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Development of radio frequency identification (RFID)-based drug management and monitoring system, case of public hospitals in Tanzania

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DEVELOPMENT OF RADIO FREQUENCY IDENTIFICATION (RFID)-BASED DRUG MANAGEMENT AND MONITORING SYSTEM, CASE OF PUBLIC HOSPITALS IN TANZANIA

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Information and Communication Science and Engineering of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

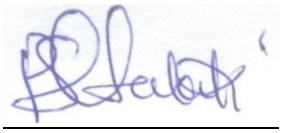
Radio Frequency Identification (RFID) is the wireless technology which uses radio frequency waves to transfer data for the purpose of automatic identification and tracking the intended objects. Recently, the adoption of Radio frequency technology in health sector has been a field of major interest due to automatic data capturing and processing capability of the technology. RFID consists of reader and tag; the reader is used to capture information stored in tag and transfer it to the enterprise information system.

RFID has recently been applied in hospitals to control and track hospital inventories, supply chain management and medication error controlling. However, the process is being done manually; paper-based documentation and records keeping are used. This manual work consumes time and resources which in turn presents difficulties during tracking and auditing. This scenario has therefore caused occurrence of incidences of drug theft and diversion by unfaithful health workers. In lieu of that, a system for management and monitoring the pharmaceutical supplies in hospital environment has been developed, in this study.

The research started with review and analysis of the existing system and procedure in hospital pharmacy management and monitoring to exploit potential gap to be fulfilled by the proposed research. Then, the analysis of the problem domain was carried out to identify the system requirements that were used to design and implement RFID based drug monitoring and management system. The developed system was implemented and validated.

DECLARATION

I, **Prisila Ishabakaki** do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.



5th April 2016

Name and signature of candidate **Date**

The above declaration is confirmed

Shubi Kaijage **6th April 2016**

Name and signature of Supervisor **Date**

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CERTIFIATION

The undersigned certify that has read and found the dissertation acceptable by the Nelson Mandela African Institution of Science and Technology.

Shubi Kaijage **05th April 2016**

Name and signature of supervisor **Date**

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DEDICATION

This research work is dedicated to my lovely family; husband (Mr Johannes Kahwa) and children (Johnson and Jensen), and my parents; Mr and Mrs Ishabakaki.

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LIST OF ABBREVIATIONS

CDM	Conceptual Data Modelling
DBMS	Database Management System
DFD	Data Flow Diagram
EPC	Electronic Product Code
FDA	Food and Drug Authority
GoT	Government of Tanzania
GUI	Graphical User Interface
HF	High Frequency
ID	Identification
HTML	Hype-Text Mark-up Language
LF	Low Frequency
MSD	Medical Store Department
NM-AIST	Nelson Mandela African Institution of Science and Technology
PHP	Hypertext Pre-processor
RF	Radio Frequency
RFID	Radio Frequency IDentification
RHPMMS	RFID Hospital Pharmacy Management and Monitoring System
SAD	System Analysis and Design
SDLC	System Development Life Cycle
SQL	Structured Query Language
SVV	System Verification and Validation
UHF	Ultra High Frequency
UML	Unified Modelling Language
USA	United State of America
V&V	Verification and Validation

CHAPTER ONE

Introduction

This chapter presents the general introduction of this study. The chapter focuses on background information, problem statement and justification of the study, research objectives, research questions, significance of the study and dissertation organization.

2.1 Background Information

Radio frequency Identification (RFID) is a technology for identification of object and people (Lozano-Nieto 2011a). RFID allows the wireless storage and automatic retrieval of information. It provides a significant improvement over, not only conventional identification, tracking, and stocking of objects, but also the barcode system. Barcodes can only be read in line of sight but RFID do not need line of sight. A basic RFID system consists of tag which carries identification information, a reader with its antenna and host computer with a program to interpret reader information or middleware (Wamba et al. 2008). Tags are small chips with antenna and there are three different types of RFID tags: passive, active and semi-passive. All these three types of tags are activated by signals from the reader. RFID tag can carry more information (such as product code, serial number, expiry date, batch code) compared to similar technology such as barcode which keeps the product code only. The RFID tag directly transmits the stored information data to a reader by radio frequency, without line of sight. The reader transfers this information to the middleware for its transmission to a central database for further processing and decision making.

Pharmacies are important units in hospitals for the completeness of health services to patients. In developing countries, lack of prescribed drugs may lead to more serious health problems (including death) to patients who cannot afford to buy the service from private pharmacies. Further to that, these public hospitals usually receive bulk quantities of drugs from distributors that need to be properly maintained until they are all dispensed to patients. Also the pharmacy department has an extra burden of tracking the drugs dispensed to patients, drugs available as well as drugs lost. The loss of drugs and improper control and monitoring of drugs has been reported as a source for insufficient availability of drugs in public hospital.

In most third world countries, the main reason for insufficient availability of drugs in public hospitals is inability of the government supply enough quantities of drugs (Global-Fund, 2009;

Bate *et al.,* 2010). Despite of this low supply, yet these available drugs are also stolen/missing or diverted to private sectors. In addition to that, health care institutions have been burdened with a complex task of record keeping and inventory management which is done on manual basis. The situation is worse in developing countries where the adoption of technology in health industry is still low (Omary et al. 2010).

The government institution responsible for storing and distributing drugs to public health facilities in Tanzania is called Medical Stores Department (MSD). MSD is an autonomous department in the Ministry of Health and Social Welfare charged with furnishing the nation with good quality drugs and medical equipment at reasonable and affordable prices. In order to manage and control drugs theft, MSD decided to label all essential drugs to ensure safety of drugs in public health facilities. Despite these initiatives by MSD, the success in controlling theft and diversion at hospital environment has been very difficult.

Information and communication technology (ICT) plays an important role in transforming healthcare delivery by enabling information access and supporting healthcare operations, management, supply and equipment monitoring as well as decision making. This calls upon demand on conducting more research in the field of e-health. The Tanzania government through its e-health initiative strategies calls upon researchers and stakeholders to come up with electronic solutions to these problems being faced by the health sector (MOH, 2013). Therefore, the development of an automated drug monitory system in public hospitals will improve drug orders and delivery and avoid the "out of stock" scenarios through notification on new order placement. This research utilizes high performance Ultra High Frequency (UHF) RFID technology to provide automated, effective, low cost and secured drug monitoring for public hospitals in Tanzania. The RFID based system offers best performance in monitoring and management of drug in that the tags used can ensure mass serialization through carrying more information (i.e. product code, serial number, expiry date, batch code) compared to other existing similar technology(Lefebvre *et al.,* 2011), thus simplifying the information acquisition process.

2.2 Research problem and justification of study

E-health facilities provide transformation of quality services delivery to patients. RFID based

system can be deployed in hospital to manage hospital patient's medication, medical processes, outpatient drug compliance, enhancing emergency services provision and patient tracking (Wicks *et al.,* 2006).

The deployment of e-health in Tanzania is still at its early stages despite many problems that are faced by the health sector. Major problems include lack of electronic patient registration and record system (Omary *et al.,* 2010), and drug theft in public hospitals. Furthermore, public hospitals in Tanzania have limited automated facility for providing drug monitoring. This research therefore intends to develop the automated drug monitoring system by using Radio Frequency Identification (RFID) which will improve the health services and improve drug availability.

The proposed research is intended to provide a technological way of drug monitoring and management which is anticipated to reduce cost and time of manual work. As a result, this new development, will increase work efficiency as well as counteracting drug theft practices in public hospitals For instance, MSD's Internal Audit investigation report of October 2007 revealed missing/stolen medicines valued USD 133,000 (163.2 million TZS) (Global-Fund, 2009). In order to tackle this problem, MSD decided to label all essential drugs , supplied to public health facilities by the government (The Guardian, 2013). However it became too difficult to perform inspections in all available pharmacies in the whole country. It was also reported that, district medical officers were not providing the drugs on time and that some of the drugs even expired before reaching their intended destinations (The Guardian, 2013). This has been possible due to lack of monitoring system in which all nearly expiring items would have been noticed and possibly be supplied to other nearby health centres before expiry. Thus the introduction of electronic means to control the process is very important. The significance of RFID technology is that; it provides real time information on the stock status, and avoid drug deficit in hospital due to late ordering and drug expiry. These necessitate the development of a sustainable technological solution to solve all the above mentioned challenges.

2.3 Objectives

1.3.1 General objective

To develop an automated drug monitoring system using RFID technology that will enhance security and availability of drugs in public hospital.

1.3.2 Specific objectives

1. To review the existing drug monitoring and management system in public hospitals.
2. To identify and analyze the system's requirements for drug monitoring and management system in the public hospital in Tanzania.
3. To design, implement and integrate frontend and backend system for the drug monitoring and management system and RFID reader information processing.
4. To verify and validate the performance of the developed RFID based drug monitoring and management system.

2.4 Research questions

1. What are the existing drug monitoring system current used in public hospital?
2. What are the information requirements for drug monitoring and management system in public hospitals?
3. How can a user-friendly interface and central processing database for the drug monitoring and management system be developed and integrated?
4. What is the performance of the developed drug monitoring and management system?

2.5 Significance of the research

This research aims at addressing the challenges existing in most public hospital pharmacies which include drug theft and diversion, manual record keeping, lack of accountability among health workers, unknowingly drug stock expiry and unexpected stock out. Through the use of Hospital Pharmacy Management and Monitoring system (HPMMS) based on RFID technology; efficiency and accuracy of pharmacy record keeping will increase, stock outs shall be prevented through provision of early alerts, drug diversion and theft will be prevented by providing full time pharmacy monitoring.

CHAPTER TWO

[1]RADIO FREQUENCY IDENTIFICATION BASED DRUG MANAGEMENT AND MONITORING SYSTEM, CASE OF PUBLIC HOSPITALS IN TANZANIA, REVIEW PAPER.

Abstract

RFID is an automatic identification technology that enables tracking of people and objects. Recently, the RFID technology has been deployed in hospitals for patient and equipment tracking, surgical equipment monitoring, medication monitoring, and improving health record access in emergency cases. The pharmacy department in public hospitals faces challenges due to manual record keeping and inventory management, which result in theft and diversion of the drugs by unfaithful workers. This work identifies the potentials behind use of the RFID technology in addressing these challenges. The chapter focuses on reviewing the current situation at the hospitals to identify gap and later suggests the solution based on RFID to counteract the challenges. The case study methodology is used where five public hospitals in Tanzania were visited to obtain data based on real situation. It was discovered that the drug management and monitoring process is done manually, involves paper based record keeping, manual counting of stock during each staff shifting time, which is hard to track in case of any loss. Therefore, there is need to develop a technological solution to manage the process and secure the drugs

2.1 Introduction

The health sector uses different technologies in healthcare services delivery, including the Radio Frequency Identification (RFID). The RFID is an automatic identification technology that enables tracking of people and objects (Bouet & Dos Santos 2008). It utilizes electromagnetic waves for transmitting and receiving information stored in a tag to or from a reader (Rida et al. 2010). A typical RFID system is made of at least three components: the radio frequency

[1]This chapter is based on the paper: Prisila Ishabakaki and Shubi Kaijage, "Radio Frequency Identification based Drug Management and Monitoring System; case of Public Hospitals in Tanzania: Review Paper", International Journal of Computer Science and Information Security, ISSN 1947-5500, August 2015, Vol. 13 No. 8

transponder (tag), the reader, which is basically a transceiver controlled by a microprocessor used to inquire a tag, and client software to communicate with a reader through a reader protocol, collecting, storing and/or processing codes retrieved from the tags.

Public hospitals are all healthcare service providers owned and operated by the government to serve the citizenry. Pharmacy departments at hospitals coordinate drug orders from suppliers and distribute the drugs to patients and other hospital units. In Tanzania, all public hospitals receive or purchase drugs/medications from the Medical Stores Department (MSD) and few drugs from other suppliers or distributors. The pharmacists in healthcare institutions are increasingly burdened with handling complex manual work involving record keeping and inventory management as hospitals serve a large number of patients every day (Broadfield et al. 2000).

The pharmacists in hospitals are responsible for a range of work activities including filling in patients' medical prescriptions, daily maintenance of drug inventories making sure that the hospital has enough quantity for each drug for administering to patients, accounting for the hospital's purchase and usage of drugs and for provision of drugs to individual patients, and distributing the drugs to the appropriate nursing stations and wards within the hospital to suit each station's daily demands. Hospital pharmacists are also responsible for tracking of drug lot numbers and expiration dates to get rid of expired drugs, and reporting to the hospital management on all matters concerning drug ordering, dispensing and delivery.

However, there have been several instances reported on theft and loss of drugs in hospitals. For instance, the MSD's Internal Audit investigation report of October 2007 indicated that medicines valued at USD 133,000 (163.2 million TZS) were missing or stolen (Global-Fund 2009). Another reported case in Bate *et al.* (2010) revealed that some medicines meant for public hospitals have been diverted to private hospitals and pharmacies. Preliminary survey of the drugs market discovered that medicines intended for free dispensing in public health facilities are sold at varying market rates in the private sector. These drugs may have been acquired through donations by countries or manufacturers as part of aid programs, or sold at very good discounts to support public health service delivery in Tanzania (Bate et al. 2010). Our study revealed loopholes in the information management system in relation to pharmacists' duties and responsibilities of purchasing, distribution and dispensing of medicines, which result into some medicines being channelled from the public health facilities to the private markets. Despite the fact that these duties can be simplified by integrating the information management system, we

found that there is no electronic system deployed in public hospitals in Tanzania. Various attempts have been made to assist hospitals' pharmacy departments with maintaining accurate records and reduce challenges in managing drug distribution information. Thus, developing a technological solution for monitoring drugs supplied to hospitals to reduce losses and unintended use of drugs is essential. This paper provides a review of different technologies, which are used for drug monitoring and management.

2.2 Literature review

2.2.1 Overview of RFID Technology

RFID is a generic technology that uses radio waves to identify objects (Angeles 2005). Other identification technologies related to RFID include barcodes, biometrics, magnetic stripe, optical card readers, voice recognition etc. The difference between RFID and these other technologies is that RFID is an automatic identification technology, which utilizes radio waves to transfer its information. Furthermore, it doesn't require line of sight for communication, and it can sustain harsh physical environments, allows simultaneous identification, has excellent data storage, wide read range, and it is efficient in terms of cost and power (Turcu n.d.; Lozano-Nieto 2011a). In the health sector, the RFID has been deployed for various applications such as patient identification, anti-counterfeiting, hospital inventory management, staff and patient location and medication adherence enhancement (Turcu et al. 2009; Hamid & Asher 2014; Cerlinca et al. 2010).

2.2.2 RFID system Architecture

Basically, the RFID system has three components: the RFID tag or transponder, the RFID reader device or transceiver, and a backend information system (servers). Figure 1 shows the main components of the RFID system. The RFID tag typically has an electronic chip that holds a certain amount of data, and an antenna used to communicate with the reader. There are also RFID tags with no chips; these utilize certain Radio Frequency (RF) reflecting properties of materials. RFID tags can be characterized as active, passive or semi-passive. An active tag uses a battery to power the microchip's circuitry and broadcast signals to the reader. It has more memory capacity and provides wide read range. A passive tag does not use batteries and is powered by electromagnetic waves sent by a reader to induce a current in the tag's antenna. The passive tag has less memory capacity; it can store little basic information such as identification number and

short coverage range. A semi-passive tag uses both the battery and waves sent by the reader. Cost of RFID tags depends on the type; active tags are more cost than passive ones. The choice of tag depends on the kind of application where the aspects like read range, amount of information to be stored on tags and cost should be considered.

The communication between RFID reader device and the RFID tag is through RF waves. This communication with the RFIED reader device with the tag differs between the types of RFID tags. The RFID reader communicates with tags through inductive coupling method. The tag's read range depends on both the reader's power and the frequency used to communicate. Radio-frequency communication between the tag and reader may occur on the following frequency bands: Low frequency (LF) band is in the range of 125–134 kHz and 140–148.5 kHz channels, high frequency (HF) band is at 13.56 MHz, and ultra-high frequency (UHF) band is in the range of 868–928 MHz (Gaukler et al. 2007). The RFID system operates in Industrial-Scientific Medical (ISM) band, which is freely used by low-power, short-range systems. A higher frequency results into a longer communication range and a faster communication means that more data can be transmitted, but requires more energy output from the readers. In addition to these components, the RFID system receives large amounts of data generated from the movement of physical goods in a real world setting; the data is rarely clean and it is often noisy, erroneous, and may be unusable in its native form (Fisher & Monahan 2008). As a result, it was necessary to develop an intelligent component, called middle ware, to filter, aggregate, sort and add missing information in the data before it is sent to the host system.

Figure 1: RFID System components

2.2.3 RFID tagging levels

The RFID tag is placed at the item for identification. Level of tagging depends on the application. RFID tagging can take place at essentially three levels of granularity. First, in supply chain RFID tagging can be at pallet level, a tag is affixed to a pallet. When the pallet is ready for shipment, a tag ID is programmed into the tag and attached on pallet. This tag ID is typically cross referenced to a purchase order and a list of the inventory on the pallet. At the shipment destination, the tag ID can be cross referenced again to the database record that contains the pallet information. Second, case level tagging, tag is placed on the case. The tag typically cross references purchase order and inventory information. The primary advantage of case level tagging over pallet-level tagging is that it allows for more detailed tracking. If inventory is moved in case quantities, then full inventory visibility can be achieved with case-level tagging. Case tagging also saves labor time by automatically reporting case counts and thus making manual counting of cases unnecessary.

Third, item level tags are usually part of the item packaging. The tags are placed at each product item during manufacturer packaging. This kind of tagging gives the highest possible granularity of visibility. Depending on the RFID application environment tagging can be at item level, case level or pallet level. In this intended application best tagging position will be at case level since the item level and the distribution at pharmacy store is basically at carton box also will reduce tag cost as item level tagging is costliest solution (Gaukler et al. 2007). However the cost of RFID tags was expected to be 5 cents by 2007 (Tzeng et al. 2008). According to RFID journal the cost tag cost differs based on volume, the amount of memory on the tag and the packaging of the tag thus this cost would much lower foe high volume requirement (Kelle et al. 2012).

2.2.4 The potential of RFID technology in Health Sector

One of reasons for slow deployment of the RFID technology in many sectors is its potential in solving the intended problem due to its cost of implementation. However, making the cost benefit analysis informs the importance of the technology; that is, consideration of the cost to the hospital, government, and donor and indirectly to patients who miss treatment will eventually conclude that the cost for implementation is much less compared to the loss incurred. Studies have been conducted in different countries with the aim of examining the potential of RFID implementation in hospitals. Some of the studies include those done in Taiwan, USA (Bose et al.

2009) , and Taiwan (Matalka et al. 2009)(Sultanow & Brockmann 2013). In our review, we found that (Fisher & Monahan 2008) conducted a study on how information technology can be used to initiate change and improve the healthcare. The results of this study showed that implementation of the RFID in the health industry can help to measure, control, and improve workflow processes. A study by Wang et.al involved implementation of the RFID at the Taiwan Medical University Hospital. In their work, the authors explain the growth in use of the RFID in improving monitoring and management of drugs as well as the RFID planning and related strategy for implementing the RFID projects in hospitals.

A study by (Sultanow & Brockmann 2013), investigated the impact of implementing the RFID technology in the hospitals and how it affects the hospital staff and the society. The findings of this study showed that the nursing staff at the hospital had signs of worries as the technology involved close scrutiny and supervision. However, these findings basically apply to the tracking application of the technology where the nurses had to be directly involved. We believe this feeling will not be experienced on pharmacy staffs since the application intends to serve their burden by automating the work. Another study (Tzeng et al. 2008) used case studies of 5 hospitals to find the value of using RFID in business. The case hospitals had implemented the RFID technology in 2003 with the specific aim of minimizing the impact of the Severe Acute Respiratory Syndrome (SARS). In the study, measuring the value of the RFID technology at the execution stage involved identifying a number of intentions. The researchers concluded that including the RFID technology in the whole business framework can result into successful implementation of the technology. These studies prove that integration of the RFID technology in the health sector is very promising provided that the whole business environment is considered at early stages.

2.3 Current Drug Management issues in Public Hospital in Tanzania

The significant cost of purchasing and storing pharmaceutical products and their respective control requirements largely contributes to the healthcare industry costs (Kelle et al. 2012). Although the health industry is seen as the most important industries in the world, both in developed and developing countries, little attention has been given to the area of drug management and monitoring which is at the core of effective healthcare delivery. Pharmacies in Tanzania's public hospitals use traditional paper-based processes to document disbursed drugs, order drugs from suppliers, follow up on orders before delivery and receive the ordered drugs.

Moreover, they also need to verify the orders, keep received drugs in stores, maintaining them in the storage facility till they got dispatched to the intended public health unit. Also, pharmacists are responsible for keeping records on all pharmacy related matters, keep track on drugs and carefully dispose the expired drugs. Furthermore, pharmacists spend most of their time on paper work to ensure all drug records are updated. The pharmacy stores receive drugs and medical equipment from suppliers in bulk, and thus have to maintain them in stores until they are dispatched to the intended public health facilities.

At the dispensing unit where patients obtain drugs from, the records are kept by filling in individual patient prescriptions and amount of money paid for the drugs on paper forms. Basically, the whole procedure is done by filling in information on the papers and monitoring activities need to be done manually as indicated in fig 2. The manual process at each hospital unit presents huge challenge in controlling and managing the drugs in hospital environment. This creates the loop hole for unfaithful workers to divert the pharmaceutical supplies to their private hospitals. Again lack of an efficient way to track each drug uniquely adds more chance for diversion because no one can be held responsible.

Furthermore different circumstances drugs can be diverted exist; most common includes employees making drug transactions during off-shift or unscheduled time, Substitution with inexpensive Medications, dispensing medications to patient in high dosage as the one prescribed.

In 2007, the Global Pharma Health Fund established the protocol on assessing the quality of anti-malaria drugs in private health sectors. Unfortunately during sample collection, they found some public intended drugs being sold in private retails. This was followed by the study by (Bate et al. 2010) in which they identified the anti-malaria medicines being diverted into the African markets, especially in such countries as Nigeria, Tanzania, the Central African Republic, Senegal and Zambia. This might be due to the current management process where no one is held responsible for the government or donor supplied drugs to public hospital. A study by (Bose et al. 2009) identified that inefficiency and inaccuracy in the inventory operations and controls of pharmaceuticals is among the major challenges facing management of the operations and processes in public hospitals.

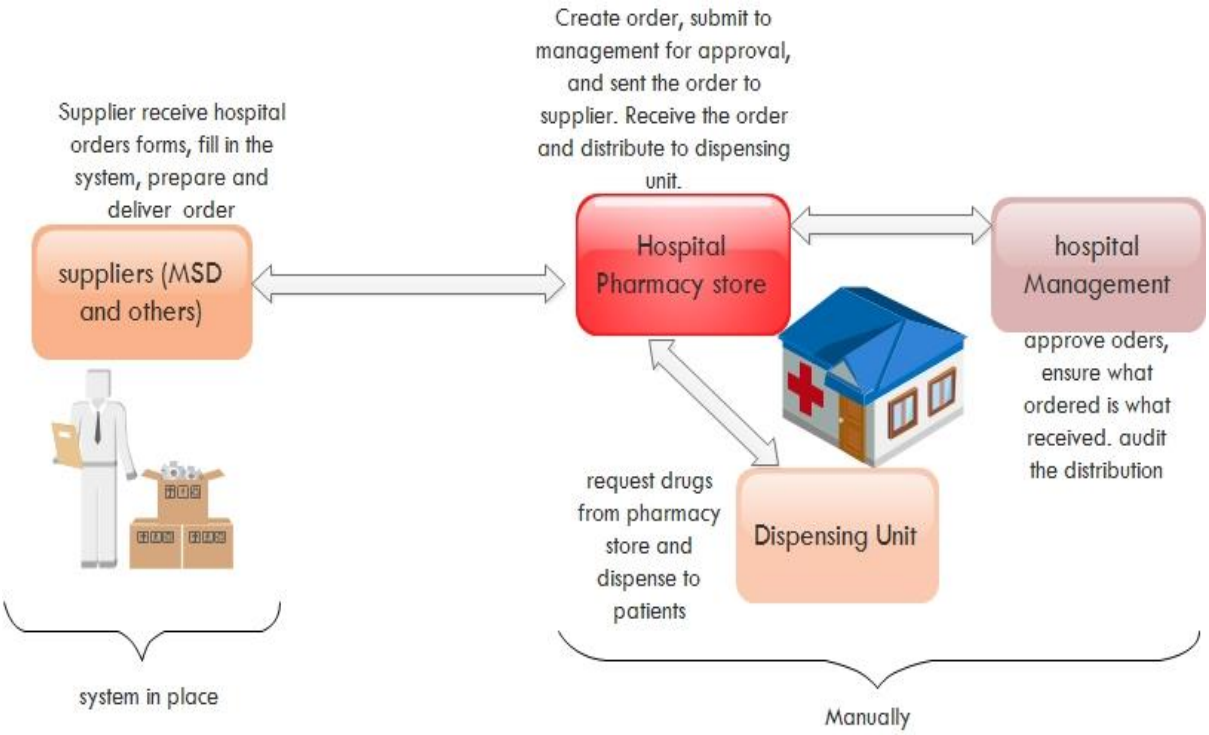

Figure 2: Current drug management process

2.4 Related works

The problem involving pharmacy management and monitoring has been noted by many researchers. In addressing the hospital pharmacy management problems, several studies from academia and industry have been carried out. This section discusses some literatures addressing pharmaceuticals research problems and we review how these can provide a better solution to similar challenges faced by public hospitals in Tanzania. This section reviews related works on pharmaceutical supply chain management, drug dispensing systems, and medication monitoring systems.

2.4.1 Pharmaceutical supply chain management

The works on pharmaceutical supply chain management concentrated on establishing the protocols and procedures to manage and monitor drugs in the hospital environment. Work done in (Kelle et al. 2012) developed a model for proper utilization of resources at the pharmacy store. The study came out with order and refill levels of drugs in the information systems. This

provides the basis for system designing whereby the proposed refill level could be used as reference stock level to alert users to reorder prior to total stock out.

Other researches focused on drug counterfeit detection systems. Among the major challenge in the pharmacy industry worldwide is the counterfeit drug penetration to the market. This affects both manufacturers and consumers of the pharmaceutical products. The manufacturers are affected through business loss since the counterfeit drugs are much cheaper as the traders avert paying tax and the drugs are manufactured with low quality. As for the consumers, the counterfeit drugs are dangerous to their health. Therefore, different researchers have attempted to investigate the application of the RFID technology in pharmaceutical supply chain to detect counterfeit products (Koh et al. 2003)(Matalka et al. 2009)(Hamid & Asher 2014)(Sultanow & Brockmann 2013). The RFID based anti-counterfeit drug tracking system is designed to provide a drug verification mechanism. Figure 3 shows the manufacturer to hospital drug distribution control system.

However, the limitation for this system is the unrealistic assumption that all the key stakeholders in the drug supply chain, such as the manufacturers, distributors, wholesalers, and pharmacies, have the necessary hardware and computing ability to read and process RFID equipment information. Furthermore, the solution is not ideal for developing countries like Tanzania where the electronic system has not been introduced and hospitals do not have internet connectivity, for referral hospitals. Implementing this solution in Tanzania will be not feasible due to high cost of implementing information systems across the hospitals and interlink with manufacturers' systems. Therefore the development of a simple but effective solution feasible to the economic status of the country yet solving the problem is important.

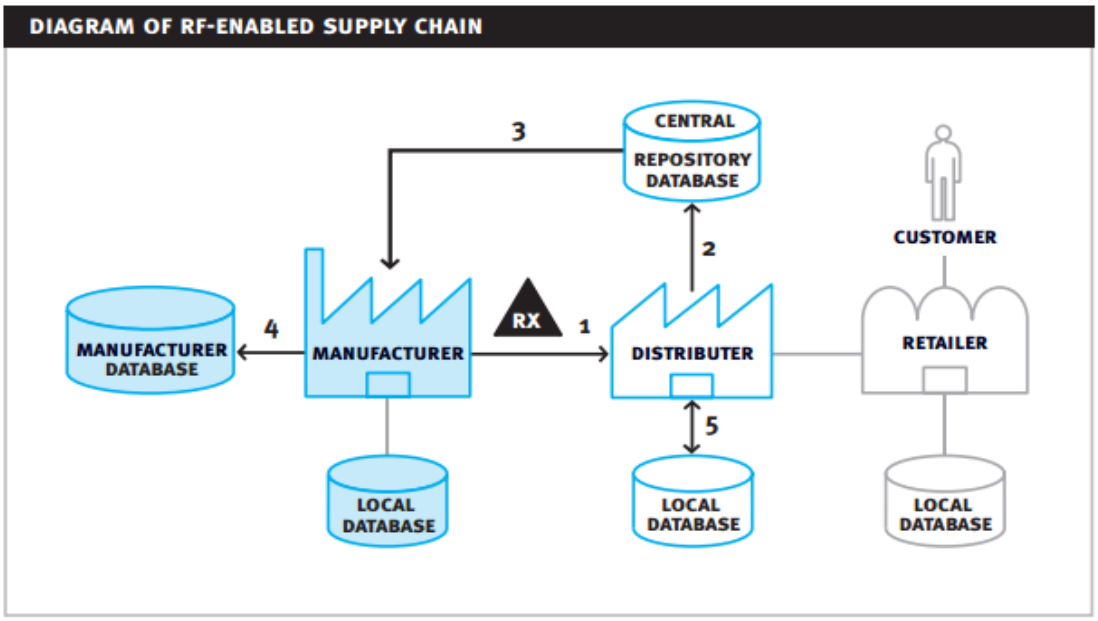

Figure 3: RFID enabled pharmaceutical supply chain

2.4.2 SMS based drug monitoring systems

Novartis Company developed an SMS-based system for monitoring anti-malarial drug distribution in the sub-Saharan Africa. The technology was developed to prevent stock-out of anti-malarial drugs in remote areas by taking advantage of the coverage of the expansive mobile phone network, which has reached rural areas. The system automatically sends weekly text messages using the SMS to mobile phones at public health facilities requesting updated information on their stock levels (Barrington et al. 2010). The major challenge on the effectiveness of this system is that the remote health centres are served by the district hospital where the automated drug monitoring and ordering system is not in place. Thus, even if the SMS from the remote health centre will be received, it will be difficult to process the request since even the district level can get out of stock without notification. This necessitates the need for developing an information system for drug monitoring and management at the hospital level.

2.4.3 Medication monitoring systems

Errors in administration of medication are a leading cause of patient morbidity and mortality and excessive costs; thus the development of an information system that assists in monitoring

medication is vital for efficient health care provision (Merry et al. 2001). Study by (Howard et al. 2013) developed a system used in maintaining drug information and communicating with medication delivery devices. The system includes software for use in the hospital pharmacy and biomedical environments. Also, ref (Zhou 2012) designed and developed the medication error control system, which was a RFID-based prototype software that can be used to monitor and administer medication in hospital environments. The pitfall with this system is that it is limited to medication error control and thus does not extend to pharmaceutical monitoring and management. And it also needs a well information technology networked hospital.

2.5 Proposed Drug Management and Monitoring system

Despite the fact that barcode labeling is an inexpensive technology, offers reliability, and is widely used, the technology's limitations including the line-of-sight requirement and short-range reading distance. This makes it a slow and labor-intensive technology (Rida et al. 2010). Receiving, storing, sorting, and shipping processes will all benefit from this wireless technology and become more efficient and effective (Lozano-Nieto 2011b). Our proposed system will utilize the RFID technology to manage and monitor drugs in the hospital environment for the case of public hospitals. The system will be of low cost as it utilizes UHF RFID tags which are low cost to label the drugs to be monitored. The system comprises of the central database, the RFID network, and user/administration interfaces. The proposed system will offer several benefits including preventing unexplained drug loss, saving the government's expenditure on hospital supplies by ensuring the available resources are well spent, and it will simplify stock keeping, prevent stock-out by integrating re-ordering notification on preset stock level. Furthermore, the system will improve record keeping, health service delivery and eliminate manual work performed by pharmacy staff. Fig 4 shows the proposed system architecture.

Traditionally, the RFID technology has been thought to be used in health care service delivery just for diagnosis of patients in emergency situations, measuring patient's vital signs, recording significant medical information and transferring to an electronic monitoring device, and monitoring the elderly. It has also been used in monitoring of goods and equipment, as well as controlling drugs administration and blood transfusions, thereby reducing medical errors in hospitals (Turcu et al. 2009). This study investigated the use of RFID in healthcare settings, specifically in drug monitoring and management. The RFID technology is classified as a wireless

automatic identification technology that uses electronic tags to store identification data and other specific information, and a reader to read and write the tags. The motivation for using the RFID technology in this research is the automatic identification and tracking capability of the objects with RFID tags which when utilizes can counteract unexplained drug loss and theft in the hospital environments.

Contrary to previous systems presented in section 2.4, the proposed system has been developed basing on the problem and challenges facing public hospitals in developing countries. The system also is extended to management of medical supplies in hospital environment.

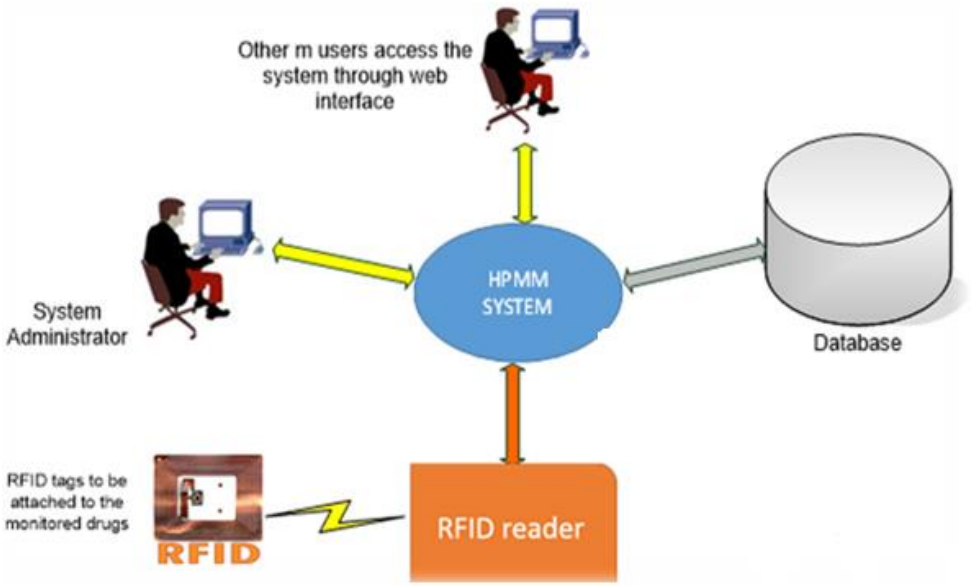

Figure 4: Proposed system architecture

2.6 Conclusion

The application of RFID technology in the health industry can provide significant benefits in improving the pharmaceuticals supply chain management in hospital environments. This paper has presented a review on the actual situation of pharmacy management practices using the case of public hospitals in Tanzania. A review on the RFID technology has been presented where the feasibility of the technology in solving the identified challenges is done. It has been revealed that there is high potential and return on investment for applying the RFID technology in the health sector.

Lastly, we introduced and proposed the RFID technology and its application in pharmacy management systems, which can be adopted to mitigate problems faced by most public hospitals in Tanzania. The system utilizes passive Ultra High Frequency (UHF) RFID tags to tag the monitored drugs, which will counteract drug diversion or loss in the government owned hospitals to the private sector and therefore ensure drug availability at the hospitals. The passive UHF tags are low cost thus making this solution cost effective.

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN FOR RADIO FREQUENCY IDENTIFICATION (RFID) BASED HOSPITAL PHARMACY MANAGEMENT AND MONITORING SYSTEM. A CASE STUDY OF TANZANIA PUBLIC HOSPITALS[2]

Abstract

Medicine diversion has been seen across numerous African markets and can lead to serious stock-outs in the public sector, which may be dangerous to countries with high burdens of disease like Tanzania. Inefficient mechanism for controlling and managing medicine in hospital setting has been major challenge leading to drug diversion. The study aims at fostering efficient drug dispensing and minimizes the diversion of medicines in the public hospital. The study applies Radio frequency identification (RFID) technologies to improve the efficiency and effectiveness of drug monitoring and management. In this paper, we present the system requirements analysis and design of RFID-based drug management and monitoring system a case of public hospitals in Tanzania. The requirements have been established from interviews with the various stakeholders, observation on hospital environment, domain analysis and literature. The established requirements turn out to be an essential input towards developing a complete RFID-based hospital pharmacy management and monitoring system.

3.1 Introduction

Radio Frequency identification (RFID) is a wireless based technology for identification of objects. The technology is now generating significant interest in the marketplace because of its robust application capabilities (Cerlinca et al. 2010). RFID utilizes electromagnetic waves for transmitting and receiving information stored in a tag to or from a reader (Rida et al. 2010). RFID Technology has an edge over other identification systems such as barcode systems, magnetic strip cards, smart cards, and biometrics because it requires no line of sight for communication, sustains harsh physical environments, allows for simultaneous identification, has excellent data storage, wide read range and is cost and power efficient.

[2]This chapter is based on the paper: Prisila Ishabakaki and Shubi Kaijage, "System analysis and Design for Radio Frequency Identification (RFID) based Hospital Pharmacy Management and Monitoring System; A Case Study of Tanzania Public Hospitals. Communications on Applied Electronics, ISSN 2394 4714, September 2015 Vol .2 No.8

RFID can contribute in improving hospital operations by improving patient care and safety, optimizing the workflows, reducing the operating costs, and reducing costly thefts. Drug theft and diversion has been major problems to most public hospitals in developing countries (The Guardian 2013; Bate et al. 2010). Resulting into serious effects to hospital stakeholders such that unavailability of drugs in hospitals, which can affect patient health, hospital loses money in replacing the loss and the government undergoes loss in fighting this problem. These challenges had stimulated researchers to find how the RFID technology can help to counteract the challenges. Apart from counteracting theft and diversion of the drugs also by implementing RFID in a hospital environment can as well benefit in reducing out-of-stocks, reducing the time staff spends searching for medicine, optimizing the utilization of current stock especially near expiring items and identification of drugs to be ordered. This study present system analysis and design for the RFID based drug management and monitoring system in (RHPMMS) hospital environment with UML.

The Unified Modelling Language (UML) is a graphical modelling language mainly used for specifying, constructing and documenting aspects of object-oriented software (Rumbaugh et al. 2004). UML has the advantage of being a powerful and flexible language in system analysis due consistent notation and integration capacity of diagramming techniques. System development life cycle (SDLC) defines four development phases through which the complete system is developed, these includes planning, analysis, design and implementation (Dennis et al. 2005). System planning is the process of understanding why an information system is required and determining how to go about building the system. System analysis basically is essential in determining who is going to use the system, what will the system do (system requirements) and when it will be used. The analysis phase also includes the analysis of current system (manual system or information system) and requirement gathering through various gathering techniques(Pandey et al. 2010). The requirements are the descriptions of the services provided by the system and its operational constraints. The requirement engineering process is often called business process modeling which is very essential in developing an enterprise information system (Shen et al. 2004). The requirement specification must comply to the characteristics, such as complete, consistent, correct, modifiable, ranked, traceable, unambiguous and verifiable (Wilson et al. 1997).

Design phase of the SDLC involves determining how the system will operate, in terms of the

hardware, software, network infrastructure, the user interface, forms, reports, databases, and files that will be needed. This step explains exactly how the system operates.

3.2 Materials and Methods

The requirement gathering was conducted in Dar es Salaam and Arusha where by four public hospitals were visited. Various data collection methods were used to capture system requirements these included observation, interview as well as written documentation reviews. The techniques employed are further explained below.

3.2.1 Domain analysis

Domain analysis is a process which involve understanding the background needed so as to be able to elicit the problem and make intelligent decisions (Lethbridge & Laganière 2005). The term domain means the general field of business or technology in which the customers expect to be using the software. The software developer has to understand the domain in which the system is thought to be implemented. The domain analysis in this study was conducted in two public hospitals in each region Dar es Salaam and Arusha Tanzania. Through interviewing with domain experts and observation a researcher was able to analyse the domain. It was identified that these hospital has no any system in place to assist the process. The pharmacy supply chain in hospitals start by the pharmacist preparing the order and submit to management for authorization. The hospital receives drugs in bulk quantity, the pharmacists in store, distribute to other hospital units. The process of tracking if the distributed drugs reach intended patients is difficult, rarely carried out by management paper based records pose challenges. Sometimes the staffs do not update the record, especially during rush hours. It was identified that to fully monitor and manage the drug at public hospital settings there must be an end to end information system implementation that is from pharmacy store to each hospital unit. However, due to time constraints, this work is limited only to pharmacy store. Throughout this paper the requirement gathered and analysed is for hospital pharmacy store management and monitoring.

3.2.2 Feasibility study

Involves information assessment, information collection and report writing. The information assessment identifies whether the system contributes to the overall objectives of the organization,

cost effectiveness of the system and whether the expected system could be integrated with the existing system. The feasibility study was conducted in three public hospitals in Dar Es Salaam and Arusha regions, the hospitals had no system in place that serve the purpose despite the fact that the challenges persists. The use of RFID Technology in addressing the problems is very promising as through literature the technology has been reported being efficient in providing advantages like cost reduction by maintaining stock levels, reducing the out-of-stocks, counterfeit protection, shrinkage protection, and real-time tracking of supplies (Hamid & Asher 2014)(Wicks et al. 2006).

3.2.3 Interview

The requirements elicitation from the hospital in this study was achieved by conducting open interviews at hospitals. The main stakeholder involved in this interview was Medical in charge, IT personnel and pharmacists in each hospital visited. The researcher gathered information on how the process is conducted in which the system goal could be identified. Requirements can be gathered by means of open interviews. A more efficient way to gather requirements is to conduct less open interviews by reusing requirements patterns. These patterns can be used on new cases to guide the identification of requirements.

3.2.4 Observation

Observation means taking a note and shadowing important potential users as they do their work, writing down everything they do (Barclay & Savage 2004). It is a technique in requirement gathering where a developer get the information that could be forgotten or ignored during interview or any other technique. The researcher used this technique to observer the process at pharmacy store and was able to identify that the process of retrieving information about the disbursement of the drugs say for last three month is very difficult it require one to go through several books to obtain the required information and this could be the loophole for diversion since one knows how difficult is to track the process.

3.3 Results

3.3.1 System Requirements

Functional and non-functional system requirement were identified as presented in Table 1 and 2 respectively

3.3.1.1 Functional Requirements

Table 1: System Functional Requirements

Requirements	Description
Authenticating users	The system must allow only authorized users to login and interact with the system. The system administrator the IT personnel will be responsible to create users and password and share it, users can edit the password after logging into the system.
Receive and distribute drugs	Receive and distribute drug supplies in all hospital settings (such as wards, outpatients, emergency, etc.) These hospital settings are regarded as customers to pharmacy store.
Creating a drug profile	Each drug has its own profile, the system will allow the pharmacist to create, update or delete drug profiles.
Stock ordering and approval	The pharmacist creates new order requirement expected purchase list depending on stock levels and submit the order to medical in charge for approval. The medical in charge has to approve the prepared list before it is sent to the supplier.
Notification on stock status	The system has to display alerts to pharmacists and management personnel up on nearly expiring items this has to be done two weeks before expiring the alerts will be activated. The system also has to alerts the pharmacist and management upon reorder level.
Interfacing with RFID Reader	For the purpose of drug monitoring the system will be interfaced with RFID Reader, the system should receive the information gathered from reader initiate communication, process and store information read by readers and trigger the alarm and alert the authority upon unauthorized

	detection transaction.
Summaries and report	The system should allow the management and audit team to track all system transactions by providing a summary and report on all transactions in a specified period.
System Administration	The system should allow the administrator to monitor system activities such as registering new users, remove or update user details.
Customer request processing	The pharmacy store is responsible in distributing the drug across all hospital settings (these will be regarded as a customer into our system). The system should allow customer to request the drugs.

3.3.1.2 Non-functional requirements

Table 2: Nonfunctional system requirements

Requirement	Description
Operability	The system code shall be in web based programming languages such as HTML and PHP. It shall also be able to interconnect with MySQL database and the selected RFID reader.
Availability	The system shall be capable of being available both online and local, depending on the available infrastructure on the hospital
Maintainability	The system shall be able to upgrade to connect with external supplier systems such as MSD to offer fully automated drug ordering and management system. The system also should allow interconnection with pharmacy dispensing units for more efficient control process
Security	The system shall provide access to only registered users. The authorized users will be given login credentials to login. The algorithms for strong password will be deployed to prevent brute force
Performance	The total response time for an RFID reader to detect a tag, communicate with a system and system response will keep short.
User Interface	Graphical User Interface (GUI) is generally provides easy way use the system even for non-computer literacy. The system should implement graphical user interface.
Receiving alerts	

3.3.2 System Requirement Modeling

In this section we present the system requirement models where the use case, data flow diagram and entity relation diagram are presented.

3.3.2.1 Use case modelling

Use case is the diagram that shows the relationships among actors and use cases within a system. Sommerville defined use case as scenario based technique for requirement elicitation and they are used for describing object oriented system models (Sommerville 2007). It actually provides an overview of all or part of the usage requirements for a system or organization in the form of an essential model or a business model, communicate the scope of system development and model analysis of usage system requirements. Requirements are described with system use case diagrams in UML approach. Business use case models facilitate the development of system use case models(Jacobson et al. 1999). Four actors were identified for developing hospital pharmacy management and monitoring system. Fig. 5 depicts interactions between the actors and the hospital pharmacy management and monitoring system. Since this system development is use-case driven means that use cases are the primary modeling tool to define the behavior of the system from the use case other models will be derived.

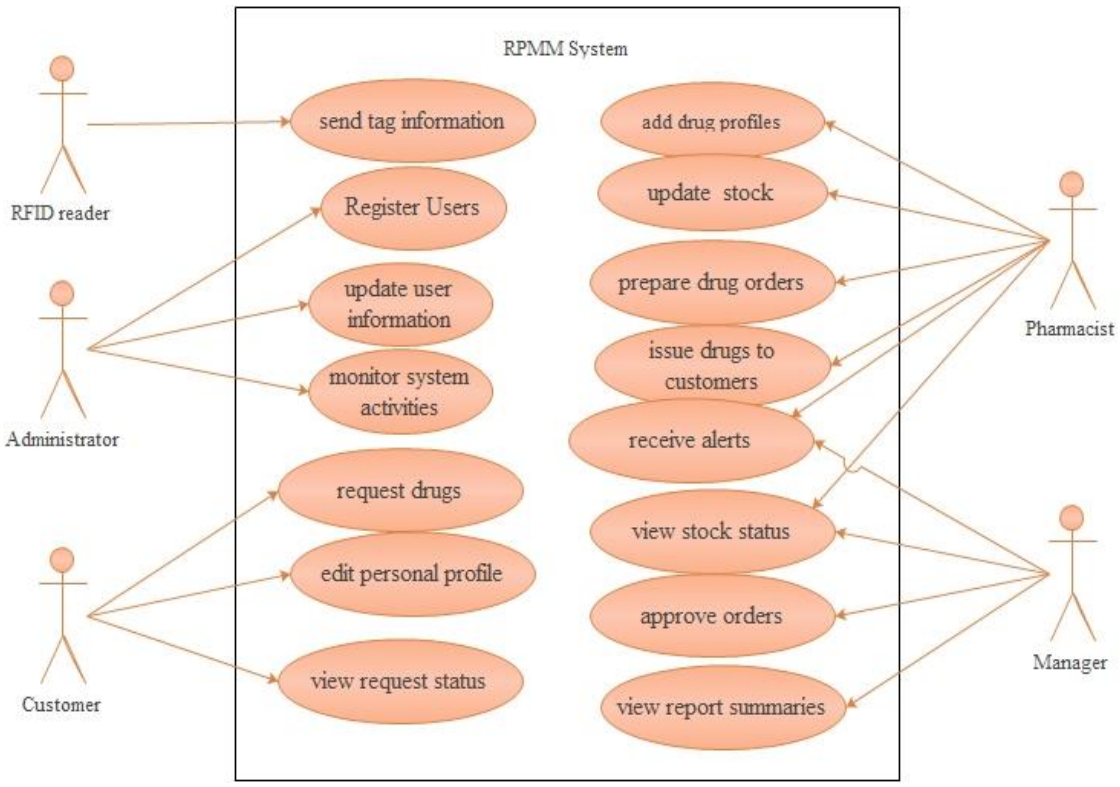

Figure 5: System use case

Detailed use case

Under this section the author has selected some use case to elaborate it in details. Table 3 shows the details of the "Add drug profile" use case:

Table 3: Detailed "add drug profile" use case

Use case	Add drug profile
Actor	Pharmacist
Pre request	• Pharmacist in charge has been registered on the system • The pharmacist has login credentials
Flow of events	1. Pharmacist in charge provides login credentials 2. Pharmacist in charge select the add drug profile link 3. An interface for adding drug profile is provided be the system 4. The drug information is filled, and submitted to the system 5. The update information stored in the database
Exceptions	• Invalid data type inputs • Entering the details that already exist
Post-condition	• The entered information is stored into the system.

Table 4 details the use case "Register user".

Table 4: "Register user" use case

Use case	Register new user
Actor	Administrator
Pre-condition	• The administrator has been given admin privilege in the system • User to be registered must be a health worker at a given hospital either a pharmacist, hospital units staff or management audit time
Flow of events	1. Administrator login by providing his/her credentials 2. Administrator fills the user details and submit to the system 3. The system validates details and stores the entries.
Exceptions	• Repeating user information • Some information is missing
Post-condition	Entries are saved into the system

Table 5 details the "update stock" uses case where by the actor is pharmacist.

Table 5: "Update stock" use case

Use case	Update stock
Actor	Pharmacist
Pre-condition	• The pharmacist has been registered in the system • The pharmacist has login credentials • The hospital has received new drug stock.
Flow of events	1. Pharmacist login 2. Pharmacist select update stock from system menu. 3. Add item and scan its RFID tag 4. The entries are updated into the system
Exceptions	• Missing information • Tag_id in use by other item
Post-condition	The stock is updated into the system.

3.3.2.2 Data Flow Model

The data flow model as an intuitive way of showing how data is processed by a system (Sommerville 2007). The data flow model is used to show how data flows through a sequence of processing steps. DFDs also model holding tanks (data stores),and external entities, which represent interfaces with objects outside the bounds of the system being modeled (Shen et al. 2004). The advantage of a DFD is that it can describe information flows clearly, from the source to the destination. The common representation of the data flow model is the UML data flow diagrams. Data flow diagram (DFD) is a graphical tool that allows analysts to depict the flow of data in an information system. DFDs help system designers and stakeholders during initial analysis stages visualize a current system or one that may be necessary to meet new requirements. The DFD in this study is used to show how data flow within the system. The context diagram explains the system within the context of its environment. It also shows the boundaries, external environment and major information flow into the system. The highest-level view is shown in Fig.6. The general system process labeled 0 represents the entire system. We further narrow down the main system process; eight sub processes are identified as presented in fig.7.

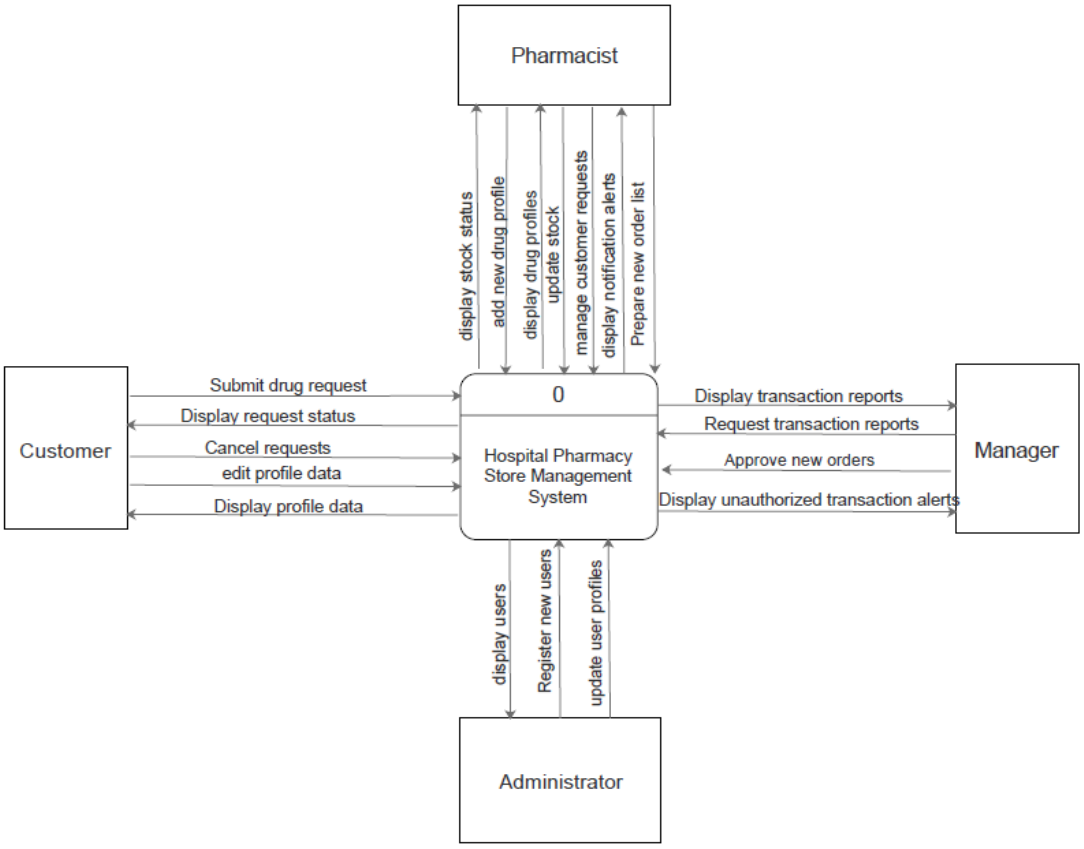

Figure 6: System Context diagram

3.3.2.3 Conceptual data modelling

A conceptual data model (CDM) provides a notation by which the structural properties of data (the structuring of data and their relationships) from a certain domain (Paton et al. 2002). The data structures include data objects or often called data types, associations between data objects (the relationship), and rules which govern operations on the objects. The goal of database modeling is to design an efficient and appropriate database for intended system (Thalheim 2013). Performance, integrity, comprehensibility and expandability are the most important criteria in conceptual modeling. However, it was identified by researchers that the optimal database design is difficult to achieve requiring an in-depth and careful requirement analysis to determine how the different and conflicting informational needs of users can best be satisfied. Therefore in this study the development of conceptual model has been careful derived from the user requirements described above and it has been the result of other requirement modeling such as data flow diagram and use case presented in previous subsections. The common output of the stage of system design is the entity relationship diagram (ERD). The most widely used conceptual model

is an entity relation (ER) model and class diagram of the UML. In this paper, we present the entity relation diagram as shown in fig. 8.

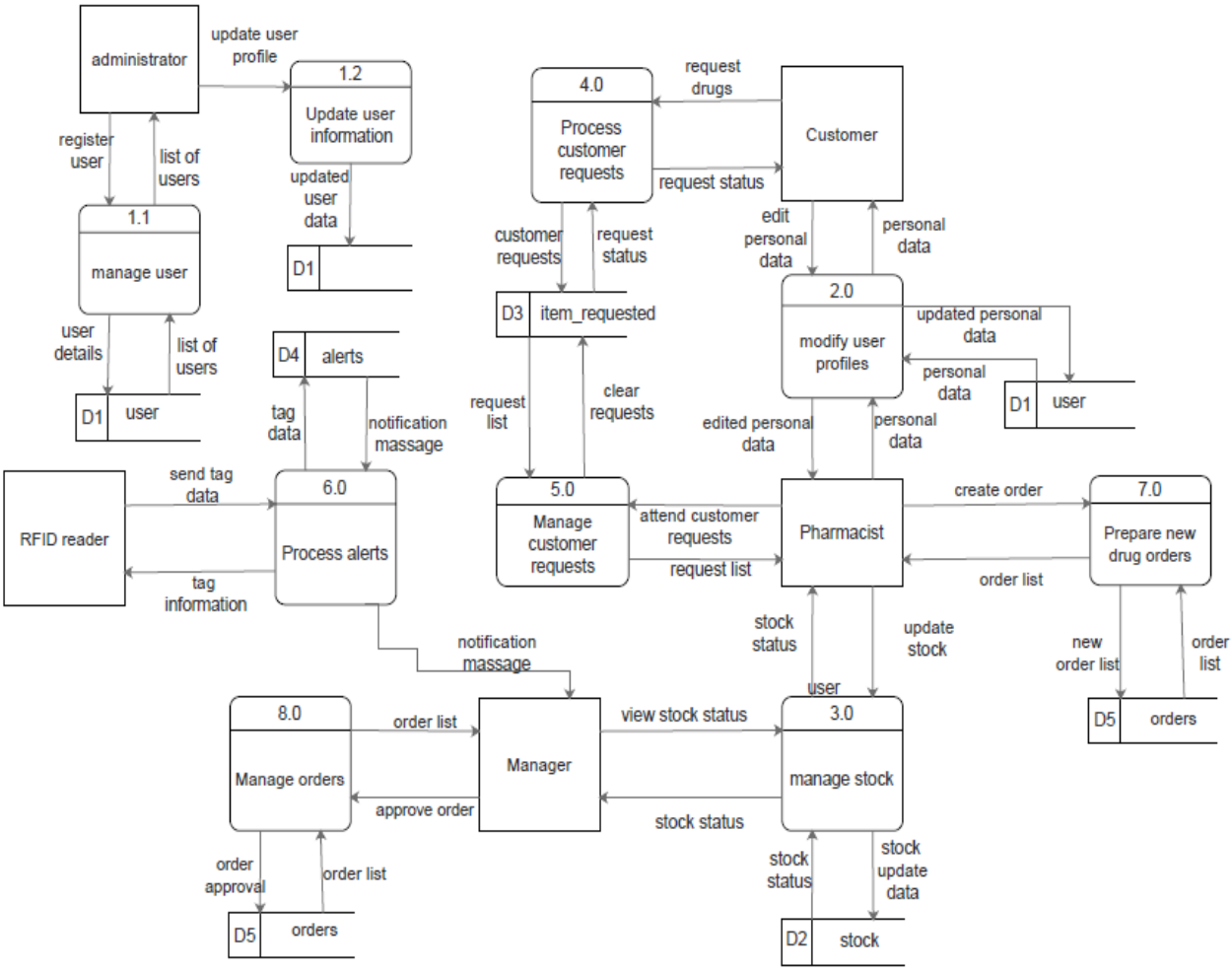

Figure 7: Level 0 DFD of RHPMMS

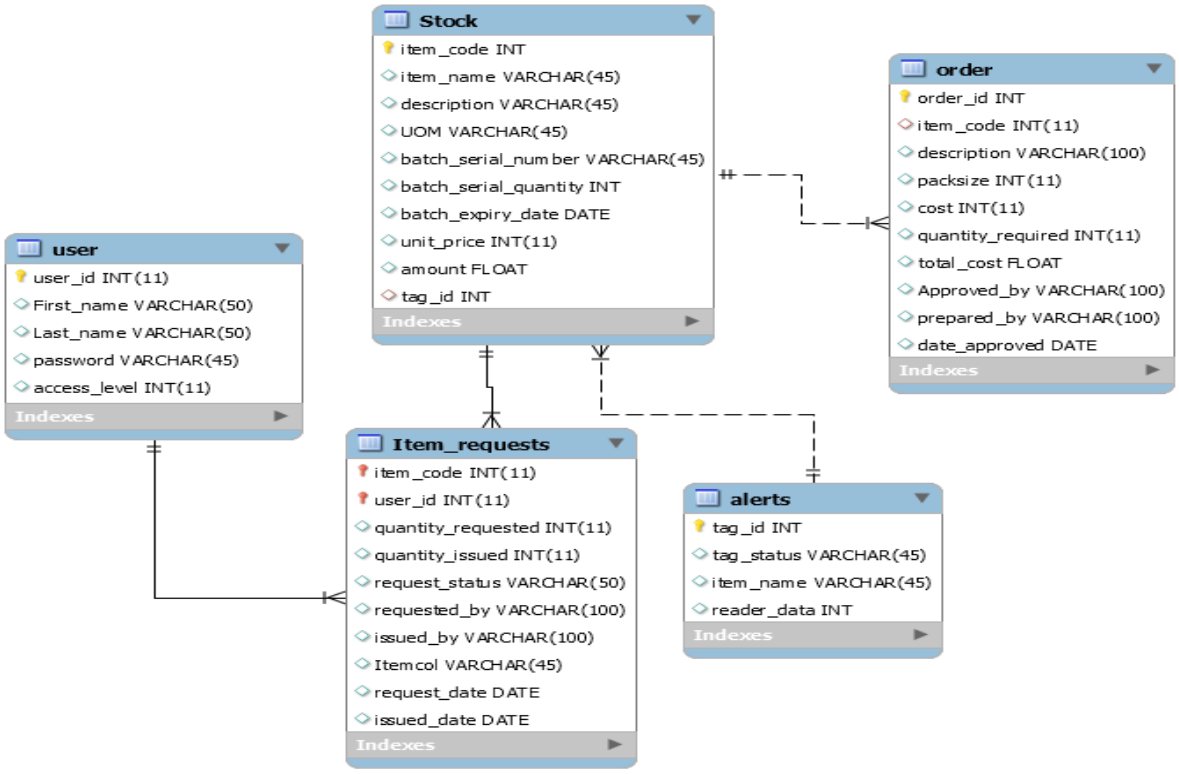

Figure 8: Entity Relation Diagram of RHPMMS

3.4 System design

3.4.1 User interface

The user interface is the part of the system with which user interact to system. It involves the displays that provide navigation through the system, forms that capture data, and the reports that the system produces. Generally the system user interface design is made up of three components; navigation design, input design, and output design. The system user interface for RHPMMS is for all users are the web based interface designed with PHP. Fig. 9 depicts the pharmacist interface for registering new drug item into the system. PHP is the open source server side scripting language with high power in making dynamic and interactive Web pages. The advantages of PHP in web based software development are; independent of platform, open source, has high performance, flexibility and scalability; reliable and has security. Taking these advantages the system user interface was designed with PHP. User experience is a key criterion for designing user interfaces. Interfaces should be designed for both non experienced and experienced users. Novice users are concerned with ease of learning how quickly they can learn

new systems. Expert users are most concerned with ease of use such that how quickly they can use the system. According to interviews done with expected system users they are non-experienced and thus the interface design for each user incorporates menu which shows all available system functions as this promote ease of learning

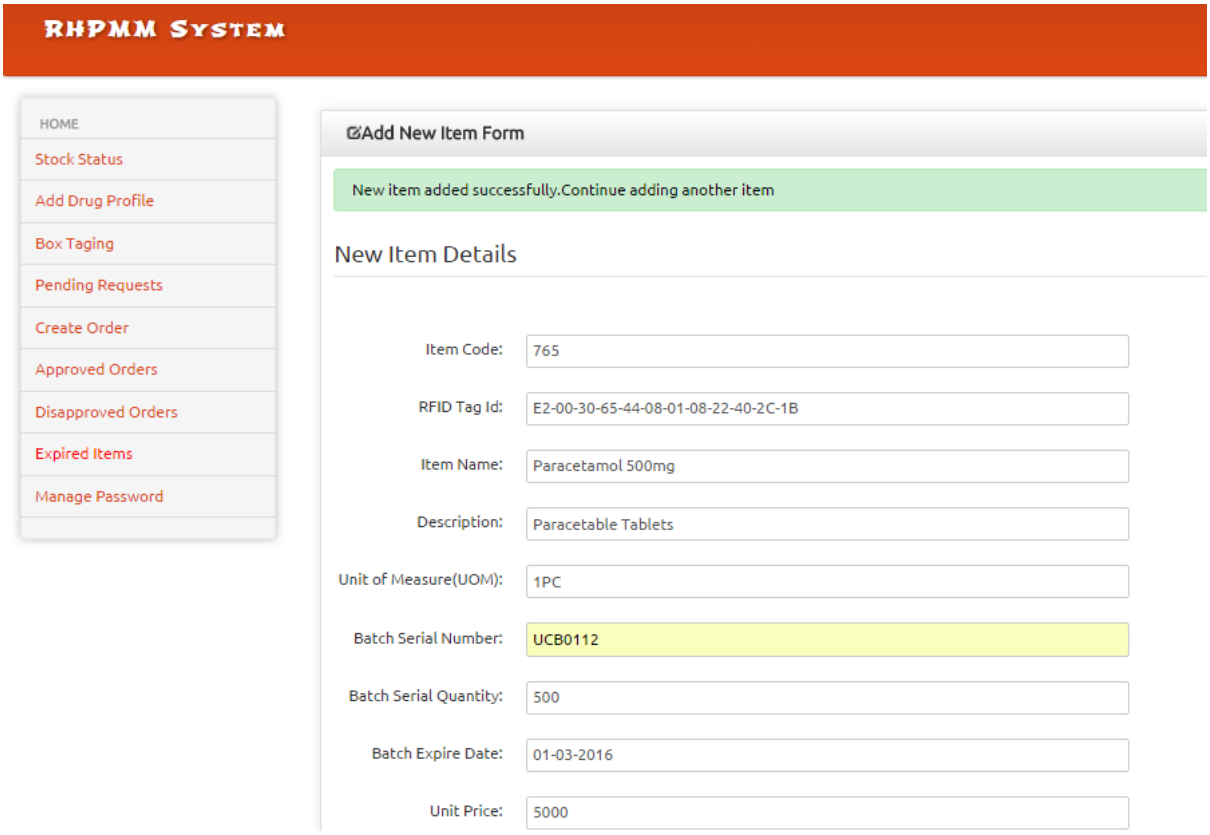

Figure 9: Registering new drug into system

3.4.2 Data management

The study adopts the database management system (DBMS) and structured query language (SQL) statement to provide the function of data retrieval and storage for users. It helps minimize the time used and human mistakes in preparing the program statement for obtaining the required datasets are avoided. In order to increase the speed of data retrieval in the database, Query optimization technique is applied into RHPMMS. Fig. 10 shows the general system architecture, the RFID network consisting of tags and reader is deployed to capture data, the data is stored in the central database, it is accessed by the processing module through query optimization techniques. The RFID middleware is a module for filtering and routing the data to the database.

The software plays a vital role in removing duplicates, efficient use of network bandwidth as well as avoiding confusing information into the system(Ma et al. 2011).

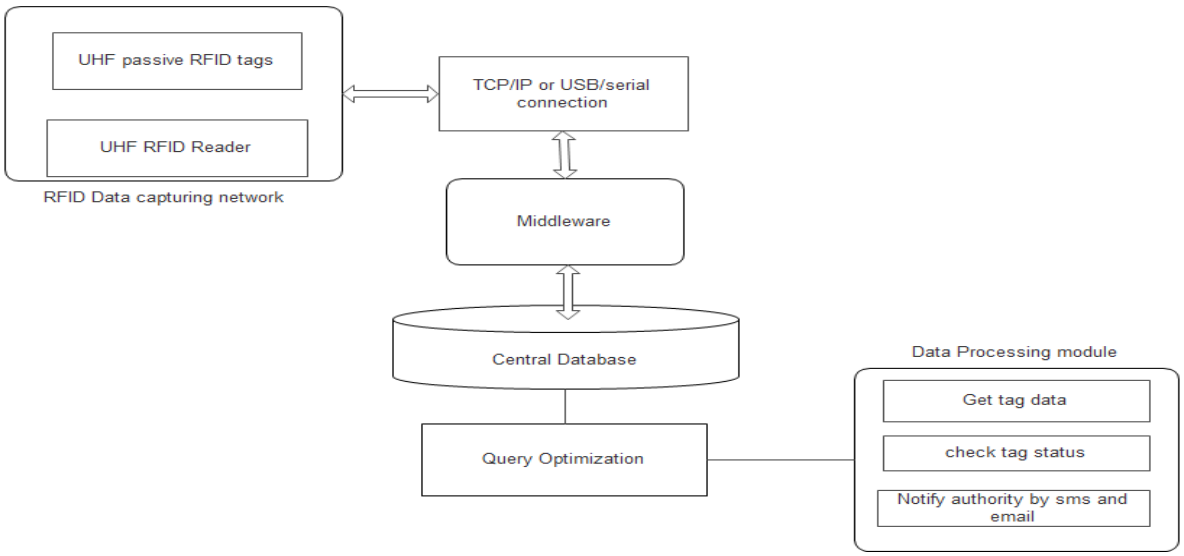

Figure 10: General System architecture

3.5 Discussion and Conclusion

Deploying RFID technology in addressing health sector problem is promising due to the automated capability of this technology, therefore calling for less human involvement in operating the system. However, in any information system development one has to undergo the four basic phases of the System development life cycle (SDLC) which are planned, analysis, design and implementation. In this study, we introduced a system analysis and design phases which are very significant processed in software development to ensure that the project resolves the right problem with a right approach. Failure in these stages will lead to project failure and can bring catastrophes in information system being developed. Results presented will be the basis for the implementation of hospital pharmacy management and monitoring system and integrated with RFID technology. As a consequence of this work system analysis and design, can be concluded that information system plays vital role in addressing health sector challenges, thus system developer must take care the initial design phases to ensure the intended design will fit user requirements and real environment considered.

CHAPTER FOUR

PERFORMANCE ANALYSIS AND SPECIFICATION OF RFID EQUIPMENTS FOR APPLICATION IN HOSPITAL ENVIRONMENTS

Abstract

EPC global standards recommend the UHF passive tag as being reliable in supply chain management and inventory control. However, passive UHF RFID has many benefits over other RFID bands, reliable operation as the tag attached to various material is essentially difficult to predict and can represent a significant challenge. Various material natures tend to affect the radio frequency communication between tag and reader. These materials (metal, liquid, etc.) tend to present interference to the signal leading to misreading or total signal fading. In this paper, we present theoretical and practical experimental in analysis the effect of different drug and medical supplies in pharmacy to the performance of UHF RFID tags.

4.1 Introduction

Radio Frequency identification is an automatic wireless data collection technology with long history roots that can be traced back during second world war (Landt, 2005). RFID system can be classified as passive or active depending on powering option of the tag. Passive RFID system, the reader transmits a modulated Radio Frequency (RF) signal. The tag consists of an antenna and an electronic chip powered only by RF energy generated by reader. The chip responds to the reader by changing its input impedance between two states (typically, high, power collecting, and low, close to short circuit), and thus modulating the backscattered signal.

RFID is considered as an investment for the future, providing advantages such that cost reduction by maintaining stock levels, reducing the out-of-stocks, counterfeit protection, diversion and theft protection, and real-time tracking of supplies. it has been encouraged by governmental organization such as the US Food and drug authorities that the pharmaceutical manufacturers to implement RFID for controlling drug counterfeits (US Food and Drug Administration 2004). In most cases vendor tend provide bias information about product performance, hence there is a need to conduct performance analysis to be sure on the device to be deployed in applications. Also there are several performances limiting factors of UHF RFID

systems basically the environmental attenuation, due to reflection, refraction of radio waves on materials and object in the surrounding. Therefore it is very important to conduct performance analysis of the RFID system chosen in a particular environment. This chapter examine the performance of RFID reader and passive alien 9622 tag thought to be implemented in drug management and control.

4.2 Literature review

The study of RFID system performance has created attention of many researchers, where several studies is carried out to justify the commercial tag and reader performance. Nikitin and Rao (2006) presented several performance limitations on both tag and reader. The study asserted that chip sensitivity, tag antenna gain, antenna polarization, impedance match and tag detuning as performance limitation factors for tag performance (Nikitin & Rao 2006). Reader performance limitation factors include reader sensitivity and effective isotropic radiated power (EIRP) of the reader.

Metallic objects and liquid supplies around a reader and/or tags may significantly affect the read range of RFID system. The pharmaceutical supplies especially drugs involve both metallic and liquid packed drugs thus tagging these materials need some prior considerations. In mitigating this challenge the near field UHF tag are designed which seems to be suitable in pharmaceutical supply (Nikitin et al. 2007; Qing et al. 2009) however this kind of RFID is perfect in manufacturer environment where the reading/sensing distance is short, for the case of our application to control theft the sensing or reading distance must be considerable longer, at least 5m.

Zhang et.al (2009) suggested that the RFID network should operate away from metallic or liquid object the materials which affect signal strength constructively or destructively (Zhang et al. 2009). However this is applicable if the material to be tagged is not metal made; the suggestion was perfect in ware house environment. Furthermore, the study identified that the plastic material does not affect the readability of tag therefore can be tagged on its surface.

Humid and Asher (2014) in their study proposed that for the liquid drug pack the tag should be place at the seal to prevent the effect of liquid onto tag detection and also for blister packed drug the tagging is very trick due to the metallic, thus it should be placed separately on surroundings of each card board box (Hamid & Asher 2014). It further suggests that for metal container pack

used to pack the vitamins drug the tagging should be as for case of blister pack. One of major limitations of this suggests is that it lacks experimental proof. Thus it is important to call out experimental analysis to examine best location of the tags onto pharmaceutical products.

4.3 Materials and Methods

This section present the theoretical and experimental RFID system performance analysis, also the specifications of devices used in implementing the RFID system for management and monitoring of pharmacy product in the hospital environment.

4.3.1 RFID System Link Budget

The fundamental antenna theory and propagation model, the Friis equation can be used to calculate possible forward link budget of RFID reader to tag, separated at distance *d*; assuming only line of site path the reader antenna and the RFID tag. Through these calculations will be able to calculate the maximum possible range that will allow data exchange between the reader and the tag which is actually the maximum possible forward link budget that corresponds to the minimum power at the terminals of the chip that is required for it to be energized (Nikkari et al. 2008). When the available power is lower than this minimum power (threshold), the chip cannot be energized and, therefore, there is no modulated backscattered signal toward the reader antenna. The power incident to tag chip is given by equation 3.1 (Nikkari et al. 2008);

$$P_{rec} = \text{EIRP}\ PL \tag{3.1}$$

Where $P_{rec}$is the power received at tag antenna, *EIRP* is the effective isotropic radiated power of the reader antenna and *PL* is the path propagation loss. The *EIRP* is given by equation 3.2 where G_{tx} reader antenna gain, τ_t is the impedance matching coefficient and P_t is the power radiated by reader antenna.

$$EIRP = P_t \tau_t\, G_{tx} \tag{3.2}$$

The maximum forward link budget is given by equation 3.3 (Griffin et al. 2006);

$$d_{max} = \left(\frac{\lambda}{4\pi}\right)\sqrt{\frac{P_{tx}G_{tx}G_t(PLF)(1-|\Gamma|^2)}{L_c P_{tag}(\min)}} \tag{3.3}$$

Where,

P_{tx} – Effective Radiated Power (ERP=2W for Europe)

G_{tx}– Transmitting antenna gain (reader antenna)

G_t – Receiving antenna gain (tag antenna)

PLF – Polarization Loss Factor between the incident field and the tag antenna

Γ – Complex reflection coefficient at the terminals of the tag antenna for a given chip input impedance

L_c – Cable loss due to attenuation.

P_{chip}(min) – minimum power required by chip (chip sensitivity).

From equation 3.3, mathematically the tag range is inversely proportional to operating frequency, and it is also affected by other factors such as polarization loss and reflection coefficient. For UHF RFID system which conforms to EPC global standard the power of the reader antenna transmitted to tag is limited to the value of 4W (36dBm). UHF tag operates in a frequency range between 860-960MHZ, basing on ISM band which RFID system is mandated to operate the actual frequency of operation is between 865-868 MHZ, 902-928 MHZ. The tag sensitivity is -17dBm sensitivity, the reader has an EIRP of 2W (Europe standard which we adopt in Tanzania) (Polycarpou et al. 2011).

4.3.2 The Tags

A RFID tag is a small chip attached to an object. It emits a unique bit string serving as the object identity (Duc et al. 2006). RFID can be active, passive or semi passive. The active tags have battery to power up the chip while the passive tag has no internal battery it collect power from RF sent by reader. EPCglobal, a non-profit joint venture between EAN International and the Uniform Code Council (UCC), was organized to establish and support the EPC network as the global standard for the automatic and accurate identification of any item passing through the supply chain of any industry (Angeles 2005). The Electronic Product Code (EPC) global provides standard for passive RFID tag to be used in supply chain application. Each product is given a unique identifier called EPC number. The current standard is the EPC Global gen 2 (means a second generation). The Gen-2 RFID tag communicates at UHF band (800-960 MHz) and has communication range is from 2 to 10m. In this study we use the alien 9662 depicted in fig.11 which is a multipurpose RFID tag compliant to international standards such as EPC Gen 2, ISO/IEC 18000-6C.

Figure 11: Alien UHF adhesive tags

4.3.3 The RFID reader

RFID reader or interrogator is a network connected device (fixed or mobile) with an antenna that sends power as well as data and commands to the tags. It provides the connection between the tag and the enterprise system. The read range of the tag depends on both the reader's power and the frequency used to communicate. The higher frequency tags can be read from longer distances but they require more power output from the readers (Wicks et al. 2006). We had selected the impinj 4 ports reader depicted in fig.12 in this study. The reader consists of four ports for four antenna connection, this is important in maximizing the coverage and catchment area. Two antennas will place at one point and the other two onto other point of detection. The reader antennas have 9.6dBi gain and are circularly polarized.

4.3.4 Software

RFID reader often receive data from tag which are noisy, therefore it needs software to manage the reading data to appropriate format and error free. The main component of the system used to manage this is called middleware. The middleware is an interface between RFID network and enterprise system. RFID middleware facilitates connectivity with readers, lower the volume of information that medical applications need to process by grouping and filtering raw RFID observations from readers (Chowdhury & Khosla 2007). The software also allow to reader management, where frequency operation range, maximum power output, and reading mode are

done. Also this middleware provide an interface for tag access, where one can write/read tag information. During the visual basic based software called UHF demo was used for testing.

Figure 12: 4 ports RFID reader

4.3.5 Tag performance in different materials

Testing of RFID system performance was done at the institutes' dispensary pharmacy. Where by tag performance on various material was carried out, by examining the maximum distance at which tag can be read when attached to the real product. To test the product we manually marked out the floor at 1m intervals, and placed the tagged drug at top of the stool which was approximately 1 meter higher. For the case of small items, the product was placed in front of plastic container this is because the plastic container does not interference the radio wave while maintaining the visibility of item to the antenna. The experiment settings were as shown in fig. 13 and fig. 14 shows the reader antenna placed at height of 1m. Fig.15, fig. 16 and fig.17 depict some sample tagged items. The stand was placed at starting point on the grid marks, when the tag was detected the point was recorded; the stand is then moved to the next point, again the reading was taken. The process was repeated till a point where the tag was not detected, the last detection point range was recorded. This was the point of interest as this point mark the maximum read range of the selected tag when attached to particular material.

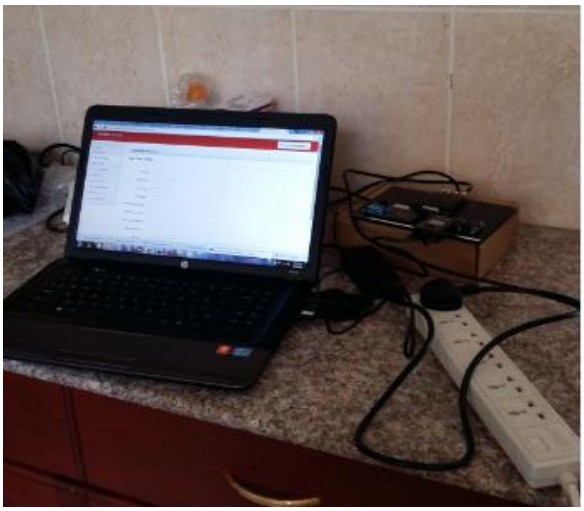

Figure 13: RFID System setting

Figure 14: RFID reader antenna place at height of 1m

Figure 15: Tag on plastic material

Figure 16: Tag on blister material

Figure 17: Tag on glass bottle

4.4 Results

The frequency operation range of the reader was set at 902-928 MHZ; we could not fix a single frequency since the software used to activate the reader allows range selection. The test result for tag performance analysis test experiment is presented in table 6.

Table 6: Tag performance measurement results

Material	Item tested	Maximum range (meter)	Range Tag above paper (meter)
Glass	Metronidazole oral suspension	3	N/A
Blister	Omeprazole capsule	Not detected	2
Foil wrapped item	Chromic catgut	Not detected	0.5
Liquid in plastic container	Ringer Lactate	0.5	1.5
Plastic	Mebendazole tablets	5.5	N/A
Carton box	Panadol	5.5	N/A

4.5 Discussion and Conclusion

Tag position is match challenging, since one has to consider security concerns as well as readability issues. Positioning at open place is a risk since can be removed or tempered and thus affecting the intended purpose. In this paper we have analyzed the performance of the RFID system specifically the tools we selected to be used in the application of drug control and monitoring system. From the experiment results we have observed that the metallic objects (blister and foil packages) tend to destruct radio waves, and therefore when the tag was placed directly to these metal the reader failed to detect it. However the read was improved by first placing the paper material on the container and putting the tag on top. By doing this the 0.5m and 1m read range extension was achieved for foil wrapped and liquid packed in plastic materials respectively. It was also observed that when the blister packed drugs is tagged at the surroundings of card board box the read range was not affected, therefore it is suggested that the tagging for this drugs is better be placed at card box as the seal of the packing to avoid tempering with individual packs inside.

CHAPTER FIVE

IMPLEMENTATION AND INTEGRATION OF RADIO FREQUENCY IDENTIFICATION BASED DRUG MANAGEMENT AND MONITORING SYSTEM.

(Case of Public hospitals in Tanzania)

Abstract

Management of pharmaceuticals supplies in most public hospitals in Tanzania and other developing countries is still done manually; the pharmacists fill the paper based form to order new stock from supplier. When receiving new order, the pharmacist manually enter each item record in ledger book for further reference during dispensing. The process is tedious and consumes a lot of time; also provides an opportunity for unfaithful workers to divert the drugs, say to private hospital which present major challenges to patients due to insufficient drugs, loss of revenue to both government and hospitals. In this paper, the Radio frequency Identification based drug monitoring and management system implementation and integration is discussed. The system aims at first automating the process, providing continuous monitoring of all pharmaceutical supplies in hospital settings. The system development used PHP language to build user interfaces, MySQL for back-end database and Visual Basic for RFID middle.

5.1 Introduction

Radio frequency identification (RFID) technology provides the capability of wireless identification and tracking objects in the warehouse, supply chain, control system, and automation process (Finkelzeller & Muller 2010). A basic RFID system consists of tag which carry identification information, a reader with its antenna and host computer with a program to interpret reader information or middleware (Wamba et al. 2008). Tags are small chip with an antenna and there are three different types of RFID tags: passive ones that use the reader's signal to be activated, and active tags which have battery, and semi-passive which battery-assisted, activated by a signal from the reader. Depending on the type of tag, RFID tag can carry more information (such as product code, serial number, expiry date, batch code) as compared to similar technology such as barcode which keep only product code. The RFID tag transmits the information data stored directly and without direct line of sight to a reader by radio frequency. The reader transfers this information to the middleware for its transmission to a central database

for further processing and decision making. The drive of using RFID technology in this research is the automatic identification and tracking of the objects capability which can mitigate hospital pharmaceutical challenges.

Pharmacies in hospitals are important units in hospitals for the completeness of service to patients. Lack of availability of drugs prescribed for the diagnosed sickness may lead to several problems it may result into death of the patient. Specifically in public hospitals in developing countries where by its client cannot afford to buy the service from private pharmacies. Different reasons on insufficient availability of drugs in public hospitals exist among them being low supply ability of the government due to limited budgets for the sector despite the fact that the supply has been low yet the drug are stolen/missing or diverted to private sectors (Bate et al. 2010)(Global-Fund 2009). The health care institutions have been burdened with the increasingly complex manual work of record keeping and inventory management. The paper presents the part implementation of RFID technology to the control and management of drug in public hospitals for the case of Tanzania.

5.2 Literature review

The RFID Technology has brought significance improvement in supply chain management in addressing the sector challenges which includes:

- Preventing the risks in industries especially the counterfeit drugs in pharmaceutical industry
- Warehousing efficiencies by combining the technology with information systems
- The ability to locate every product
- Ability to curb theft issues in several sectors, e.g. supermarket, hospitals etc.

RFID technology offers best performance in pharmaceutical industry supply chain risks, shipping documentations, passport control, library resource control and monitoring, point of sale data collection, better information retrieval in emergency cases as well as improving assets, patient and staff tracking at hospital (Cerlinca et al. 2010)(Turcu et al. 2009). RFID technology contrary to barcode technology has five more capability such as it requires no line of sight for communication, sustains harsh physical environments, allows simultaneous identification, has excellent data storage, wide read range and is cost and power efficient (Nikitin et al. 2007). RFID enhances the efficiency in healthcare and pharmaceutical industry's supply chain

management activities by securing the products also lowers indirect and direct labor cost(Wicks et al. 2006). Application of RFID in health industry has been a field of major interest by many researchers. Many research works done focusing using RFID to combat drug counterfeits in pharmaceutical supply chain (Lefebvre et al. 2011; Wamba et al. 2008; Hamid & Asher 2014), (Agbaraji 2012). These researches proposed the model for controlling drug counterfeit penetration to drug supply chain by using RFID. They proposed that the tagging should start from ingredient supply to the pharmaceutical manufacturer; this process if implemented would result in full control of the drug supply chain from the manufacturer to the hospitals or pharmacies. In addition to that some government organization are encouraging the implementation of RFID in pharmaceutical manufacturing for future benefits, for instance Food and Drug Administration (FDA) encouraged the pharmaceutical companies to use RFID (US Food and Drug Administration 2004). However the studies did not consider stock control at the hospital environment where the counterfeit penetration is not predominant but theft and diversion which in many cases lead to shortage of drugs and hence results to the huge loss to the government. Absence of drugs in health facilities is a major obstacle to attaining quality services for Tanzanians. Therefore our study will bridge the gap through proposing the ways of controlling the drug supplies at hospital environment.

5.3 Materials and Methods

Following field visits where we visited public hospitals for actual situation visualization and acquiring of system requirements, It has been identified that the possible location for drug diversion is at each hospital unit, such that from pharmacy store itself to wards, outpatient dispensing unit and other units where the drugs are dispensed. The RFID based drug management and monitoring system model starts by assigning each product with RFID tag which contains global unique number for identification commonly known as Electronic Product Code (EPC). In developing the operating specifications of RHPMMS there are four stages involved namely;

- Hospital pharmacy layout study
- Evaluation of RFID equipment
- RFID reading performance tests
- Implementation of the system

5.3.1 Hospital pharmacy layout study

It is essential to perform a real environment study before the digging deep in the system development to ensure the proposed solution reflects the scenario. The physical and environmental factors, such as the size of the hospital, the kind of material found in store, the types of products stored affect the read range and accuracy of tags (Finkelzeller & Muller 2010). By studying the actual environment the specification of the pharmacy store is determined for RFID equipment selection and system requirements.

5.3.2 Evaluation of RFID equipment

There are different kinds of RFID tags, such that the passive, semi passive and active tags. The difference between them is the power source to operate the chip, the active tag has battery and thus can initiate communication while the passive is dormant depend on radiated radio frequency from the reader. This also differentiates the items in terms of size, cost, reading performance, and in application domains. The active and semi passive tags are expensive as compared to passive, considering the financial situation of hospitals deploying active tags will be not feasible. Therefore the passive tags are selected to be used. The system utilizes the passive Ultra High Frequency tags (Gen 2) to minimize tag costs operating at frequency of 860-960MHz. RFID equipment used in supply chain is the UHF alien 9662 tag. RFID tags used in supply chain carry a unique serial number called Electronic Product Code (EPC), and it is mandated to comply with benchmark metrics (Ramakrishnan & Deavours 2006).

5.3.3 RFID reading performance test

To evaluate the device performance, the experiment testing was arranged and constructed at hospital environment. Test procedures and results are presented in chapter four of this dissertation.

5.3.4 System Implementation

5.3.4.1 Frontend system development

Developing this system we used a Hypertext Pre-processor (PHP), a web-based programming language that runs on Apache web server. PHP is open source web based programming language that is widely used by programmers. The reason for high adoption of PHP is that it the server

side scripting language that is independent of operating system. The system was developed basing on user requirements.

5.3.4.2 Backend System development

The backend central database was developed using MySQL. MySQL is open source software which is very popular to developers due to its capability in terms of large data management. In this study we used MySQL Database to allow systematic structuring of repository of indexed information (usually as a group of linked data files) that allows easy retrieval, updating, analysis, and output of data stored usually in a computer. This data could be in the form of graphics, scripts, reports, tables, text, etc., representing almost every kind of data. MySQL provides powerful mechanisms for ensuring only authorized users have entry to the database server, with the ability to block users down to the client machine level being possible.

5.3.4.3 System process flow

The entire system process is illustrated in fig.18 where by the process involves as far as the drug management and monitoring system is concerned. Once there is new stock, the pharmacist in collaboration with representative of the management team will check the stock to ensure the ordered item is the received one. They will place the RFID tag on each item; the tags been already programmed with unique identification number, and then will update the stock received into the system. System users from other dispensing units have access to log into the system where one can place amount of drugs needed. The requests will be sent to pharmacist and one on-duty will issue the requested drugs. When issuing, the system will automatically indicate the item as authorized. Since there are RFID readers installed at each exit of the pharmacy store, every drug passing by RFID reader its tag ID will be sent to system for checking if authorized or not. If not authorized the system automatically generates notification alert which will be sent to the hospital manager for immediate intervention, at the same time the system will trigger the alarm to notify security officer.

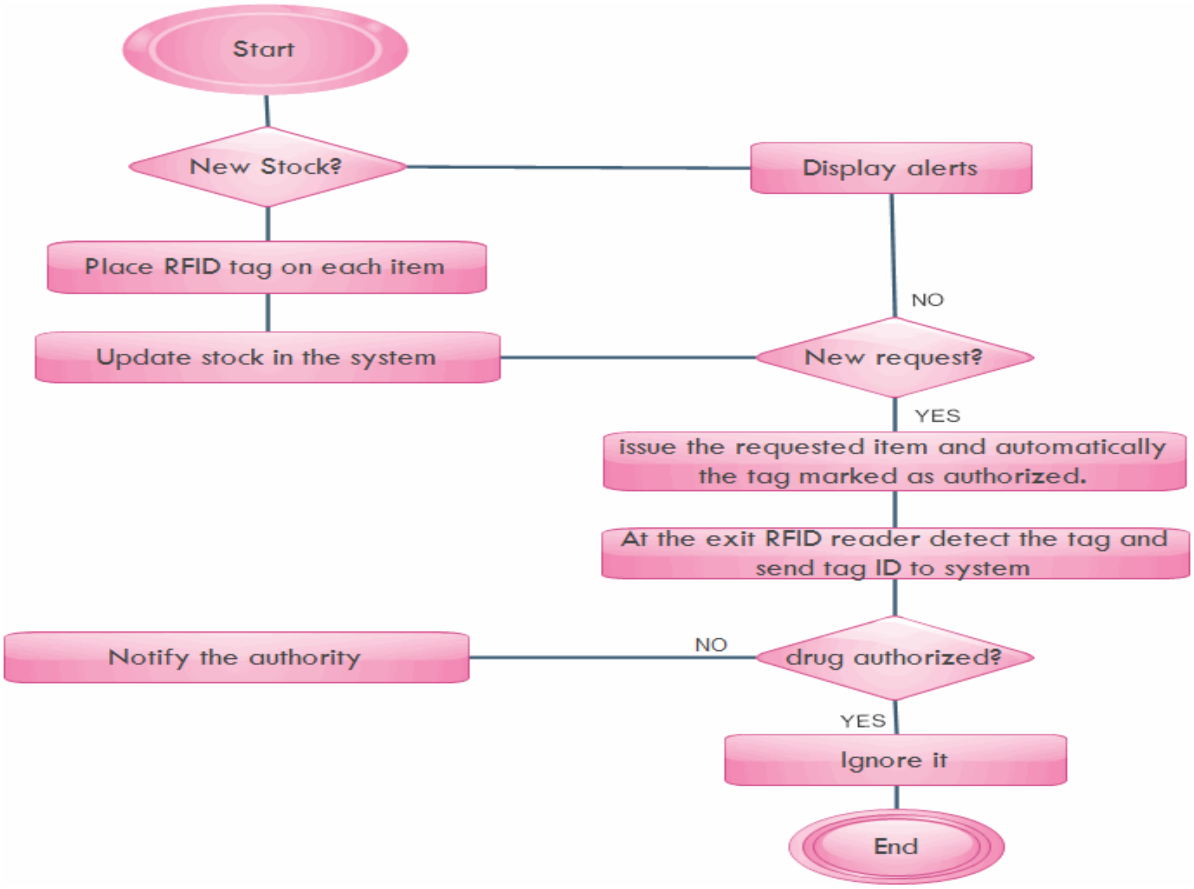

Figure 18: RPMMS process flow diagram

5.4 Results

A RDID based drug management system has been developed as a result to manage and control flow of drug and medical supplies in hospital environment. Result show the system web interface which is used by system users to manage system activities and the central database.

5.4.1 Web interface

System user will access the system through web interface; the importance of web based application is that can be extended to online platform when hosted. This will result in accessing the system at any point with in hospital. A nurse from his/her working can log into the system and place requests to the required items. Fig. 19 shows a manager (hospital medical in charge) web based interface showing the stock status and alerts.

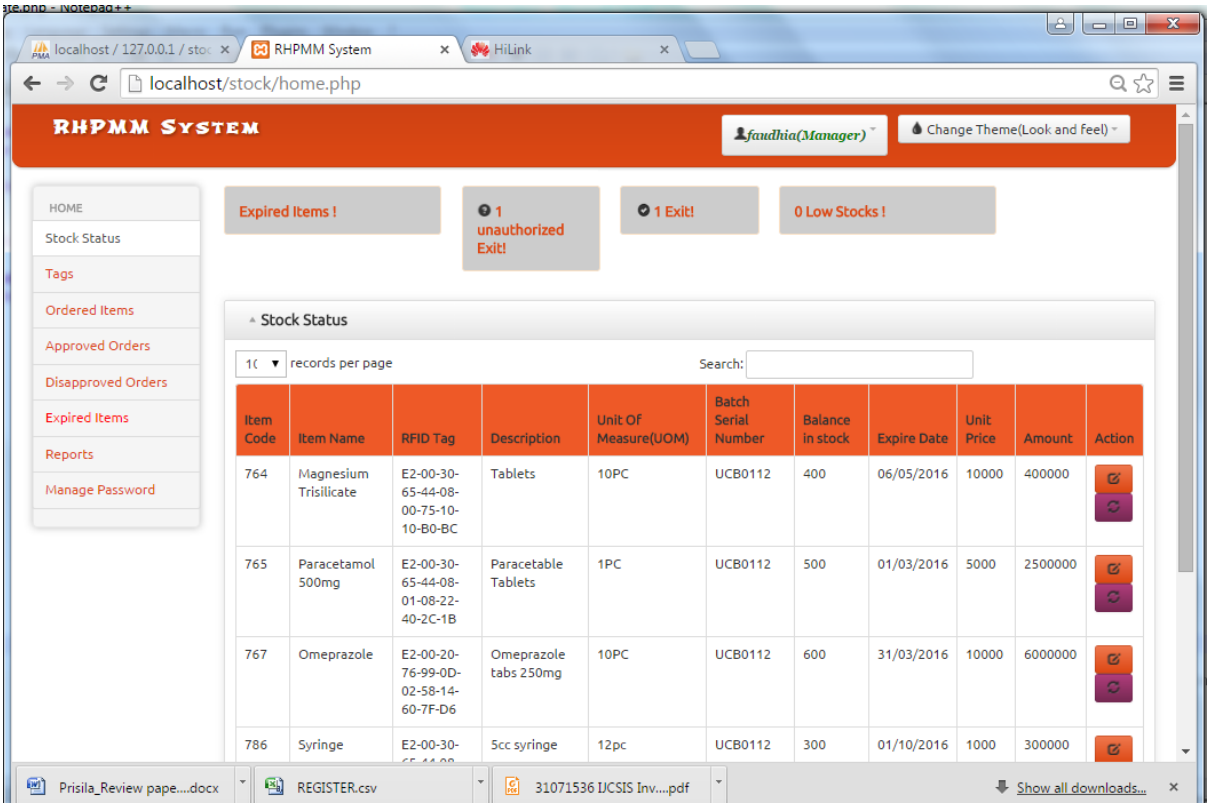

Figure 19: Manager Web interface

5.4.2 User Notification alerts

One of major advantage of RFID technology is to provide a means to reduce unexpected stock out and loss due to expired items. This system has been designed to incorporate a feature where the drug expiry date will be closely monitored. One month before an item is expired system will send notification to users, so as the hospital management can take measure to prevent the loss by asking MSD to replace the stock, and distribute the nearly expiring to other hospital with high demands. Also for the case of low stock items a message will be sent to both pharmaceutical and medical in charge so as to make ordering prior to total stock out. Since the RFID reader will be placed at exit of pharmacy store, so that any item passing will be scanned and its tag ID sent to system for checking up. When the detected tag indicate active in the system then the alert massage will be generated and sent to manager instantly. In actual implementation this will be realized by deploying alerting devices like bell. Figure 20 shows an interface for pharmacist, showing notification alerts and stock status.

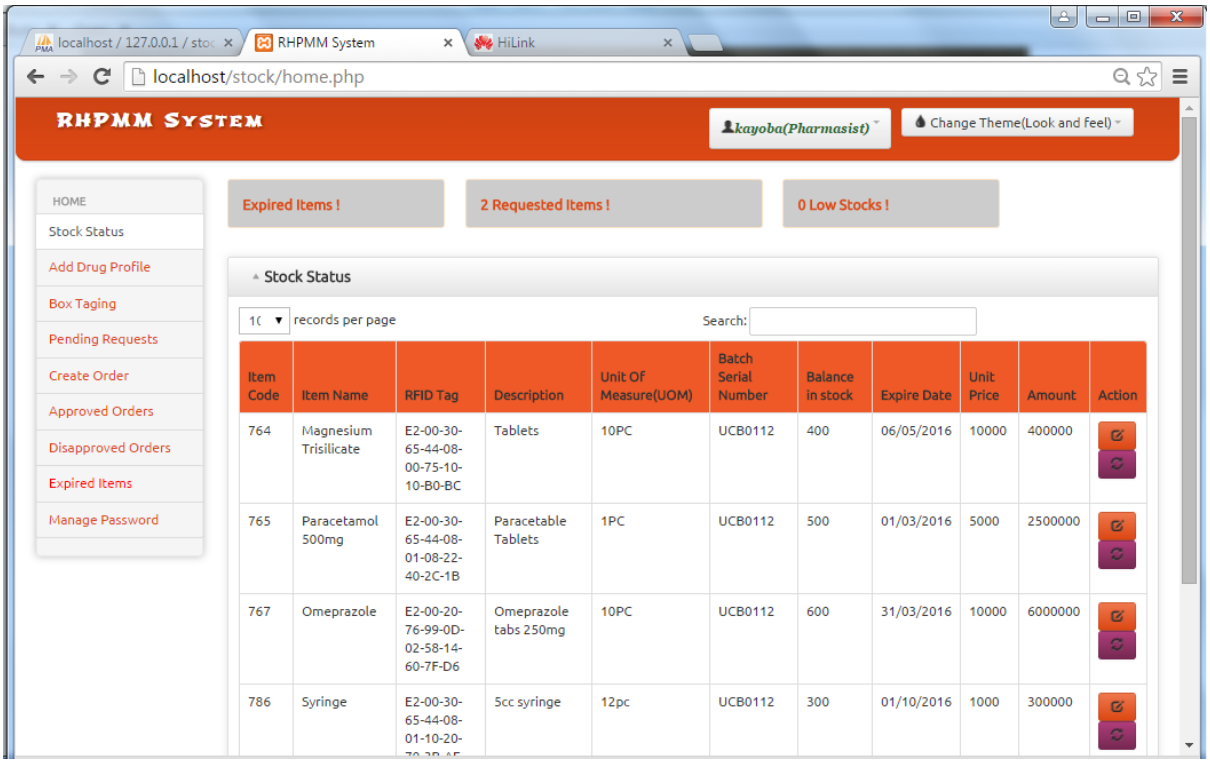

Figure 20: Notification alerts

5.5 Discussion and Conclusion

The system implementation of the RFID based pharmacy management system is presented in this paper. Web based interface system is chosen in order to provide ease of update of information and allowing online system implementation. Also, public hospitals work in close relation with MSD developing a web based system will easy integration and exchange of information between the two organizations in feature. In addition to that the system has been developed with more automated functionalities such as drop down menu, search options so as to reduce system complexity to users.

CHAPTER SIX

VERIFICATION AND VALIDATION OF RADIO FREQUENCY IDENTIFICATION BASED DRUG MANAGEMENT AND MONITORING SYSTEM.

Abstract

This paper presents a systematic testing and evaluation of an RFID based drug management and monitoring system. The system was developed for the purpose of controlling and minimizing the drug diversion in public hospital and enhancing efficient drug management. The system targeted public hospitals in Tanzania as is among the countries in sub Saharan Africa receiving medicine aids from developed countries, however there is incidences in which public supplied medicines are found in private pharmacies implying some illegal diversion. This paper, we present how the system was tested and evaluated for use under such environments. Different kinds of tests were conducted such as unit testing, integration test and system testing to determine the system functionalities in regard to the system requirements set earlier. Classic V model for system development was adopted where all here tests were done in each system development life cycle. Furthermore the system was installed at the institution dispensary and trained some health worker on system functionality and later questionnaire were given to them to evaluate system performance and usefulness. The testing and evaluation results depicted that the system well performing and very useful in addressing the problem of diversion in public hospitals.

6.1 Introduction

Software validation and verification (SVV) is the quality assessment of software products throughout their lifecycle (Tamura et al. 2013). System verification is the process of evaluating a system or component to determine whether the products of a given development phase satisfy the system requirements conditions imposed earlier (IEEE6 10.12-1990 1990). System verification involves reviewing, inspecting, testing, checking, auditing, or otherwise establishing and documenting whether items, processes, services or documents conform to specified requirements (IEEE 1986). According to IEEE, validation is the process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements, thus can be concluded that validation is an end to end verification (IEEE 2012). In

this chapter we present the software verification and validation (SVV) for developed drug management and monitoring system against the requirements of the system presented in chapter 3.

Traditionally system development life cycle (SDLC) involves four fundamental phases: architecture, design and implementation. These process guides the system developer in accomplishing system development. However, developing system through these phases does not guarantee system functionality as desired. Therefore one has to undergo system verification and validation. The classic V model for system development extends the traditional SDLC to accommodate the verification and validation. Fig. 21 illustrates how SVV activities are organized in traditional software engineering to ensure that the software satisfies a given set of requirements, at the different levels of system development. Each development phase is subject to a corresponding verification and validation phase horizontal layers as the software is built and integrated. The paper focuses on the right-hand side of the Class V model to justify the developed system satisfies the system goals.

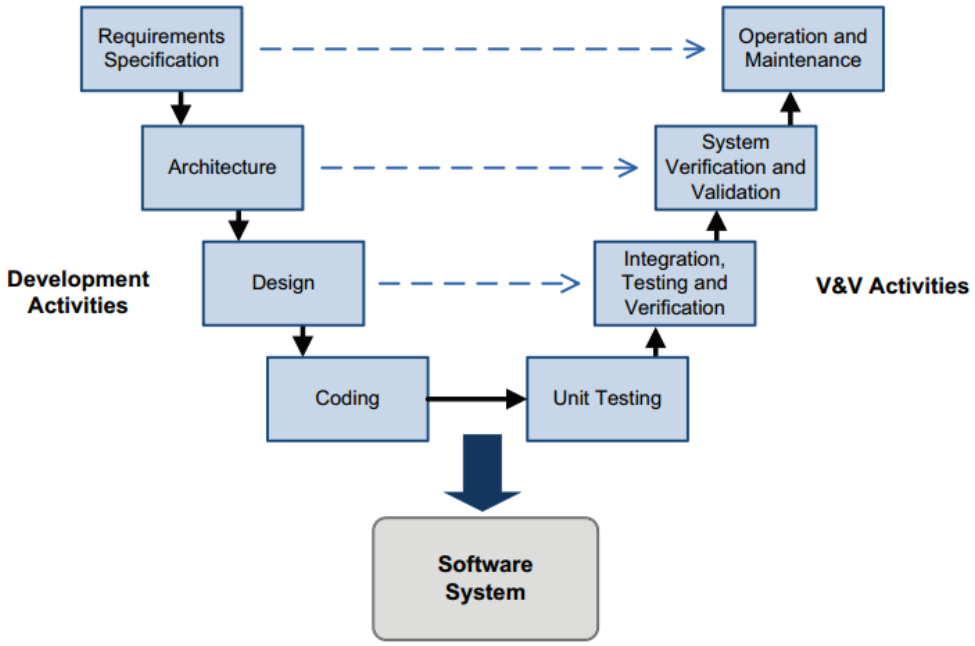

Figure 21: Classic V model for system development(Thayer et al. 1997)

6.2 Literature review

This section discusses various methods used in the study for verification and validation. The research design, population of the study, sampling size, sampling technique and verification and validation techniques, data analysis and results are presented.

Although the data collection and requirements were collected at district and regional offices in Dar es Salaam and Arusha, the system testing and validation was conducted at NM-AIST dispensary due to insufficient resources. The pharmacist at dispensary was working experience from Temeke hospital, this made it easy to test and understand the system. The system testing involved doctors (as manager in our system), nurses (as customer from hospital unit who request drugs and medical supply from the system) and one IT expert from NM-AIST's IT department since are the one serving dispensary for any IT related issues as well. We introduced to them and the system works.

Data entries into the system were done by obtaining help and details from pharmacist. We then tested system functionality with each user by practising his role in the system. We identified some module was not working correctly, the errors was corrected and tested again till all were clear. Then every study participant was given to evaluate the system.

6.2.1 Sample size

Sample size of study involved 5 participants: 2 nurses, 1 doctor, 1 ICT expertise, and 1 pharmacist. These participants are the one directly involved in the process of pharmaceutical process flow in hospitals.

6.2.2 Verification and validation techniques

A number of tests were performed on the RFID based drug management and monitoring system before users where allowed to interact with it, to ensure that the entire system would work as designed.

6.2.2.1 Unit testing

This involves verify that the software subsystems and components work correctly in isolation, and as specified in the detailed design or implementation of the SDLC. In this testing smallest testable parts of an application called units are individually and independently check for proper operation

6.2.2.2 Integration testing

Integration testing, verify that the major software components work correctly with the rest of the system, and as specified in the architectural design. It is achieved by taking independent units that already tested and integrated, and they combined units are tested for proper operations. A component, in this case, refers to a combination of more than one unit. The idea is to test combination of pieces and eventually expand the process to test the modules with those of other groups.

6.2.2.3 System Testing

Verify that the software system meets the software requirements; it involves testing of entire complete system against the specified system requirements. The system testing was performed to evaluate integrated RFID network and developed software as expected and also weather the tags are detected at each item pass. This was accomplished by configuring test environment at institution dispensary pharmacy.

6.2.2.4 User acceptance testing

We tested the system with the intent of confirming the readiness and acceptance by users. The system was installed at dispensary and connected with RFID network. Then, we conducted a short introduction about the system functionality and user functions in the system. We conducted interview with the users to obtain their views on the system. Also they were given open ended questionnaire for examining the acceptance and general evaluation of the system. The user acceptance testing is the technique for system validation.

The reader antenna layout and settings were done as explained in chapter 4 section 4.3.5 of this dissertation.

6.3 Results

6.3.1 Test reports

A test is an activity in which a system or component is executed under specified conditions, the results are observed and recorded, and an evaluation of some aspect of the system or component is conducted. Testing also can be defined as the process of executing a program with the intent of

finding errors (Myers et al. 2011). Testing as one of method used in SVV is the most preferable method because it executes the software, and allows one to observe the software response. This section presents the test result of our drug management and monitoring system.

Table 7: Login Test

Login test		
Checked	Test	Results
✓	System grant permission to only authorized users registered in the system	Pass
✓	Deny to the user with wrong username or password to the system	Pass

Table 8: Stock updating test

Receive and update stock		
✓	The system allow registration of new drug information	Pass
✓	System allow updating stock counts up on receive	Pass
✓	System allow issuing drug to the authorized customer	Pass

Table 9: Database test results

Database testing		
Checked	Test performed	Results
✓	When tag EPC IS detected and sent the database updates	Pass
✓	Update user information up on modification	Pass
✓	Deduct item count up on issue	Pass
✓	Database deny empty inputs	Pass

Table 10: Tracing transaction test

Tracing system transactions		
Checked	Test performed	Results
✓	The management can get report on transaction on specified dates	Pass
✓	System keeps user logs	Pass

Table 11: Notification alerts test

Notification alerts tests		
Checked	Test performed	Results
✓	The system sends alerts up on detecting unauthorized item at the exit.	Pass
✓	System notify users on low stock items basing on re-order level	Pass
✓	System send start alerting pharmacists on nearly expiring or expired items.	Pass

6.3.2 User acceptance test results

We statistically analyzed the data collected through the questionnaire. Questionnaire data were exported to SPSS for analysis and results are summarized in the graph as presented in this subsection. Figure 22 presents the summary of results obtained from health workers, IT expertise for the entire system.

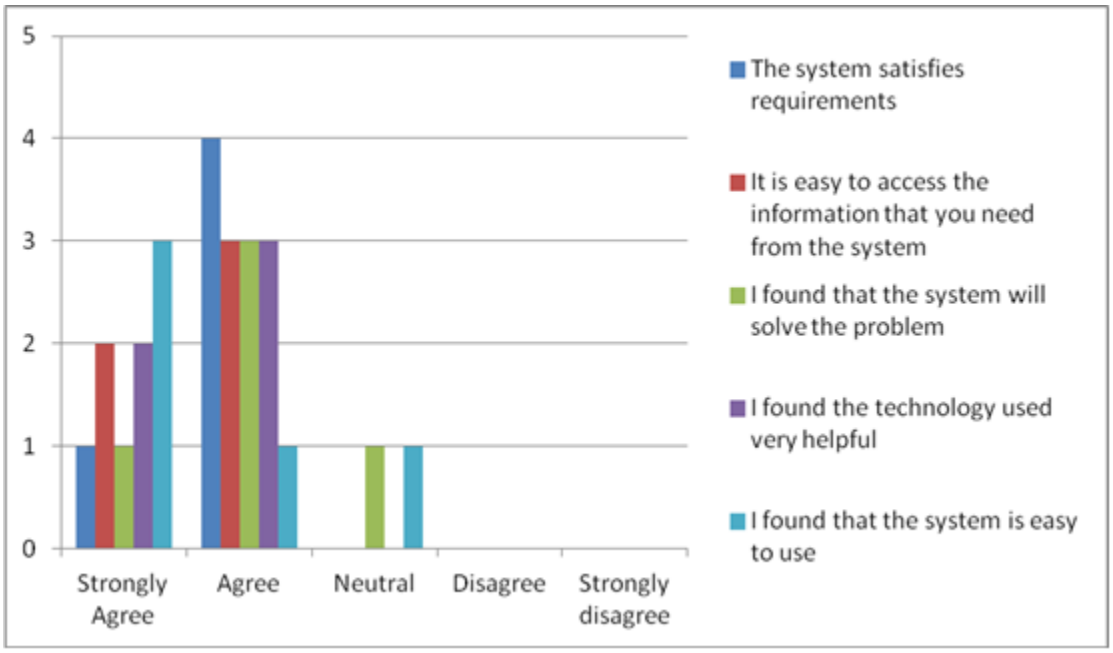

Figure 22: System validation user views

6.4 Discussion and Conclusion

The paper demonstrated various verification and validation methods of the system and validation

methods the testing included function, integration and system testing which were done in the RFID based hospital pharmacy management system. System components ware tested to make sure that it is working effectively. The integrated system was then tested to realize how the system components work with each other.

CHAPTERSEVEN
GENERAL DISCUSSION, CONCLUSION AND RECOMENDATION

7.1 GENERAL DISCUSSION

In this study, a review on drugs management and monitoring system in public hospitals was performed. It was revealed that the current system involves paper based operations that presents various challenges including time consumption and difficulty in tracing transactions. The paper based system is also subjected to human error. Addressing these challenges, this study designed and developed a prototype system basing on RFID technology; the solution has been developed based on the actual public hospital scenario through critical analysis of system requirements. The proposed RFID system consists of four antenna ports reader which is important in maximizing radio coverage at the monitored area. The antennas will be placed at different exit of the hospital pharmacy and all being controlled by a single reader which implies cost reduction. The system also uses passive UHF RFID tags which are low cost and provide high read range.

The proposed system was tested for its performance. However, some drugs and medical tools provide poor read due to material interference with RFID tag. These package materials include the blister packed items, foil packaged materials and liquid contained drugs. Various ways are proposed to avoid or minimize the interference, whereby, for the case of blister packed drugs, the RFID tag would be placed on top of the package. The tag may act as a seal to the product. Likewise, to the foil packaged items, placing a paper between the tag and the product improves readability (Hamid & Asher, 2014).

7.2 CONCLUSION

The designed RFID based drug management and monitoring system has demonstrated a great potential in preventing drugs theft/diversion, unexpected stock-out through the automation of notification and identification process. The application of RFID technology in health industry can provide significant benefits for the improvement of pharmaceuticals supply chain management in hospital environment. The study utilizes cost effective passive UHF RFID tags which facilitate auto detection of a tagged object as it passes the interrogation zone. This will counteract drug diversion and thus ensure drug availability. Hence, this model can be deemed suitable in health facilities to ensure provision of quality health services in Tanzanian public

hospitals. However, to achieve full control over the process, each hospital unit i.e. dispensing, and wards has to implement the system

7.3 RECOMENDATIONS

This study was conducted to improve efficiency in drug disbursement process as well as counteracting drug theft and diversion in public hospitals. The system will replace the manual system current being used. Since all drugs and other health products available at public hospitals are supplied by MSD, therefore, this study is recommending the government of Tanzania to advise MSD to assist in placing RFID tags in all their pharmaceutical products before disbursing the products to local public hospitals. This will fasten the process, ensure integrity of the product and also will increase security to the products. Since the pharmacists and other health workers will not be aware on the security tag position, then it would be hard to temper with it

In ensuring that the supplied products are used as intended, monitoring should not end at the pharmacy store only, the system should be extended to other hospital units such as dispensing units and wards. This will result to total monitoring and control of the supplied health products and thus reduce unnecessary loss that the government is currently incurring. Also, successful monitoring and management will imply good health provision to customers/patients.

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APPENDICES

Appendix 1: Processing expired Item

```
<?php
        foreach($rows As $row)
         {
         echo '<tr>
         <td>'.$row['ItemCode'].'</td>
         <td>'.$row['ItemName'].'</td>
         <td>'.$row['Description'].'</td>
         <td>'.$row['UOM'].'</td>
         <td>'.$row['BatchSerialNumber'].'</td>
         <td>'.$row['BatchSerialQty'].'</td>
         <td>'.date('d/m/Y',strtotime($row['BatchExpireDate'])).'</td>
         <td>'.$row['UnitPrice'].'</td>
         <td>'.$row['Amount'].'</td>
         <td class="center">'.'<a class="btn btn-primary" href="EditItemform.php?
         id='.$row['ItemCode'].'">Edit</a>'.   '<a  class="btn btn-info"
         href="UpdateItemform.php
         id='.$row['ItemCode'].'">update</a>'.'</td>
         </tr>';
         }
         ?>
```

Appendix 2: Drug request processing codes

```php
<?php
require_once('db/db.php');
session_start();
//$user=$_SESSION['uid'];
$user=$_SESSION['user'];

$query="SELECT * FROM customeritems ci inner join items i on ci.
itemCode=i.itemCode where requester='Nurse1'";
                                    $results=$dbh->query($query);
                                     $rows=$results->fetchAll();
$date=date('Y-m-d');
$nRows1 = $dbh->query("SELECT * FROM items
WHERE BatchExpireDate<='".$date."';")->fetchColumn();
//$nRows2 = $dbh->query('select count(*) from customeritems
WHERE issuedBy !="'')->fetchColumn();
$nRows3 = $dbh->query('select count(*) from items WHERE
BatchSerialQty <=10')->fetchColumn();
?>
```

```php
<?php
  foreach($rows As $row)
  {


  echo '<tr>

          <td>'.date('d/m/Y',strtotime($row['requestdate'])).'</td>
          <td>'.$row['ItemCode'].'</td>
      <td>'.$row['ItemName'].'</td>
  <td>'.$row['Description'].'</td>
      <td>'.$row['UOM'].'</td>

      <td>'.$row['BatchSerialNumber'].'</td>
      <td>'.$row['Required_Qty'].'</td>
  <td>'.$row['BatchSerialQty'].'</td>
      <td>'.date('d/m/Y',strtotime($row['BatchExpireDate'])).'</td>
      <td>'.$row['UnitPrice'].'</td>
      <td>'.$row['Amount'].'</td>
      <td>'.$row['Status'].'</td>

  </tr>';
  }
  ?>
```

Appendix 3: New order processing

```php
<?php
require_once('db/db.php');
$id=$_GET['id'];

$query="SELECT * FROM items WHERE ItemCode='$id'";
                $results=$dbh->query($query);
                 $rows=$results->fetch();
session_start();
//$user=$_SESSION['uid'];
$user=$_SESSION['user'];
$aclevel=$_SESSION['AccessLevel'];

?>
```

```php
<?php
    if(isset($_GET['error']))
{
if($_GET['error']==1)
{
echo '<div class="alert alert-error">'.'Empty Customer
Account or Customer name field '.'</br>'.'</div>';
}elseif($_GET['error']==2)
{
echo '<div class="alert alert-error">'.'An item with the
same item Code  Exist in the system please cross-check before
entering again'.'</br>'.'</div>';
}
}
if(isset($_GET['success']))
{
if($_GET['success']==1)
{
echo '<div class="alert alert-success" style="color:black">'.
'New item added successfully.Continue adding another item'.'</br>'.
'</div>';
}elseif($_GET['success']==2){
echo '<div class="alert alert-success" style="color:black">'.'Risk
updated successfully'.'</br>'.'</div>';
}
}
    ?>
```

Appendix 4: Summaries and report

```php
<?php
$query="SELECT RequestionNo,ItemName,Description,UOM,BatchExpireDate,
Issued_Qty,Instockqty,Issuedto,issuedBy,issuedate from items i
inner join customeritems ci on i.ItemCode=ci.ItemCode ORDER BY
RequestionNo ASC";
    $results=$dbh->query($query);
     $rows=$results->fetchAll();
  foreach($rows As $row)
  {
  echo '<tr>
      <td>'.$row['RequestionNo'].'</td>
      <td>'.$row['ItemName'].'</td>
  <td>'.$row['Description'].'</td>
      <td>'.$row['UOM'].'</td>
          <td>'.date('d/m/Y',strtotime($row['BatchExpireDate'])).'</td>
      <td>'.$row['Issued_Qty'].'</td>
  <td>'.$row['Instockqty'].'</td>

      <td>'.$row['Issuedto'].'</td>
      <td>'.$row['issuedBy'].'</td>
      <td>'.date('d/m/Y',strtotime($row['issuedate'])).'</td>

  </tr>';
  }
  ?>
<?php
$query="select * from items where  (TO_DAYS(`BatchExpireDate`)-
To_DAYS(NOW())<=14)  order by `itemCode` asc";
    $results=$dbh->query($query);
     $rows=$results->fetchAll();
  foreach($rows As $row)
  {
  echo '<tr>
      <td>'.$row['ItemName'].'</td>
  <td>'.$row['Description'].'</td>
      <td>'.$row['UOM'].'</td>
      <td>'.$row['BatchSerialNumber'].'</td>

      <td>'.$row['BatchSerialQty'].'</td>
      <td>'.date('d/m/Y',strtotime($row['BatchExpireDate'])).'</td>
  </tr>';
  }
  ?>
```

```php
<?php
$query="SELECT * FROM `stocking` INNER JOIN `items` ON `items`.
`ItemCode`=`stocking`.`fk_item_id` INNER JOIN `user` ON `user`.
`id`=`stocking`.`stocker`";
    $results=$dbh->query($query);
     $rows=$results->fetchAll();
  foreach($rows As $row)
  {
  echo '<tr>
      <td>'.$row['ItemName'].'</td>
   <td>'.$row['Description'].'</td>
      <td>'.$row['UOM'].'</td>
      <td>'.$row['BatchSerialNumber'].'</td>
      <td>'.$row['stocked_qty'].'</td>
      <td>'.date('d/m/Y',strtotime($row['stocked_date'])).'</td>
      <td>'.$row['username'].'</td>

   </tr>';
  }
  ?>
```

Appendix 5: Notification processing

```
<?php
if(isset($_GET['error']))
{
if($_GET['error']==1)
{
echo '<p style="background-color:pink; color:red;">'.
'Empty fields identified!!,make sure all fields are
correctly filled '.'</br>'.'</p>';
}
}
if(isset($_GET['success']))
{
if($_GET['success']==1)
{
echo '<div class="alert alert-success" style="color:black">'.
'New risk added successfully.Add another risk click on new key
 risk menu on your left hand side'.'</br>'.'</div>';
}elseif($_GET['success']==2){
echo '<div class="alert alert-success" style="color:black">'.
'Item Issued successfully'.'</br>'.'</div>';
}elseif($_GET['success']==3){
echo '<div class="alert alert-success" style="color:black">'.
'Item edited successfully'.'</br>'.'</div>';
}elseif($_GET['success']==4){
echo '<div class="alert alert-success" style="color:black">'.
'Item updated successfully'.'</br>'.'</div>';
}
}
?>
```

```php
<?php
  foreach($rows As $row)
  {
  echo '<tr>
        <td>'.$row['ItemCode'].'</td>
      <td>'.$row['ItemName'].'</td>
  <td>'.$row['Description'].'</td>
      <td>'.$row['UOM'].'</td>

      <td>'.$row['BatchSerialNumber'].'</td>
  <td>'.$row['BatchSerialQty'].'</td>
      <td>'.date('d/m/Y',strtotime($row['BatchExpireDate'])).'</td>
      <td>'.$row['UnitPrice'].'</td>
      <td>'.$row['Amount'].'</td>
      <td class="center">'.'<a class="btn btn-primary" href="order.
      php?id='.$row['ItemCode'].'">order</a>'.    '</td><td><a
      class="btn btn-info" href="UpdateItemform.php?id='.$row['ItemCode'].
      '">update</a>'.'</td>
  </tr>';
  }
  ?>
```

Appendix 6: Schema creation

```
CREATE TABLE IF NOT EXISTS `account` (
`Account_Id` int(11) NOT NULL,
  `Account_Nu` varchar(30) NOT NULL,
  `AccountName` varchar(30) NOT NULL
) ENGINE=InnoDB  DEFAULT CHARSET=latin1 AUTO_INCREMENT=2 ;
-- --------------------------------------------------------
-- Table structure for table `customeritems`
CREATE TABLE IF NOT EXISTS `customeritems` (
`id` int(11) NOT NULL,
  `RequestionNo` varchar(11) NOT NULL,
  `ItemCode` int(11) NOT NULL,
  `Required_Qty` int(20) NOT NULL,
  `Issued_Qty` int(11) NOT NULL,
  `issuedto` varchar(100) NOT NULL,
  `OriginalQty` int(11) NOT NULL,
  `Instockqty` int(11) NOT NULL,
  `requestdate` datetime NOT NULL,
  `issuedate` datetime NOT NULL,
  `requester` varchar(100) NOT NULL,
  `issuedBy` varchar(100) NOT NULL,
  `Status` varchar(40) NOT NULL
) ENGINE=InnoDB  DEFAULT CHARSET=latin1 AUTO_INCREMENT=9 ;
```

```
CREATE TABLE IF NOT EXISTS `customers` (
  `customerAccountNo` int(11) NOT NULL,
  `CustomerName` varchar(100) NOT NULL,
  `Location` varchar(100) NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1;
-- Dumping data for table `customers`
CREATE TABLE IF NOT EXISTS `items` (
  `ItemCode` int(11) NOT NULL,
  `tag_id` varchar(40) NOT NULL,
  `ItemName` varchar(100) NOT NULL,
  `Description` varchar(100) NOT NULL,
  `UOM` varchar(50) NOT NULL,
  `BatchSerialNumber` varchar(50) NOT NULL,
  `BatchSerialQty` int(11) NOT NULL,
  `BatchExpireDate` date NOT NULL,
  `UnitPrice` int(11) NOT NULL,
  `Amount` float NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1;
-- Table structure for table `item_order`
CREATE TABLE IF NOT EXISTS `item_order` (
`OrderId` int(11) NOT NULL,
  `ItemCode` varchar(20) NOT NULL,
  `ItemName` varchar(20) NOT NULL,
  `UOM` varchar(11) NOT NULL,
  `BatchSerialNumber` varchar(10) NOT NULL,
  `order_qty` int(10) NOT NULL,
-- Table structure for table `stocking`
CREATE TABLE IF NOT EXISTS `stocking` (
`stocking_id` int(11) NOT NULL,
  `stocked_qty` int(11) NOT NULL,
  `stocked_date` date NOT NULL,
  `fk_item_id` int(11) NOT NULL,
  `stocker` int(11) NOT NULL
) ENGINE=InnoDB  DEFAULT CHARSET=latin1 AUTO_INCREMENT=6 ;
-- Table structure for table `tag`
CREATE TABLE IF NOT EXISTS `tag` (
`Tag_Id` int(11) NOT NULL,
  `Tag_Code` varchar(20) NOT NULL,
  `Status` varchar(20) NOT NULL,
  `RequestStatus` varchar(10) NOT NULL,
  `DateIn` date NOT NULL,
  `TimeIn` time NOT NULL,
  `DateOut` date NOT NULL,
  `TimeOut` time NOT NULL,
  `fk_ItemCode` int(11) NOT NULL
) ENGINE=InnoDB  DEFAULT CHARSET=latin1 AUTO_INCREMENT=7 ;
```

```sql
CREATE TABLE IF NOT EXISTS `user` (
`id` int(11) NOT NULL,
  `username` varchar(100) NOT NULL,
  `password` varchar(100) NOT NULL,
  `FullName` varchar(20) NOT NULL,
  `Age` int(10) NOT NULL,
  `Gender` varchar(10) NOT NULL,
  `MobileNo` varchar(30) NOT NULL,
  `email` varchar(30) NOT NULL,
  `Department` varchar(20) NOT NULL,
  `Date` date NOT NULL,
  `AccessLevel` int(11) NOT NULL
) ENGINE=MyISAM  DEFAULT CHARSET=latin1 AUTO_INCREMENT=26 ;
```

Appendix 7: Questionnaire for system validation

RESEARCH ABOUT FINDING RADIO FREQUENCY IDENTIFICATION BASED DRUG MANAGEMENT AND MONITORING SYSTEM FOR PUBLIC HOSPITALS IN TANZANIA.

NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY

QUESTIONAIRE

Introduction

I am Prisila Ishabakaki, a Masters Candidate from NM-AIST, Arusha. I am currently doing research on developing the Radio Frequency identification based Drug Management and Monitoring System, case of Public hospitals in Tanzania. This questionnaire is aimed at validating the developed system by exposing users to the system and gives us the feedback by filling this questionnaire.

Questionnaire number: _____Date: _____

Hospital Name: _____

A. Respondent Information

Name: _____

Position:

Nurse: ☐ Doctor: ☐ Pharmacist: ☐ IT expert: ☐

Gender: Male: ☐ Female: ☐

B. Information about system

Please indicate the level of agreement on the following statements using the scale provided

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
The system satisfies requirements					
It is easy to access the information that you need from the system					
I found that the system will solve the problem					
I found the technology used very helpful					
I found that the system is easy to use.					