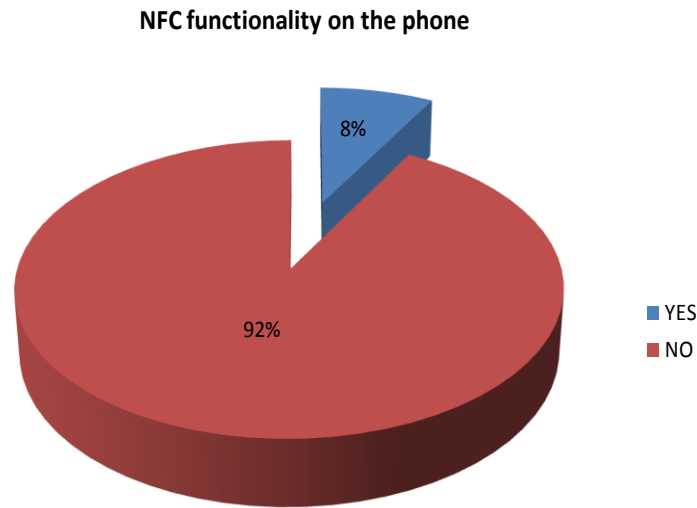


Figure 4.4 Near Field Communication (NFC) functionality on the mobile phone

The inference to this can be looked at in two ways. Firstly, either the practitioner’s mobile phones did not have NFC capability or they were not aware that their phones had this NFC functionality. This is statistically significant because it shows the level of intra-organizational digital divide that will have an effect in implementation of the system.

d) Medical phone application on the phone

Figure 4.5 shows that 5% of the practitioners respondents said they had a medical app on their phone while 95% of the respondents said they did not have any medical application installed on their smartphone. The purpose for this question was to investigate the respondents’ awareness of the importance of mobile phone health applications that are designed to assist doctors and patients in managing their health.

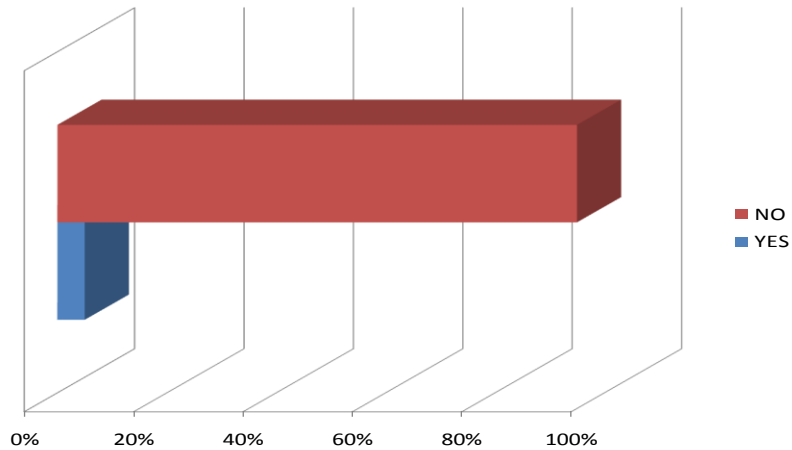


Figure 4.5 Medical phone application on the phone

e) Medical phone application and clinical management of patient

Out of the 5% of the respondents who responded that they had a medical phone application their phone, 98% indicated that this application helped manage their patients better.

Only 2% responded that this technology did not help them in patient's clinical management as is illustrated in Figure 4.6

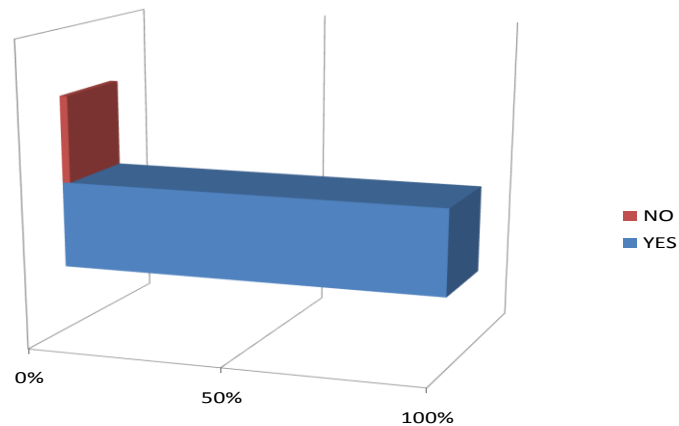


Figure 4.6 Medical phone application and clinical management of patient

This result shows that incorporation of NFC for health information portability in the hospital can help manage the patients even if this technology is initially adopted by few health

practitioners. The IT department can then ensure that through training, the rest of the clinicians can catch-up with their counterparts who will be already familiarized with and using this technology.

j) Health practitioner's recommendations of patient data portability methods

Health practitioners were asked which other health data probability technologies they would recommend other than the insurance cards. This was an open ended question, for qualitative analysis, that sought to gather data on the knowledge of the health practitioners in health portabilities and how important these technologies are in patient management. The responses varied from national identification cards, to medial cards, to medical referral letters to discharge summaries. Others included RFID, online data access and patient review cards

k) Security in medical records

Patients were asked which safety concerns, if any, they thought might present with automation of patient medical records in patient's medical cards and mobile phones. Respondents mentioned health data privacy, health information availability, lack of confidentiality and data manipulation by experienced users. This was a crucial question as issues surrounding medical record security were a key factor in both designing and implementing the system and the model as exemplified by requiring authentication functionality of password and username to access the patient's database.

l) Health information portability and healthcare

Health practitioners were asked their level of agreement with the following statement: *“When health information portability is introduced in the hospital, healthcare can be improved?”*

A likert scale from strongly agree to strongly disagree was used and Figure 4.7 shows the percentage distribution how the health practitioners responded. 80% responded that they strongly agreed, 10% agreed, 4% responded neither, 5% disagreed and lastly only 1% strongly disagreed.

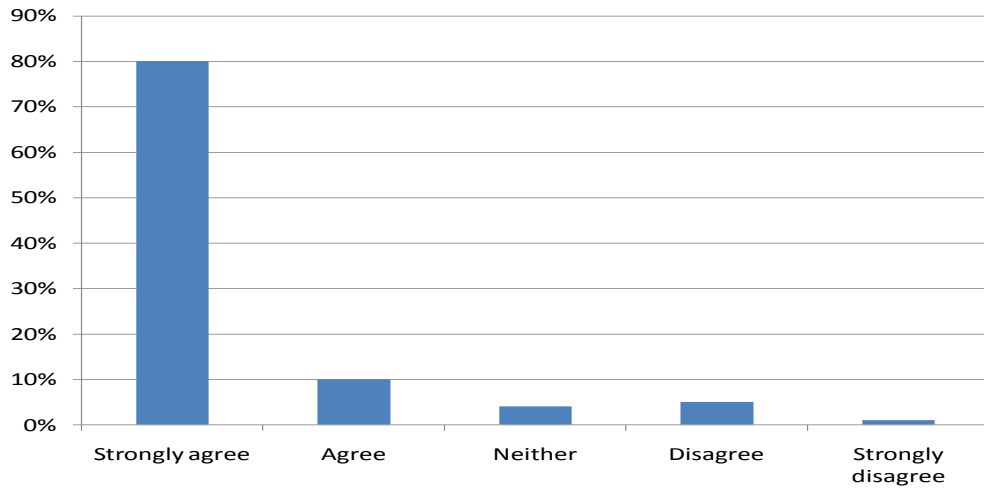


Figure 4.7 Health information portability and healthcare

4.3.2 Patient respondents

There were 126 patient respondents and the following is a presentation of how they responded to the questionnaires.

a) Patients gender analysis

Figure 4.8 shows that the female patients were the majority of the respondents against their male counterparts. Out of 126 patients, there were 80 female respondents against 46 male respondents.

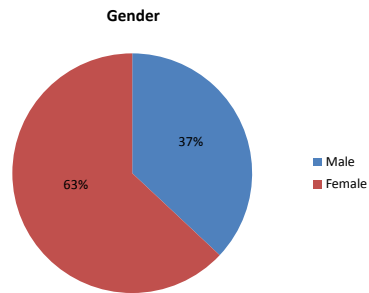
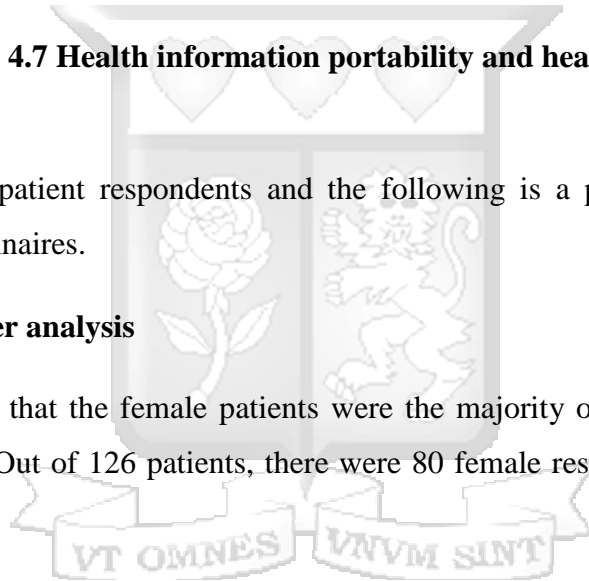


Figure 4.8 Gender of the patients respondents

b) Ownership of medical insurance card

90 out of 126 patients (71%) responded that they had a medical insurance card. On the other hand 36 out of 126 patients (29%) responded that they did not have any medical insurance card as shown on Figure 4.9 This question was meant to assess patient's health data portability, an important aspect of this research. Since 71% of the patients reported to having a medical insurance card that holds their health insurance details, this shows that a majority of patients would be comfortable carrying an NFC card which has their electronic medical record.

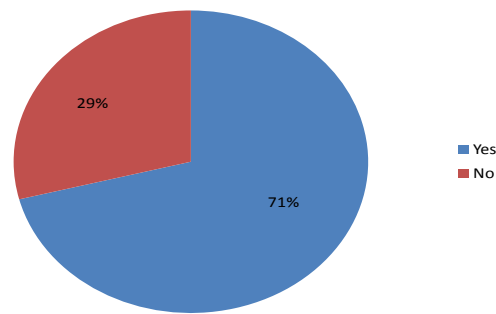


Figure 4.9 Ownership of medical insurance card

c) Benefits of medical insurance card

90 patients who responded YES to owning a medical insurance card were then asked if they felt the card was beneficial to them. A Likert scale was used to measure whether the respondents strongly agreed, agreed, neither, disagreed or strongly disagreed. Figure 4.10 shows the result of this study. Strongly agree (59%) Agree (30%) Neither (2%) Disagree (7%) Totally disagree (2%)

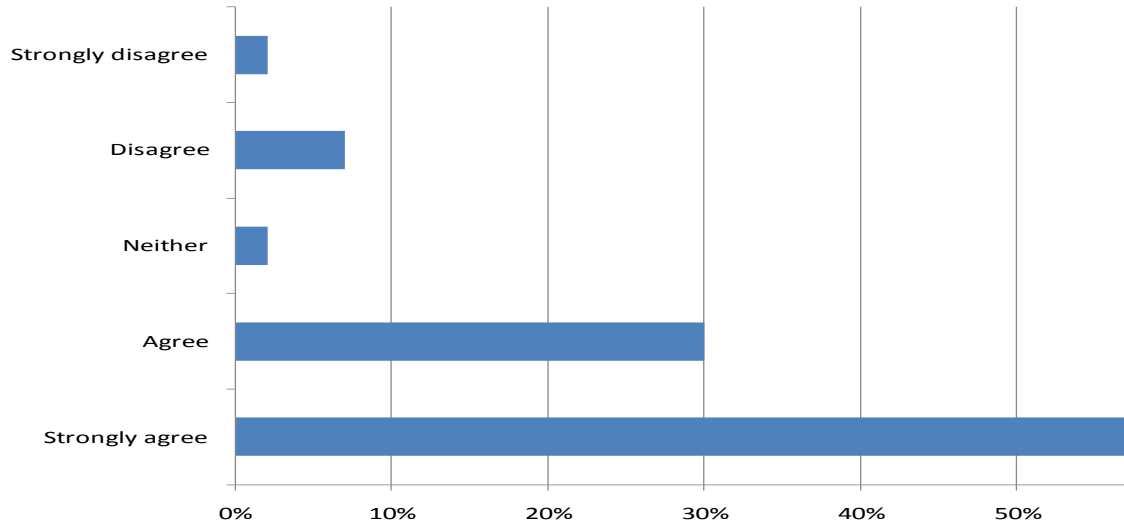


Figure 4.10 Benefits of medical insurance card

4.4 Pareto Analysis

This quality management statistical technique was used to analyze the organization issue of EMR management and how this may have an impact on the adoption of the system and the model for health information portability.

The healthcare practitioners were asked which of the following health record problems lead to bad healthcare delivery:

- i) Poor record keeping habits
- ii) Inadequate health data entry
- iii) Lack of health data sharing among clinicians
- iv) Inability of patients to move with their health data
- v) Organizational culture
- vi) Lack of technological infrastructure
- vii) Digital divide among clinicians
- viii) Problems at the hospital reception

- ix) Lack of proper medium of storage of the health data
- x) Patients providing inaccurate health data during clerking

The problems were categorized as shown on Table 4.2

Table 4.2 Categorization of health problems

Classification of health record problems	Number of responses
Health data portability	2
Culture	13
Health data entry	7
Technological infrastructure	20

The purpose of this categorization and the subsequent Pareto Analysis was to identify the key health record problems that need to be addressed in order to ensure better healthcare delivery in the hospital.

Table 4.3 shows the frequency distribution with cumulative frequency generated from Table 4.2

Table 4.3 Frequency distribution with cumulative frequency generated from Table 4.2

Item	Frequency (f)	Cumulative frequency (cf)	% cf
Technological infrastructure	20	20	47
Culture	13	33	78
Health data entry	7	40	95
Health data portability	2	42	100
	Sum=42		

Figure 4.11 shows the Pareto Analysis chart

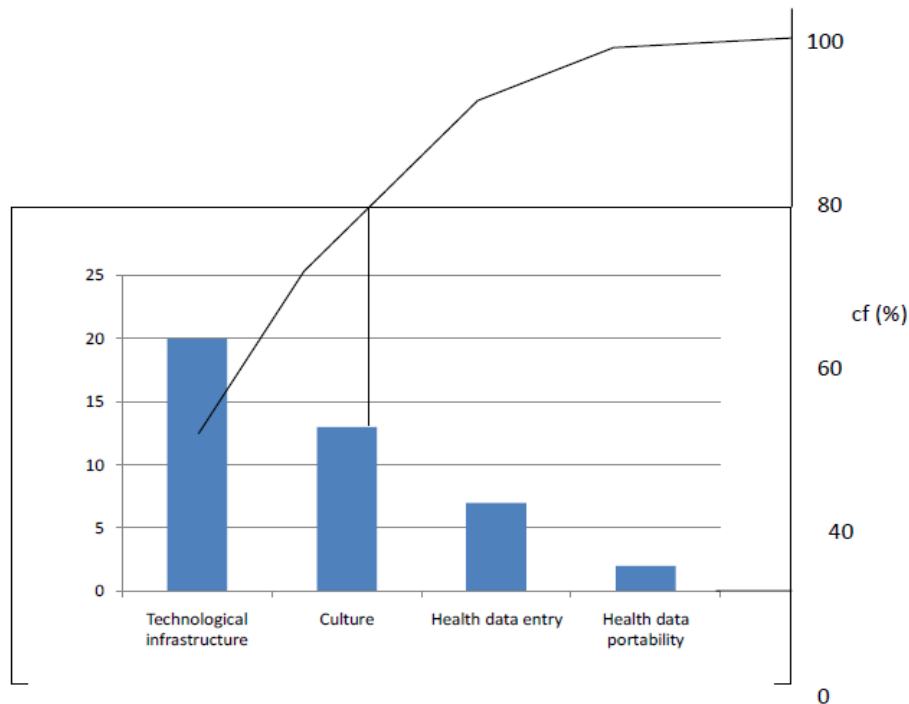


Figure 4.11 Pareto Analysis chart

4.5 Discussion of the Pareto Analysis

Figure 4.12 shows that when a line is extrapolated at 80%, what is on the left of the chart is technological infrastructure and culture. It can be concluded that by addressing issues on technological infrastructure and culture, the organization can solve most of the health record problems. EMR adoption will heavily depend on the willingness of the organization to addressing the biggest problem that might pose as a challenge and this Pareto Analysis becomes relevant in this regard.

4.6 Interview questions

The ICT team at Nairobi West Hospital was interviewed and the researcher sought to know the current modes of patient data storage in the hospital. The respondents stated that currently patient's notes are stored in paper files. The respondents also reported that a hospital management information system has been proposed and soon the hospital will be moving

towards automation of patient records, but this comes with its barriers such as the digital divide among the health practitioners and culture as well.



CHAPTER 5: SYSTEM DESIGN AND ARCHITECTURE

5.1 Introduction

This section will delve into the design of the model and the architecture as well. The model offers a proof of concept for the system, NFC mobile application. System analysis with a thorough description of the various functional and non-functional requirements has been done. Further, diagrammatic presentation of the use case diagram, flow chart of the system, entity relation diagram, sequence diagram, data flow diagram has been provided.

The NFC card will act as the patient database and its inherent portability function aids the patient in carrying their own health data and relaying this data to doctors whenever they visit a healthcare center. As a result, doctors are able to make quick medical diagnosis and treatment plan. The information that is contained in the patient's database include name of patient, allergies, vaccinations, medical diagnosis, drug prescriptions, medical and surgical history.

Lastly, a conceptual design of the model with details on the field settings data entry form, creation of database and a description of the installation of TracerPlus software on mobile phone that acts the client to the PC host has been illustrated.

5.2 NFC System Architecture

The NFC application architecture shown on Figure 5.1 borrowed the strengths of the conceptual framework illustrated on Chapter 2.

The system architecture comprises of 2 card terminals:

- i) **The patient terminal** whereby the patient presents their NFC card to the doctor. Initially, this NFC card doesn't contain any health data and it's hence the doctor to input the data into it via a mobile app. In the event the patient's card has data, the doctor, through his mobile phone app, can be able to input the data.
- ii) **The doctor's terminal** which the mobile phone application that can read and write data onto the patient's NFC card.

Medical Center Boundary

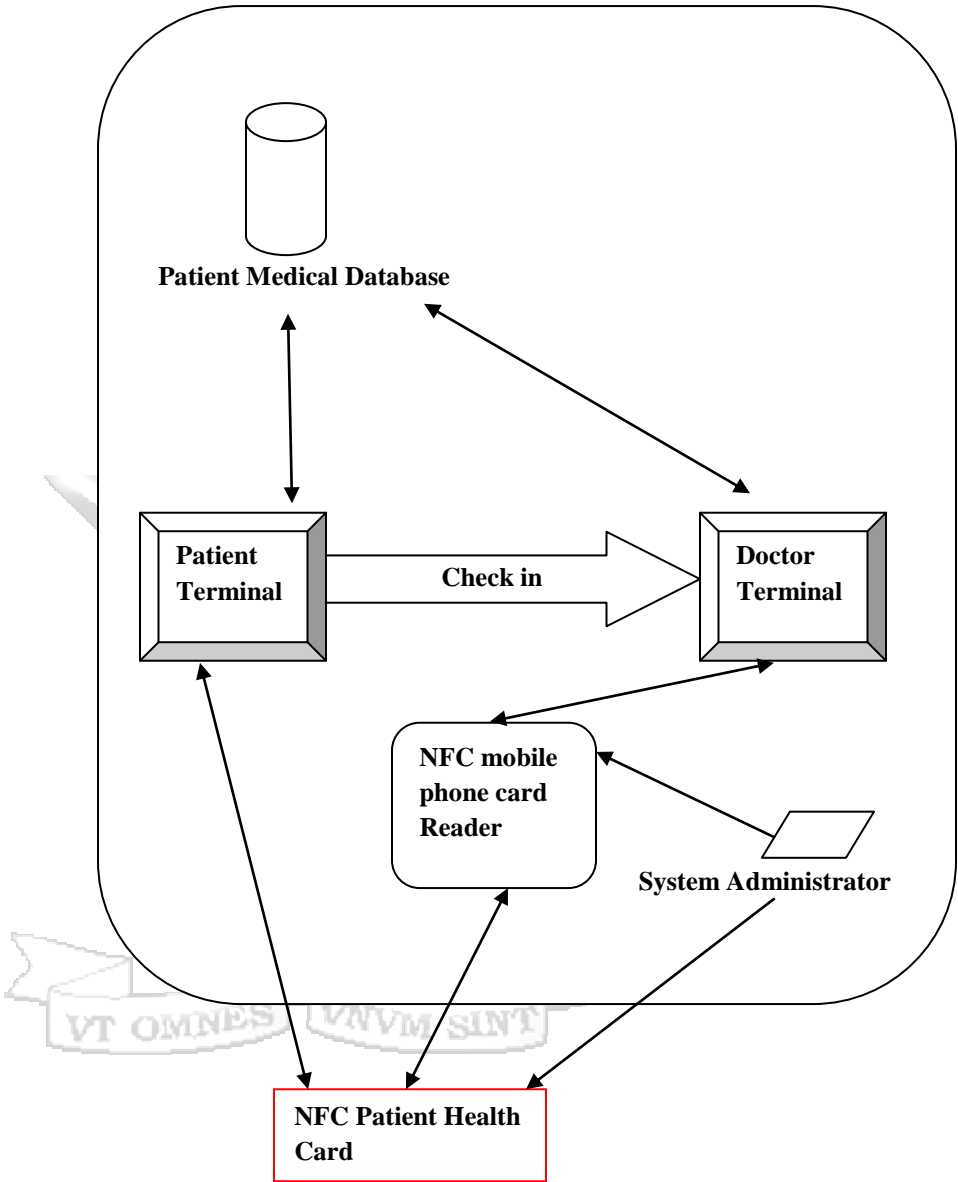


Figure 5.1 NFC Application Architecture

5.3 System Scenario

The following narration gives a picture of the scenario where a patient with an NFC card visits The Nairobi West Hospital.

“Ben is a patient who has a long history of diabetes and hypertension. He is also allergic to Penicillin drug and has had hip replacement surgery in 1998. He visits the hospital carrying his NFC medical card. He is received at the hospital’s reception where his details are captured in the Hospital Information System. He is then directed to one of the outpatient clinic where he presents his NFC card to the doctor. The doctor takes a brief history of the patient and then uses his app on his phone to read and write medical data on the patient’s phone. The assumption is that the patient’s NFC card is compatible with the doctor’s NFC-enabled mobile phone. The medical data is limited to the most important data that the doctor needs to make a clinical diagnosis and formulate a treatment plan.”

5.4 Analysis Phase

The rationale for the model developed is twofold. Firstly, is to allow for the doctor to be able to view the patient’s electronic medical record stored in the database. Secondly, it ensures that there is an efficient database of patients which is reliable, secure and that ensures that patient’s data is properly generated, stored and retrieved.

a) Functional requirements

- i. **User authentication-** The user of the application (doctor and patient) should be able to provide credentials for logging into the application.
- ii. **User verification-** Patients ought to be identified and verified as the owners of the NFC card that they present to the hospital.
- iii. **User personalization-** The patients, thorough through their doctors, should be able to create a medical profile that they can access when they need medical treatment. No two medical data should be the same as each patient has their unique medical history and presenting complaint.
- iv. **Interoperability-** The mobile application should seamlessly integrate with heterogeneous NFC cards that may have different NFC technologies. This will ensure that the patient

can be able to move with their personal health data to the healthcare enters of their choice irrespective of the NFC technology inherent in their NFC card.

- v. **Data write**- The doctor should be able to write into the patient's NFC card.
- vi. **Data reading**- The doctor should be able to read the data of the patient's NFC card.
- vii. **Machine-to-machine connectivity**. This involves direct communication between two devices. The NFC card should be able to communicate and send data to the mobile phone.

b) Non-functional requirements

- i. **User-friendly**- The application should be easy to use by the doctors during input and reading of patient's data. The user interface should be appealing as well.
- ii. **Data encryption**- This security feature is geared towards protecting the patient's health data.
- iii. **Reporting of error** when there is an unauthorized access.
- iv. **Availability**- Both the patient's NFC card and the doctor's mobile phone should be available when needed.
- v. **Performance** – There should be no major setback in performance when the application is being used. The reading and writing feature of the application should be seamless.

The NFC card stores the patient's medical data while the android-based mobile phone acts as a terminal for writing and reading the NFC card. The patient carries the card to the hospital and presents it to the doctor who will use his NFC enable mobile phone to read and/or write the contents of the NFC card. The security feature includes provision for decryption and encryption of the patient's data.

5.5 Use Case diagram, flow chart, sequence diagram, entity relationship diagram (ER), data flow diagram

a) **Main Use Case Diagram for the NFC mobile application** is as illustrated in Figure 5.2.

The actors in this diagram are patient, doctor and IT administrator

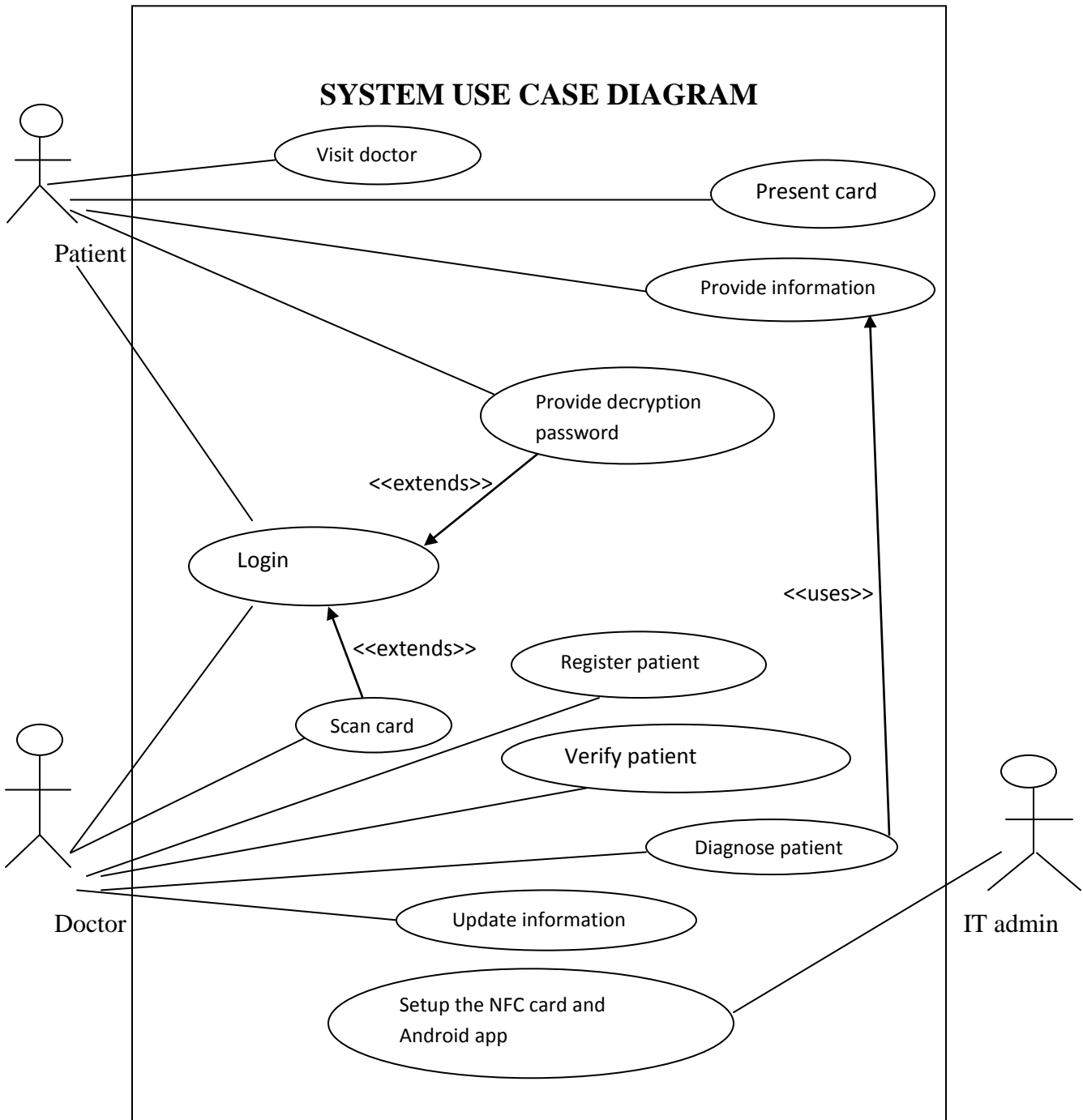


Figure 5.2 Main Use Cases Diagram

b) The Use Case diagram for the model is illustrated in Figure 5.3

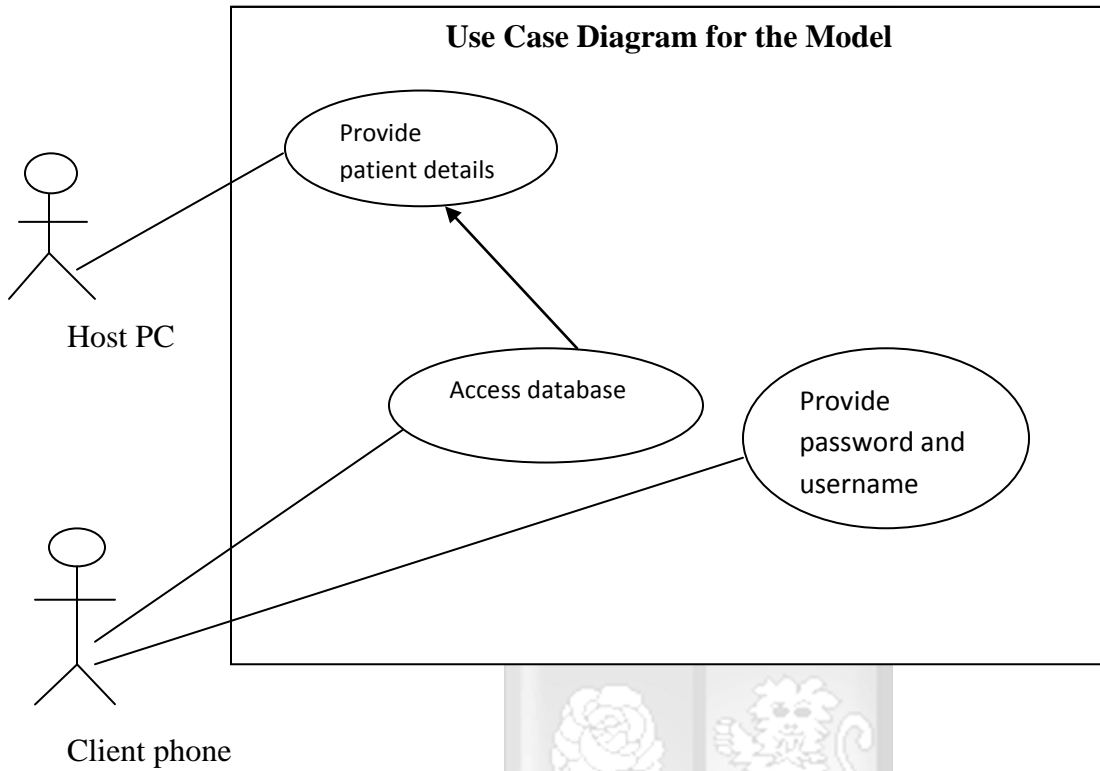


Figure 5.3 Model Use Case Diagram

c) Flow chart

The flowchart on Figure 5.4 shows the complete process that begins from the patient presenting their card to the contents of the card being read by the mobile app. It also illustrates the various steps that address data security as well.

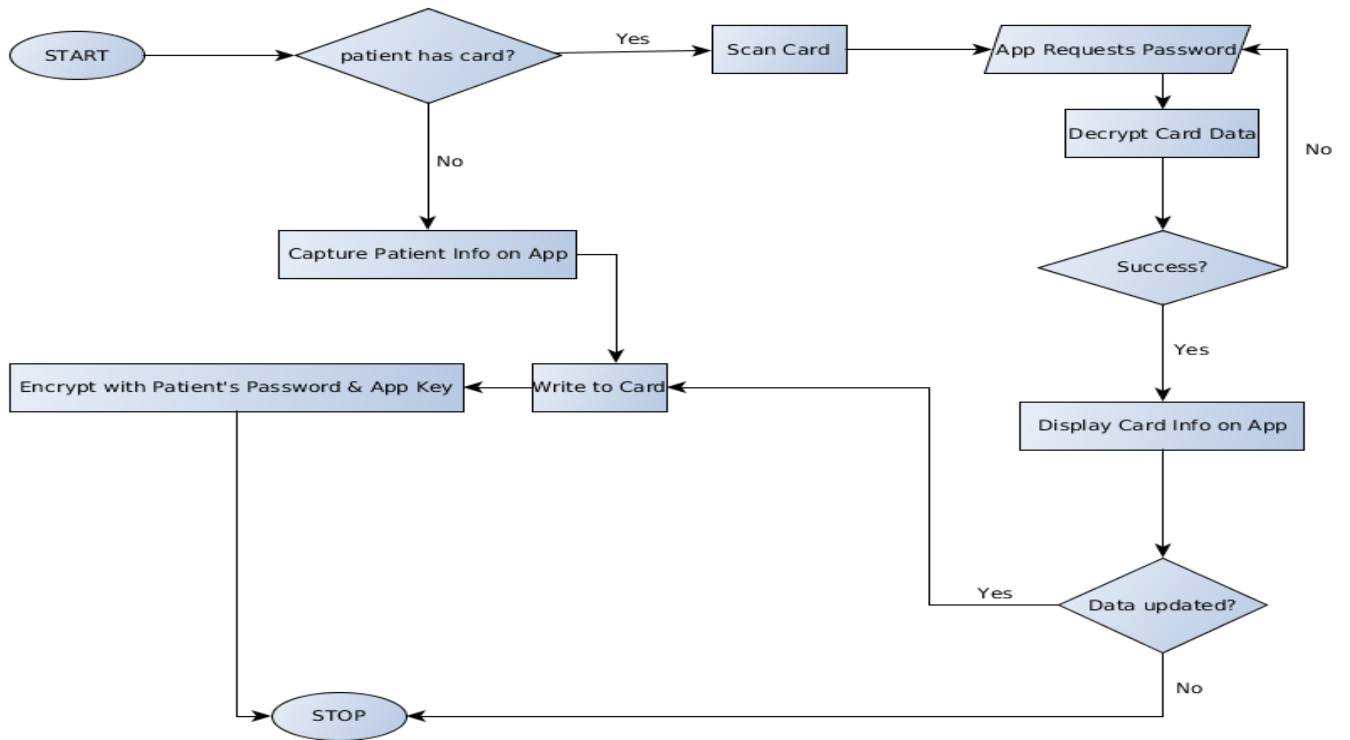


Figure 5.4 Flow chart of the system

d) Sequence diagram

Figure 5.5 shows the Application's sequence diagram.

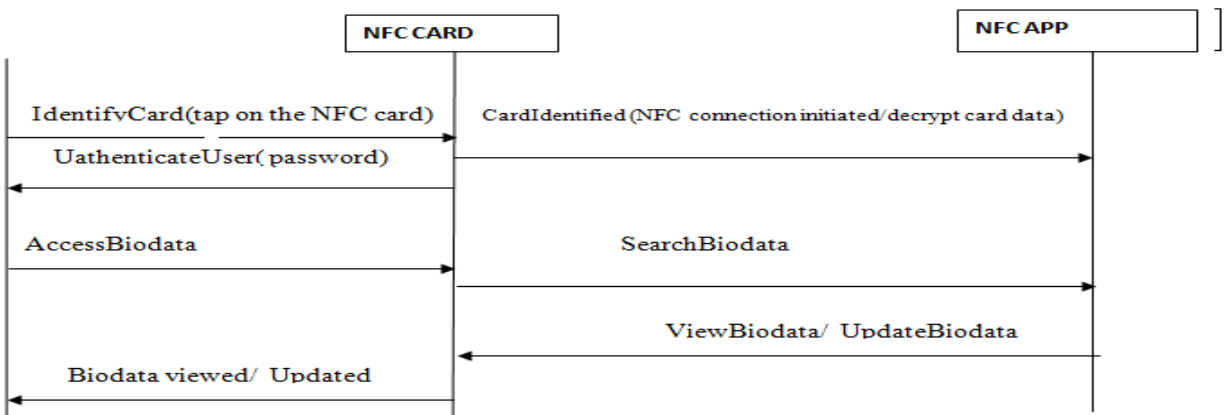


Figure 5.5 Application Sequence diagram

e) Unified Modeling Diagram (UML) Class diagram

Figure 5.6 is an illustration of the UML class diagram of the application showing the class names (patient, medical information, log) and their corresponding attributes.

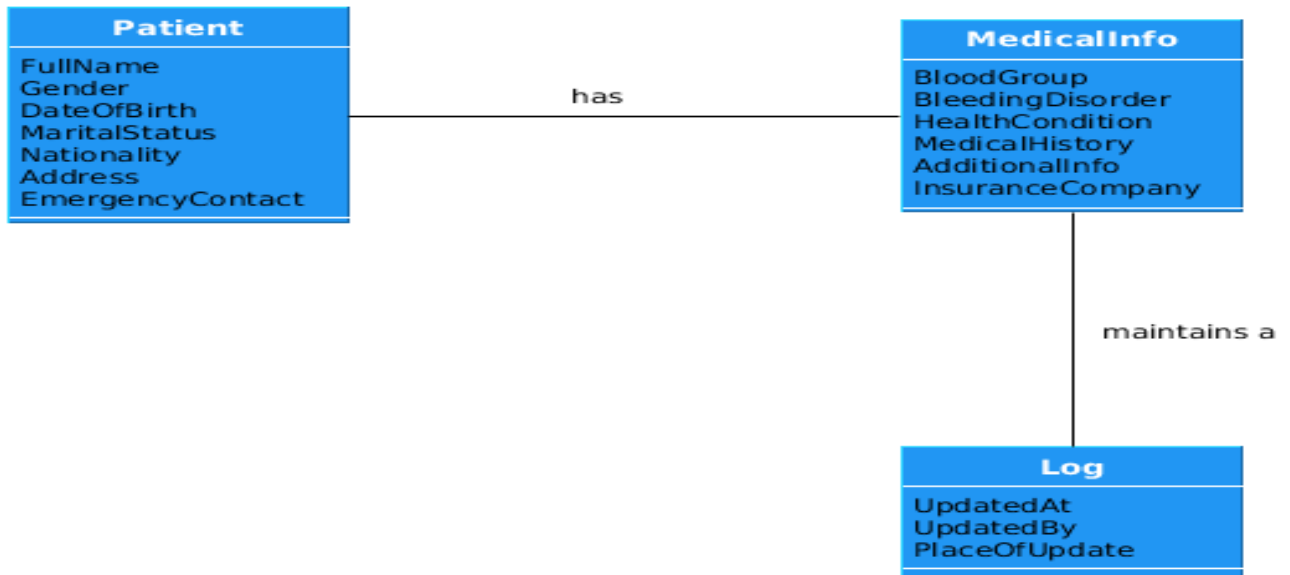


Figure 5.6 UML Class Diagram

f) Data Flow Diagramming (DFD)

Figure 5.7 shows the context diagram with the entities being NFC card, doctor, patient and NFC mobile app.

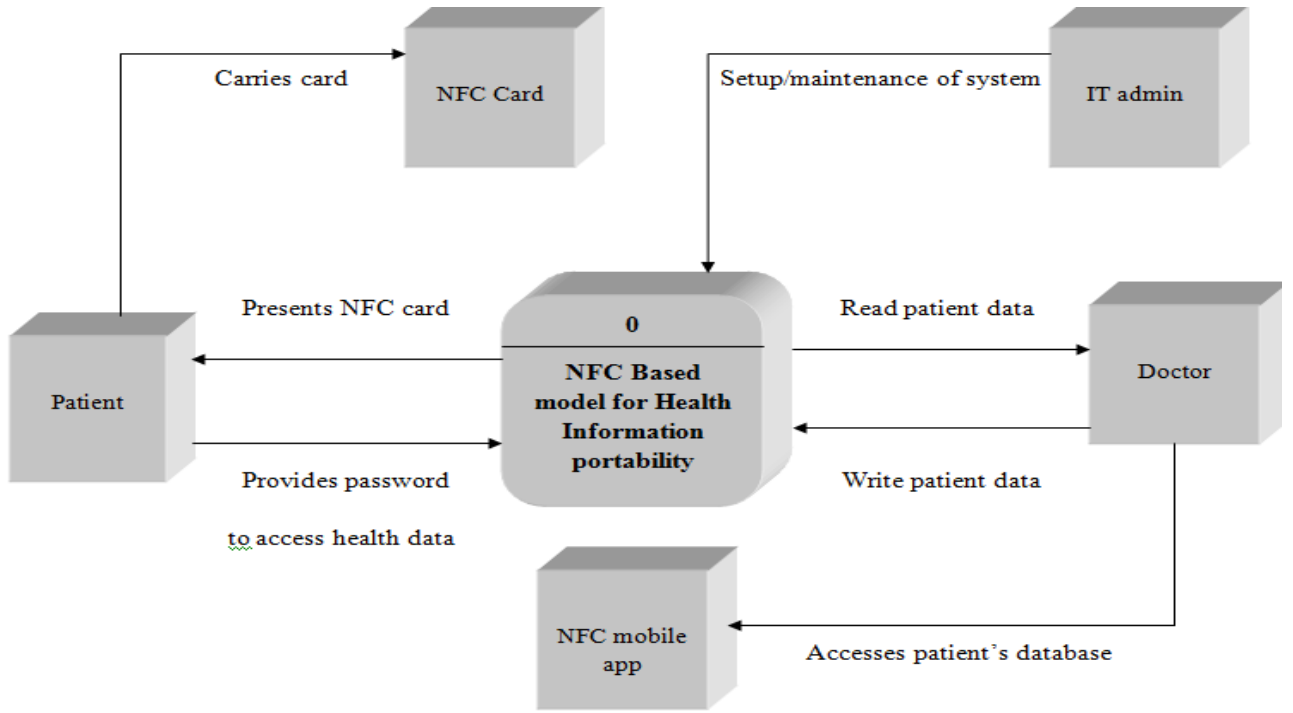


Figure 5.7 Context Diagram

g) Entity Relationship (ER) Diagram

Figure 5.8 shows the ER diagram with the entities and their corresponding attributes.

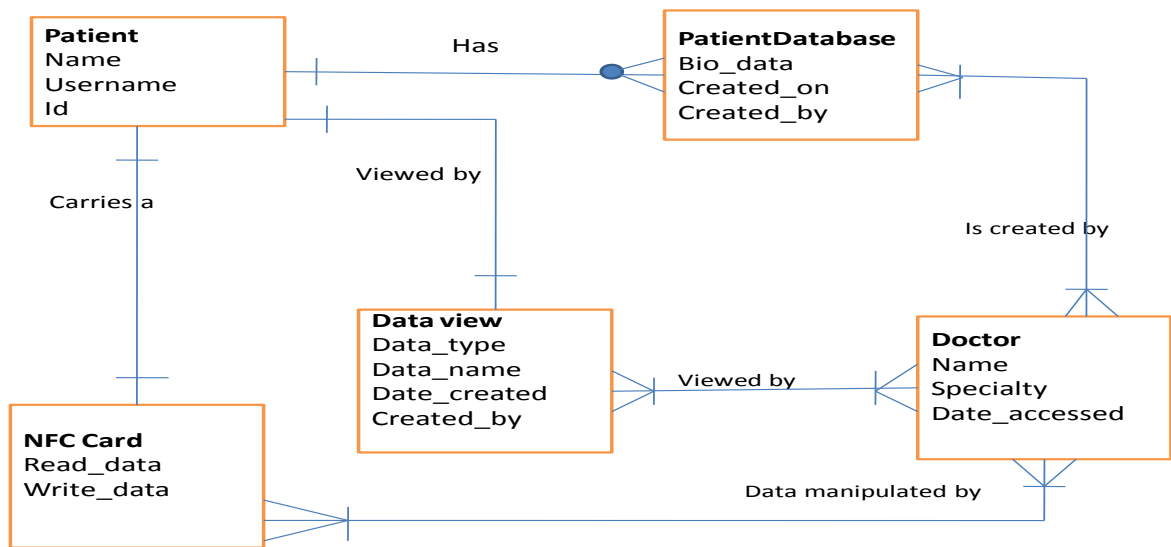


Figure 5.8 ER Diagram

h) Conceptual design of the model

The model shown in Figure 5.9 is the conceptual design that will correspond with conceptual design of the final system as illustrated earlier. This client-server architecture allows data to be accessed from the patient's database. Login authentication using username and password is needed for access to the database to be granted.

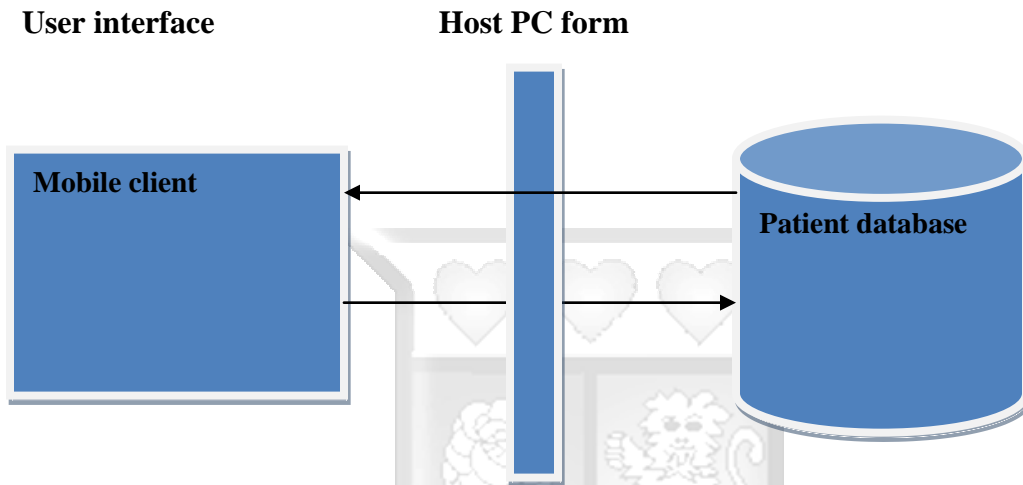


Figure 5.9 Conceptual design of the model

5.6 Model development (Proof of Concept)

In this section we will show the development of the model a proof of concept. The system that this model attempts to prove contains a database stored in a NFC card whose data can be viewed on mobile app via a card reader. Therefore we will show with the model the creation of a database, establishing a connection and viewing of patient's data.

TracerPlus software design tool was used. This software enabled creation of the model for the purpose of data collection and establishing connection between a PC host and a mobile phone. The advantage of this software is that it helps in creation of enterprise class mobile forms in an intuitive drag and drop interface.

5.6.1 System requirements

The following system requirements were considered for the development of the model:

i) Host requirements

The host is the Personal Computer that has the patients' database and which the TracerPlus Mobile Client communicates with when syncing patient's data. The laptop used is running on Window 7 Operating System.

ii) Mobile client

Mobile phone connection with Hauwei ALE-L21 (running on Android OS version 5.0.1) was done. Additionally Media Transfer protocol (MTP), a communication protocol that allowed transfer of medical data from the laptop to the mobile phone was employed.

5.6.2 Conceptual design (Machine-to-Machine Communication)

The aim of this model is twofold. First is to show machine to machine communication that is inherent in the NFC system to be developed. Using the host-client model, the model will show that the data created on the database (host computer) can be manipulated and stored on the client (mobile phone) as illustrated in Figure 5.10

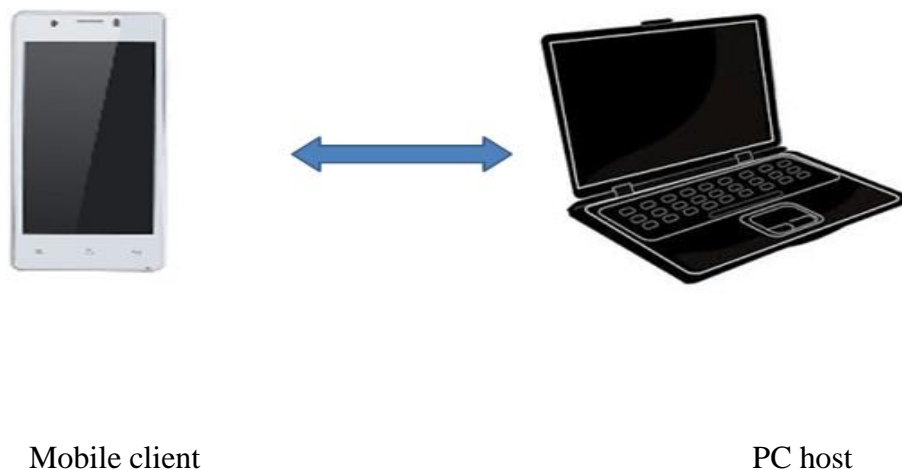


Figure 5.10 Machine-to-machine communication

a) Field settings data entry form

A new project was created from the TracerPlus software and the field settings is as illustrated on Figure 5.11 The fields include patient’s name, allergy, updated information, blood group and insurance. This entry form was then used to store the aforementioned data to be shared with a mobile session created on the mobile phone.

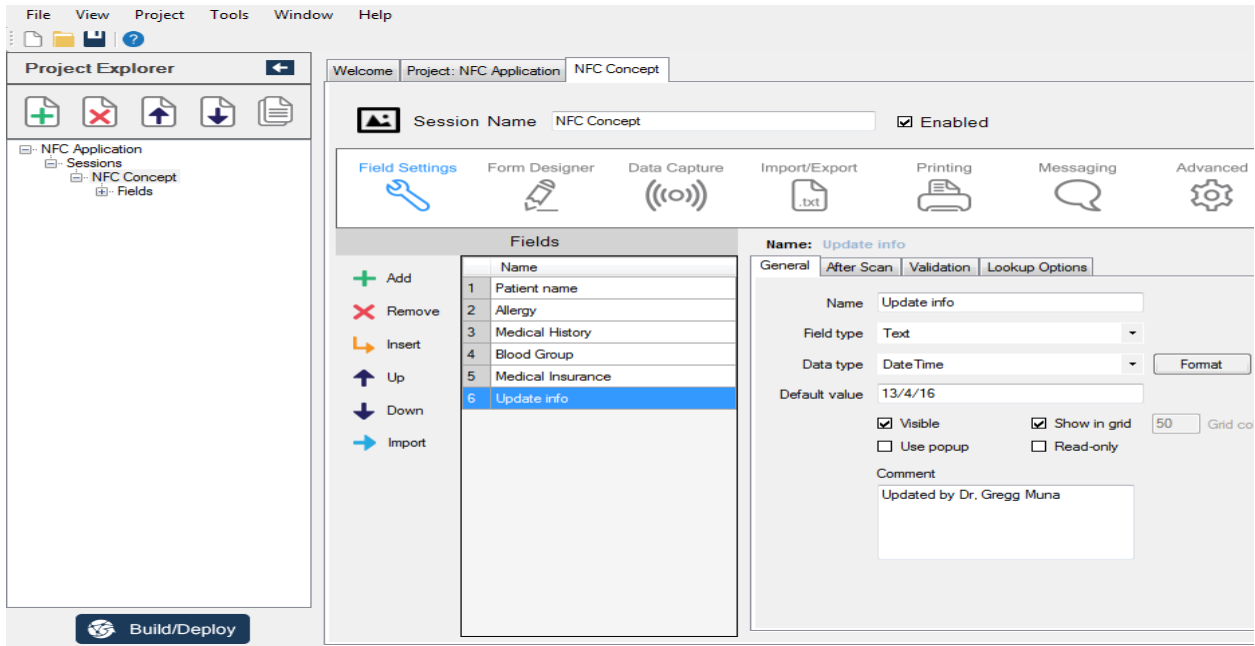


Figure 5.11 Mobile form

b) Creation of database

Table 5.1 shows the contents of the patient database that was created.

Table 5.1 Patient’s database

	Patient’s name	Allergy	Blood group	Medical Insurance	Update Information
Name	Patient’s name	Allergy	Blood group	Medical insurance	Update info
Field type	Text	Text	Text	Text	Text
Data type	General	General	General	General	DateTime
Default value	Mike Bay	Penicillin	O negative	NHIF	13/4/16

c) Form Designer

The form design created showing the form settings and the various patient data is illustrated in Figure 5.12

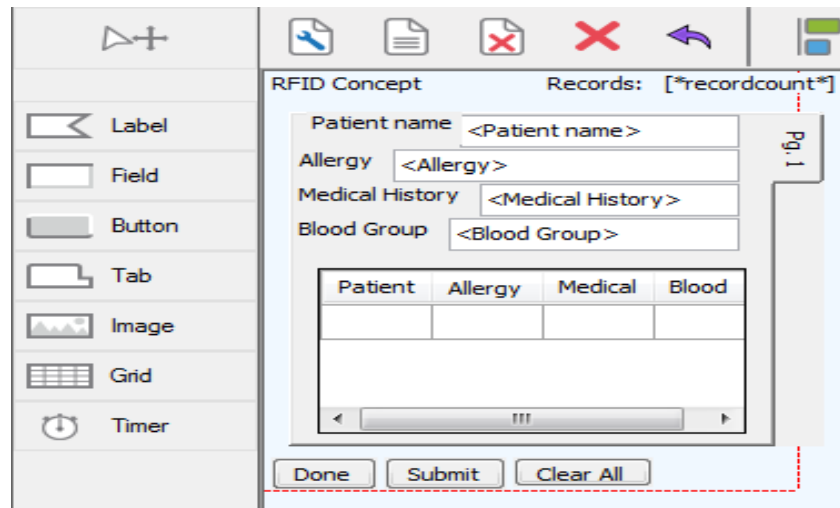


Figure 5.12 Form designer

d) Installation of TracerPlus on mobile phone

Mobile phone used was Huawei running on Android Operating System. This connected to the form created on the host computer.



CHAPTER 6: SYSTEM TESTING AND IMPLEMENTATION

6.1 Introduction

In this chapter, we will discuss the testing and implementation of the model developed. This is meant to evaluate the model in terms of whether it meets the objectives and functional and non-functional requirements of the systems that have been outlined in Chapter 5. The medical data considered in this scenario include patient name, allergy, blood group, medical history and update information.

6.2 Implementation

i) Data capture, build/deploy

Data created on the form settings was captured and deployed to the mobile phone where it can be viewed. Figure 6.1 is a representation of this functionality.

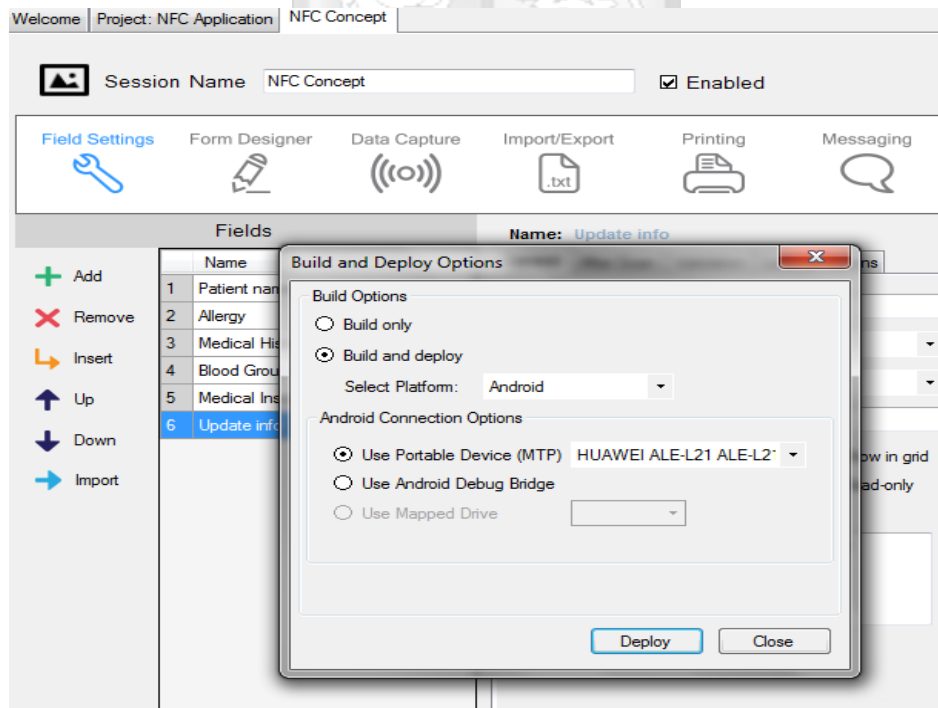


Figure 6.1 Data capture and build/deploy

ii) Authentication

When checked and fully configured, mobile client users must log in after launching TracerPlus on the mobile phone. Log in IDs can allow or limit access to TracerPlus sessions. The credentials used for the purpose of this model are: username is paulmorum and the Password provided is 12345.

The Screenshot for admin settings for mobile client can be found on Appendix section.

iii) Connect to mobile phone

This occurs after the build/deploy functionality has been initiated. It allows transfer of data from the host to the mobile client. The screenshot of the patient data view after this connection is shown in Figure 6.2 and the user interface (UI) data view is illustrated on Figure 6.3

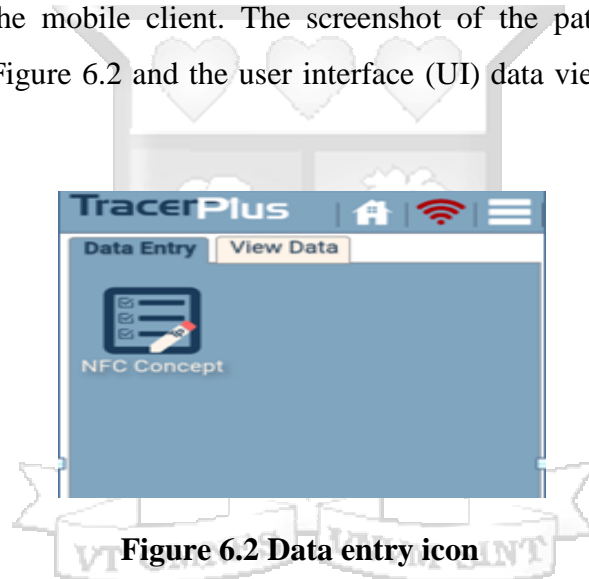


Figure 6.2 Data entry icon

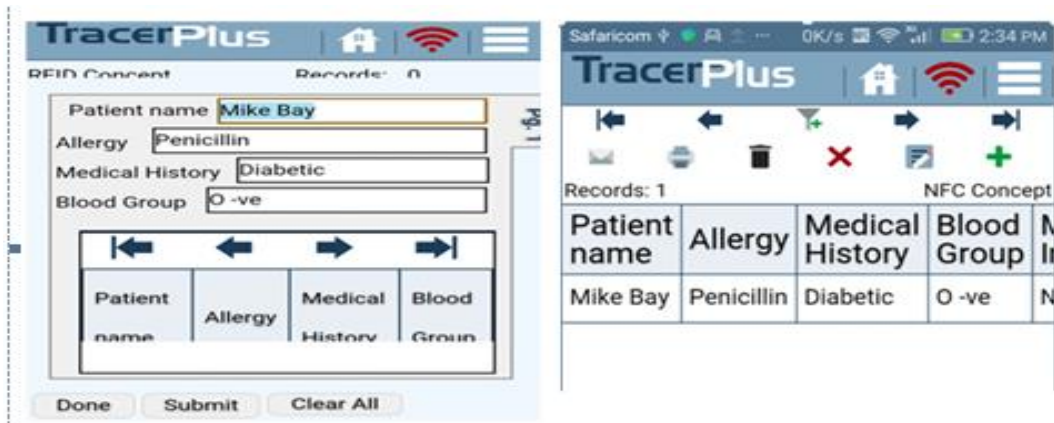


Figure 6.3 View data UI

iv) Security (Login credentials and inactivity timeout)

In addition to the required username and password, the Inactivity time out feature when checked will cause the application to return to the home screen after the specified time period has elapsed with no user activity. If Require Login is enabled, the application returns to the user login form. This timeout was set at 10 minutes.

6.3 Testing

Testing of the model was done as illustrated on the individual use cases. It should be borne in mind the use cases described below depend on whether a connection between the host PC and the mobile client can be established. The following is a breakdown of the use cases for the model:

a) Connection authentication use case

Test case name: Authentication

Test case number: 1

Description: This use case tests the login functionality using password and username as shown on Table 6.1. The configuration of users and their access levels are accomplished in this way.

Table 6.1 Connection authentication use case

Number	Action	Expected response	Result	Comments
1	Input correct username and password	Access to patient database granted	Connected and accesses patient database	OK
2	Input incorrect username and password	Connection authentication failure occurred. Reason: userID or password invalid	Pass	OK

The screenshot for authentication failure is shown on Figure 6.4

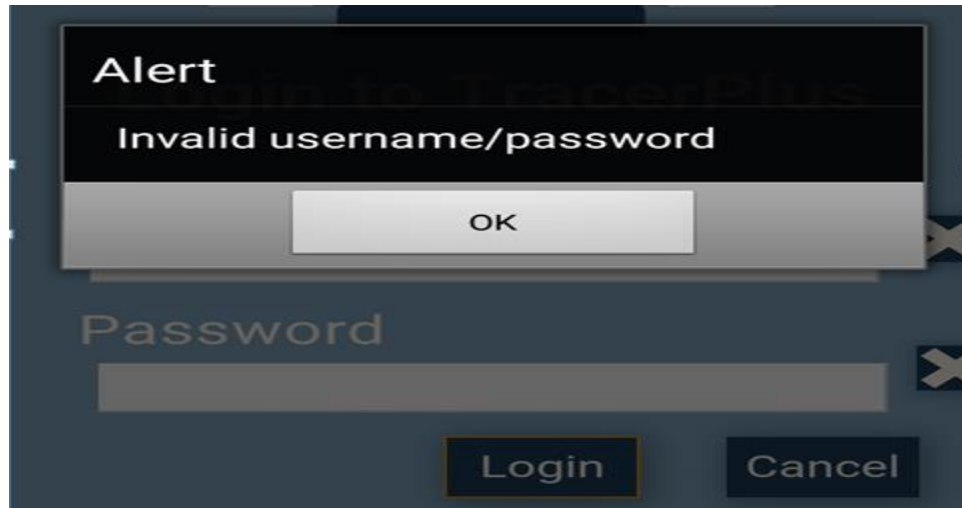


Figure 6.4 Screenshot for authentication failure

b) Update EMR card use case

Test case name: Updating the database

Test case number: 2

Description: this use case tests whether the model can update the database as shown on Table 6.2

Table 6.2 Update EMR use case

Number	Action	Expected response	Result	Comments
1	From the host, change Mike Bay's allergy data from Penicillin to sulphur.	Update data on the mobile client TracerPlus app	Pass	OK

c) New EMR use case

Test case name: New EMR data input

Test case number: 3

Description: this use case tests whether the model can input new health data as shown on Table 6.3

Table 6.3 New EMR use case

Number	Action	Expected response	Result	Comments
1	Create a new database with new patient's data	New EMR created on the host database and can be viewed on the mobile client	Pass	OK

d) Cancel new EMR use case

Test case name: Cancel new EMR

Test case number: 4

Description: this use case tests whether the model developed is able to cancel a new patient health record as shown on Table 6.4

Table 6.4 Cancel new EMR use case

Number	Action	Expected response	Result	Comments
1	Cancel new EMR after data input	Data cancelled, result of this viewed on the mobile client side	Pass	OK

e) Save new EMR use case

Test case name: Save new EMR

Test case number: 5

Description: this use case tests the model's ability to save new data as shown on Table 6.5

Table 6.5 Save new EMR use case

Number	Action	Expected response	Result	Comments
1	Save new EMR after data input	Data saved in the database after build/deploy activated.	Pass	OK

f) Model usability use case

Test case name: Model usability

Test case number: 6

Description: this use case tests usability of the model as shown on Table 6.6

Table 6.6 Model usability use case

Number	Action	Expected response	Result	Comments
1	Buttons easy to click	Button clicked, data manipulated	Pass	OK
2	Display of data on text fields	Data displayed	Pass	OK
3	Text filed large enough for data input	Data input enabled	Pass	OK

CHAPTER 7: DISCUSSIONS

7.1 Critical analysis of the model developed

Health care system is data driven and in keeping with trends in big data analytics where analysis of big sets of data is now commonplace, the following can be deduced from the model developed:

The data captured and stored included the patient name, allergy, blood group, medical history and update information. This information is described as crucial medical information since it helps the doctor make a quick clinical judgment. The questionnaire provided a global overview of the wide range of medical data which was analyzed and in the end specific data was chosen to represent the vital data that might be needed by the health practitioner. The fact that this data is small supports the idea that a not all medical data is required. In the development of the system, incorporation of the medical data in the NFC tag is done keeping in mind that the space for storing this data is limited.

It is imperative to note that only the doctor is mandated to input the patient's data as illustrated on the data capture module.

Authentication is an important security feature and as described on the model, mobile client users must log in after launching TracerPlus on the mobile phone. Log in IDs allows or limits access to TracerPlus sessions. The passwords are unique to each user and this model when replicated in the system represents the passwords provided by the patients to access their medical data.

Connect-to-phone feature of the model allows transfer of data from the host PC to the mobile client. This model when replicated in the actual system represents the mechanism in which data that is stored in the NFC card can be transferred to the mobile application via NFC standard. This module allows also for data written on the mobile app to be written on the NFC card. This two-way data transfer ensures there is machine-to-machine communication.

The inactivity time out feature causes the application to return to the home screen after the specified time period has elapsed with no user activity. This feature ensures that there is no unauthorized access to the patient's medical database in case the user forgets to log out or when

the user doesn't use the application for a specified time frame. This time is set in the settings on TracerPlus software IDE.

The testing of the model provided an assessment of whether the model functions in a real healthcare setup. The various use cases such as connection authentication, update EMR, new EMR, cancel EMR, save new EMR and model usability all showed pass results. This use cases depended entirely on whether a connection between the host PC and the mobile client can be established. The system developed ideally should follow this model. The efficiency with which the system will work will have either a positive or negative effect on the quality of healthcare delivery. This is even more crucial in cases of medical or surgical emergencies.

7.2 Unique features for NFC app system created and comparison with existing systems

The uniqueness of this research stems from the application of NFC in the healthcare setup. As outlined in the Literature Review Chapter, Smart Card Alliance (2015) states that NFC can be used for a variety of purposes including making payments by tapping the phone on a contactless card reader, reading information and picking up special offers and discounts from smart posters, storing loyalty program information and so on.

The salient features that also makes this system a novel idea is outlined as follows:

- a) **Portability of the NFC card and decentralization of medical database-** Patients are able to carry their card with their medical data and use any health service which has a card reader.
- b) **Security features-** The incorporation of password, encryption and decryption of data provides key security modalities for the system. Security of health data will be crucial for this system to be adopted.
- c) **Mobile phone ubiquity and miniaturization of computer-** Advancement of mobile phone technology in terms of processing power, availability and with respect to this study NFC technology, offers a unique opportunity for Nairobi West Hospital to utilize this technology to offer better healthcare to its patients. NFC technology incorporation in mobile technology is supported by the graph on Figure 2.3 in the Literature Review

chapter that shows total NFC-enabled device and chipset shipments world market, forecast 2009-2015 (Mulevu, 2012)

7.2.1 Comparison with existing systems: A critical appraisal

An examination of the systems described in this study offers a granular report on how influential NFC and EMR systems are to the healthcare sector. As exemplified on Figure 2.5- NFC-tag based alarm activation for medical appointment by Masud et al. (2014) which illustrates application of NFC in the medical field, a number of similarities and differences emerge. The similarities include usage of mobile application to read data from the NFC tag and the fact that both systems establish a connection between NFC reader and a mobile application. The internal storage for the NFC-tag based alarm activation for medical appointment system is 128 bytes which supports this research justification that a small number of medical data is required to make clinical decision and offer treatment to the patient. The differences between this alarm system and the system that this research developed is that whereas the former focuses on medical appointments, the latter focuses on medical diagnosis and treatment.

NFC Emergency Hospital Patient Management architecture by Krishna et al. (2013) proposes a system where the NFC reader is placed on the door and uplinked to the database so that every time it receives data it should be updated immediately. The difference is that this system is limited to emergency and therefore makes the assumption that medical data is only crucial in emergency department. NFC based system for health information portability can be used in every department in the hospital.

The SEMTAG prototype by Dünnebeil et al. (2011) puts more emphasis on encryption and decryption of medical data and these security features were adopted in the implementation of the NFC based system for health information portability as illustrated on the flowchart in Chapter 5 (Systems Design and Architecture)

7.3 Relevance of the model in NFC mobile app development

The model described in the proof of concept in Chapter 6 can be used as a basis for the development of the NFC mobile application.

The app will have a patient identification screen and health data update or delete screen. The app will also have a read and decrypt data and write and encrypt data functionality. This system that will run on mobile phones provides patients with a way to digitize their health information, a mechanism to convey their information to others and a security mechanism so that their information is not disclosed to non-authorized parts.

The NFC card will act as the patient data server and its inherent portability function aids the patient in carrying their own health data and relaying this data to doctors whenever they visit a healthcare center. As a result, doctors are able to make quick medical diagnosis and treatment plan. The mobile application will be built on Android OS whereby the Java programming language provides the logic and XML provides the design.

7.4 Adoption of the application in the healthcare sector

For this application to be adopted in the greater healthcare sector, the following should be put into consideration:

a) Adaptability of the system to the needs of the departments of the hospital

Not all departments in the hospital can implement this application. An example is the psychiatry units, High Dependency Unit (HDU) and Intensive Care Unit (ICU) because of practical reasons. This is because these patients may be too ill to provide their login credentials to the healthcare providers for authentication purposes.

b) The architecture should allow for more information sharing

This is in keeping with the trend that shows hospitals moving towards an information centric care delivery model that allows health information to be shared. The other factors to be considered are standardization of health data formats, provision of safe methods for data transfer and allowing for interoperability information exchange among all the healthcare stakeholders.

c) Cost of implementation of the technology

As the organization adopts this technology, there is a cost implication to it. This includes the cost of purchase of NFC enabled mobile phones, cost of a programmer who will design and implement the NFC app, training on usage of the technology and maintenance. As result, the organizational and technical challenges should be addressed as well.



CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The model developed offers a good foundation on which the application can be made. This will result in a system whereby the doctor is able to input and read the patient's data in an efficient manner. The importance of data portability cannot be gainsaid because of the ability of the patient to move with their data from one healthcare center to the next and this movement enables the patient not only to have a sense of ownership of their health data, but also ensure that there is continuity of care for the patient. The other aspect of this health data portability is that it will reduce the cost of repeat of medical tests. This reduction of cost will be beneficial for the patient.

The design of the Near-Field Communication Based-Model for Health Information Portability and the application, tailor-made for Nairobi West Hospital, offers a foundation onto which future research in NFC application in healthcare can be built. Of critical importance is ensuring that medical data is secure and the features on the model such as authentication were incorporated. The system had encryption and decryption of patient's data as well.

As Kenya National e- Health Strategy 2011-2017 (2011) points out, there is an important need for an e-health strategy in Kenya anchored on Vision 2030 which will ensure that Information Communication and Technology (ICT) is harnessed. NFC application in Nairobi West Hospital offers a focal point for serious discussion in the medical field on the need for inclusion of emerging technologies in the health sector. More research such as this one is catalyst and offers an impetus to the growth of medical technologies in the health sector.

However, the challenges that NFC and data portability poses great danger to health data privacy and great efforts should be made to protection manage health information privacy (Parks, 2012) This fact is supported by Clouds Standards Customer Council, (2012) that argues that a number of challenges exist when there is an attempt to leverage electronic health data storage for healthcare. While we acknowledge that ensuring that privacy issues and health data confidentiality is key in ensuring this technology gains wide acceptance, there is more work to be done. A multi-disciplinary approach is needed that brings key stakeholders such as IT

specialists, medical doctors and policy makers around a common goal of ensuring that health information portability benefits not just the patient, but the health service provider.

8.2 Recommendations

As health data portability and EMR technology becomes a critical area in the health sector, a number of strategic measures need to be taken in order to ensure that this idea materializes:

a. Data portability

As the healthcare sector is gradually adopting EHR and EMR systems, there is need to focus on how patients can carry their own data. Health data portability ensures that “*patient centricity*” is at the core of the wider value EMRs bring to the healthcare sector. Health data availability ensures improved clinical outcomes which in turn improves patient’s overall satisfaction.

b. Research and development

The benefits of NFC technology in the health sector are numerous and as this technology gains traction, it will become a crucial aspect in research and development in health informatics. Hence more research is required to find new ways of making sure NFC technology and card technology is streamlined.

c. Shift of technology and cost implications

The need for a paradigm shift in how EMRs are utilized in the health sector through health data portability using NFC technology offloads a burdensome task from the hospital IT departments with the traditional EMR systems and focus on a technology that is better to manage and is cost effective. Technological and financial support is needed to ensure that Nairobi West Hospital shifts from traditional ways of health data management to NFC technology.

d. Scalability of the technology

Scalability of the technology as Nairobi West Hospital and other healthcare providers adopt this technology and as more patients embrace the idea of carrying their personal health

data in an NFC card is something to think about. The workload capability needs to be addressed going forward.

e. Smartphone adoption in healthcare

Extending medical care to patients using the mobile platform presents the healthcare sector, and in particular the research area that is the focus of this study, with a great opportunity to utilize mobile technology which is changing and growing rapidly and this is exemplified by the miniaturization of technology in mobile phone technology. The healthcare sector will start reaping the benefits of this technology that has been utilized by other sectors such as commerce, banking and social media. It's the desire of this research to see to it that the health sector becomes a champion of how mobile phones, and indeed NFC technology, are utilized to help manage healthcare.

f. Big Data and analytics

Even though the amount of data stored in the NFC card is limited to the vital information the clinician needs, over time as this data gets updated, it provides a source for big data which can also be analyzed to help in clinical decisions.

g. Health Information Exchange

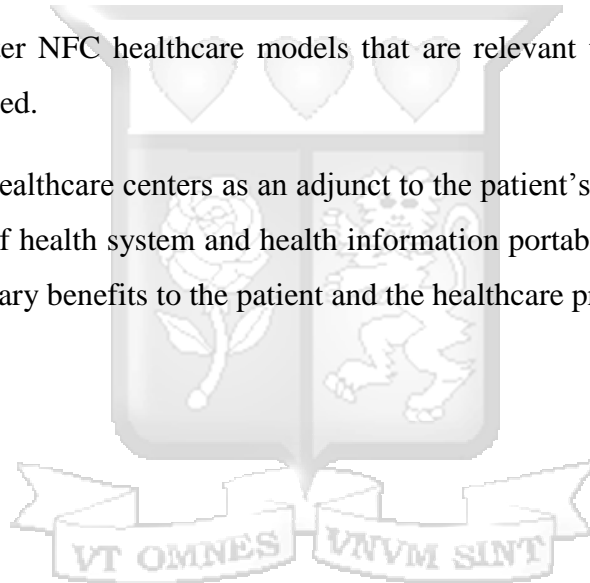
By the very nature of health information portability and patients' ability to visit various hospitals and present their health card, health information exchange among clinicians is realized. This expedites the execution of medical care across the healthcare sector.

Lastly and more specifically with regards to the NFC application for health information portability system, a strategy on which department to roll out this application is important. Results exhibited on Figure 4.2 in Chapter 4 shows the departments of the hospital in which health practitioners are stationed and since the majority of the respondents indicated that they were stationed at the outpatient and casualty department, these two departments should be considered in the pilot program.

8.3 Suggestions for future research

Future research should include the following:

- a) There will be a great benefit to the healthcare sector when the application proposed is integrated in the Hospital Management System and have the ability to show a log of the health data changes that are made into the NFC card for reference purposes.
- b) Larger capacity NFC cards are also needed to enable storage of more patient's data. This will be needed in case future research shows that more data is needed by the doctor to make certain clinical decisions.
- c) Designing of better NFC healthcare models that are relevant to emerging technologies that are NFC related.
- d) Linking various healthcare centers as an adjunct to the patient's portable NFC card. This decentralization of health system and health information portability via the NFC card will offer complementary benefits to the patient and the healthcare provider.



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APPENDICES

Appendix A: Letter of Introduction from Strathmore University



FACULTY OF INFORMATION TECHNOLOGY

Our Ref.: FIT/MSIS/RL/16/43

17th February, 2016

To whom it may Concern:

Re: Paul Morumbwa Onyancha - 83678

This is to confirm that the above named is a student at Strathmore University pursuing *Master of Science in Information Systems (MSc.IS)* since May 2014.

Paul is a research scholar who is currently in his 2nd (final year) of study and is doing a research pertaining his masters degree which is entitled: **Android-based Near-Field Communication Application for Health Information Portability: A Case of Nairobi West Hospital.**

This research being mandatory requirement towards successful completion of his studies, it would be great if you accord Paul the necessary support that he may need from your organization to enable him complete his task.

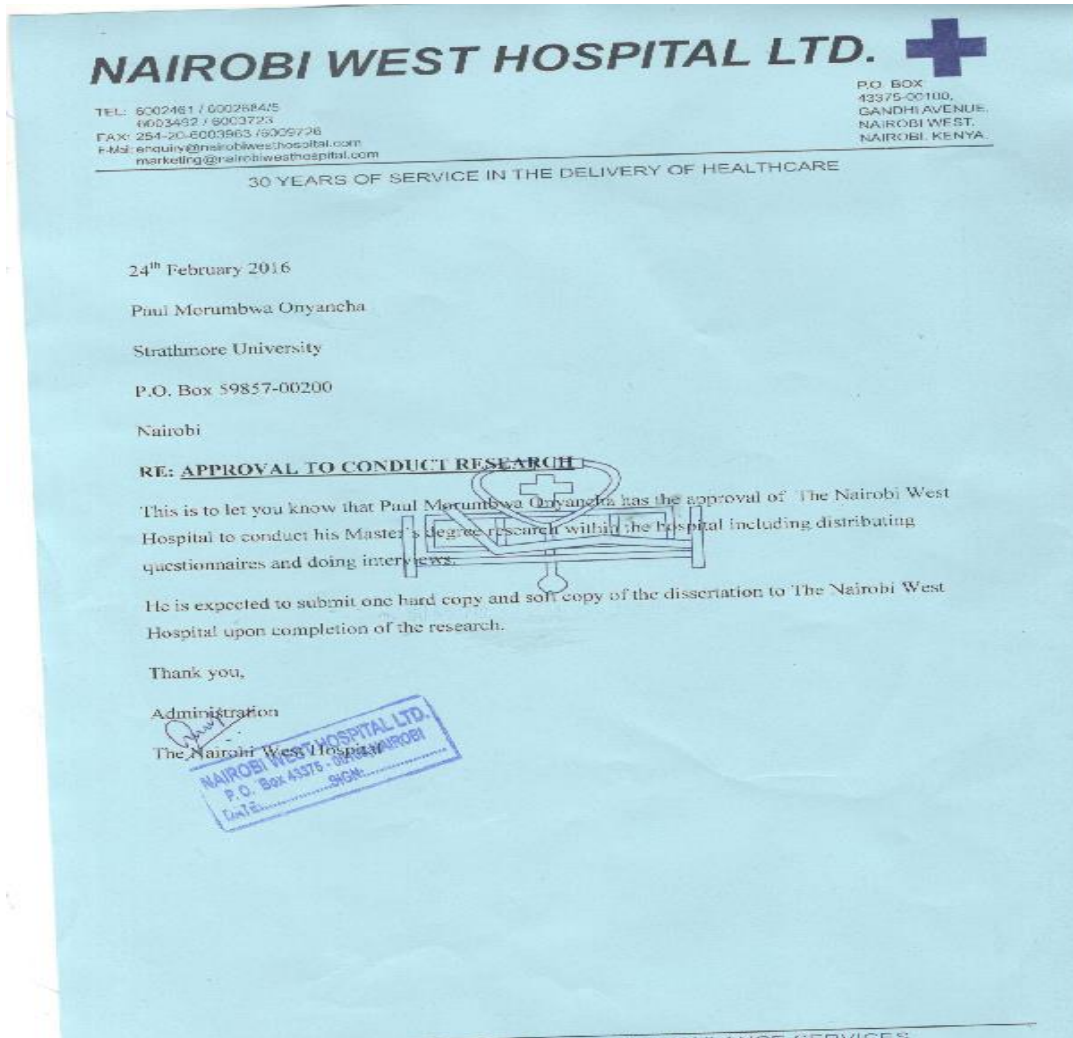
Any assistance accorded him shall be highly appreciated.

In case you would wish to clarify any issues with us, please feel free to do so.

Yours faithfully,


Danny Nyatuka (Mr.)
Administrator, Faculty of Information Technology
dnyatuka@strathmore.edu

Appendix B: Research Approval Letter from The Nairobi West Hospital



Appendix C: Questionnaires

QUESTIONNAIRE FOR HEALTH PRACTITIONERS

Researcher's name: Paul Morumbwa Onyancha

Research topic: Near-Field Communication Based-Model for Health Information Portability

Purpose: Questionnaire for the above research topic towards a degree of Master of Science in Computer-Based Information Systems at Strathmore University

The following is a structured questionnaire that seeks to have a view of the health practitioner's usage of health information portability technology.

a) Practitioner's background

- i) Your name (optional).....
.....
- ii) What is your gender? (Tick the appropriate box)
- M F
- iii) In which department of the hospital do you work?.....
.....

b) Medical record management

- i) Does your department use Electronic Medical Records System (EMR)? (Tick the appropriate box)
- Yes No
- ii) If your response to i) above is yes, do you use this mode of medical record keeping?
- Yes No
- iii) Which of the following health record problems lead to bad healthcare delivery? (Tick on the box)
- a. Poor record keeping habits
- b. Inadequate health data entry

- c. Lack of health data sharing among clinicians
- d. Inability of patients to move with their health data
- e. Organizational culture
- f. Lack of technological infrastructure
- g. Digital divide among clinicians
- h. Problems at the hospital reception
- i. Lack of proper medium of storage of the health data
- j. Patients providing inaccurate health data during clerking

iv) Which medical record(s) would you consider vital for the clinical management of a patient, and as such should be included in a patient's medical card?

(You may provide more than one example).....

.....

c) Health record and technology

i) Does your phone have Near Field Communication (NFC) functionality?

Yes

No

ii) Do you have a medical phone application on your phone?

Yes

No

iii) If Yes to ii) above, does it help in managing your patients better?

Yes

No

iv) Other than the regular insurance cards that patients carry to the hospital, which other patient data portability methods do you recommend?

.....

.....

v) Which safety concerns comes with automation of patient medical records in patient's medical cards and mobile phones?

.....
.....
vi) Please indicate your level of agreement with the following statement:

When health information portability is introduced in the hospital, healthcare can be improved

Strongly agree Agree Neither Disagree Strongly disagree

vii) Suggest any other information that you think is important in health information portability.....
.....

QUESTIONNAIRE FOR PATIENTS

Researcher's name: Paul Morumbwa Onyancha

Research topic: Near-Field Communication Based-Model for Health Information Portability

Purpose: Questionnaire for the above research topic towards a degree of Master of Science in Computer-Based Information Systems at Strathmore University

i) What is your gender? (Tick on the appropriate box)

M

F

ii) Do you have a medical insurance card? (Tick on the appropriate box)

Yes

No

iii) If your answer on ii) is yes, do you feel that the medical card is beneficial to you? (Tick on the appropriate box)

Strongly agree Agree Neither Disagree Strongly disagree

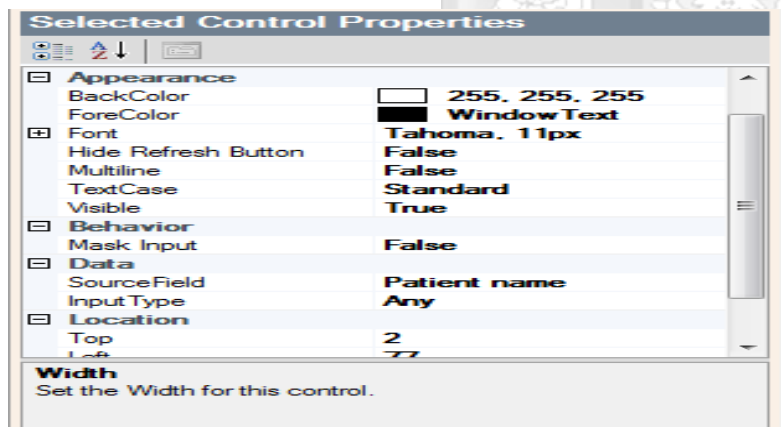
Appendix D: Interview Questions

Questions to ICT team: Nairobi West Hospital

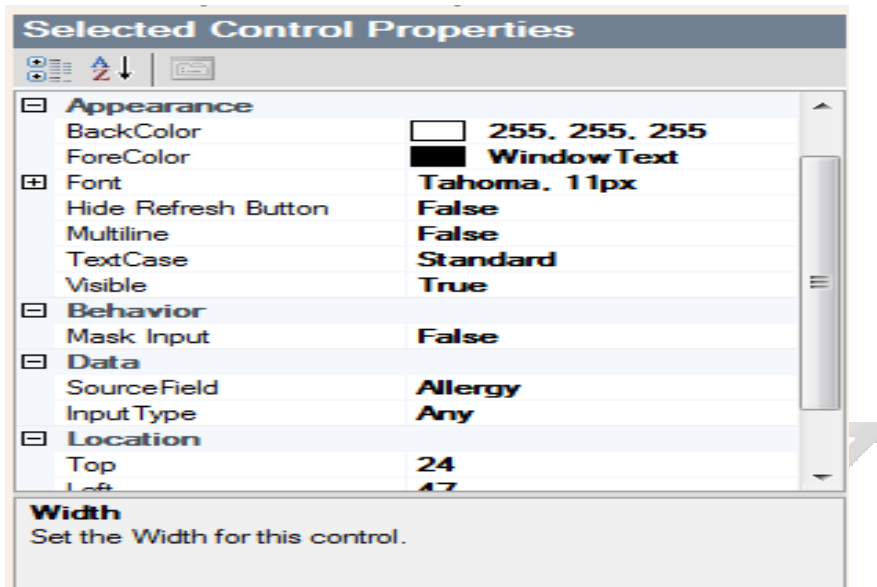
- i) What are the current modes of patient data storage in the hospital?
- ii) Which are measures taken to introduce electronic medical record in the hospital?
- iii) What are the barriers to adoption of automation of health data in the hospital?

Appendix E: Additional Screenshots of the Model

Screenshot of the control properties for Name field



Screenshot of the control properties for Allergy field



Admin settings for mobile client

