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Radio Frequency Identification based Drug Management and Monitoring System: A Case of Public Hospitals in Tanzania,

Review Paper

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***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 paper focuses on reviewing the current situation at the hospitals to identify loopholes causing these problems and later suggests the solution based on RFID to counteract the challenges. The case study methodology is used where 5 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.**

Keywords: RFID, UHF Radio Frequency, Drug management and monitoring, public hospital

I. 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 [1]. It utilizes electromagnetic waves for transmitting and receiving information stored in a tag to or from a reader [2]. A typical RFID system is made of at least three components: the radio frequency 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 [3].

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 [4]. Another reported case [4] revealed that some medicines meant for public hospitals have been diverted to private hospitals and pharmacies. Our 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 [5]. 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 channeled from the public

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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.

The rest of this paper is organized as follows: Section II covers overview of the RFID technology and its potential in enhancing information management in the health sector, Sections III and IV present reviews on the RFID technology basics and various research work done to counteract the hospital pharmacy challenges and their limitations respectively. Section V explains the proposed solution to the challenges facing pharmacy information management in hospitals, while Section VI concludes the paper.

II. Overview of the RFID Technology

RFID is a generic technology that uses radio waves to identify objects [6]. 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 [7], [8]. 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 [9]–[11].

A. 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 [12]. 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 [13]. 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.

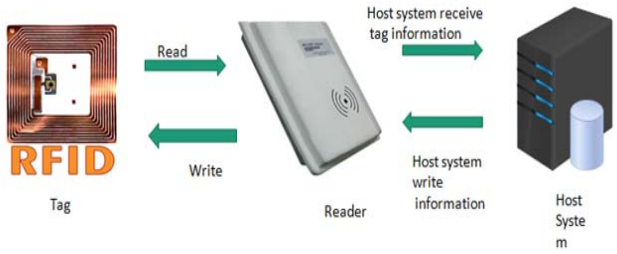

Figure 1: RFID System components

B. RFID Tagging Levels

The RFID tag is placed at the item for identification. Level of tagging depends on the application. The RFID tagging can essentially happen at three granularity levels. First, in supply chain the RFID tagging can take place at the pallet level, where the tag is attached to a pallet. In this case, the tag ID is programmed into the tag and attached on the pallet when the pallet is ready for shipment. Typically, the tag ID is cross-referenced to a list of inventory on the pallet and the purchase order. Once the shipment arrives at its destination, the cross-referencing of the tag ID can be done again to the database record containing the pallet information. The second level of granularity is case level tagging, in which the tag is attached to the case. The tag typically cross references information for the purchase order and inventory. The case level tagging has a primary advantage over pallet-level tagging, which is that

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more detailed tracking can be done. Case-level tagging allows for full inventory visibility as the inventory can be moved in case quantities. The automatic reporting of case counts means that case level tagging saves labor time and it makes manual case counting unnecessary.

Thirdly, item level tagging is where the tags are on the packaging of the items. The tags are attached to each product item during the manufacturer's packaging. Item level tagging provides the highest visible granularity. Depending on the RFID application environment, tagging can be at item level, case level or pallet level. In this intended application, the best tagging position will be at the case level since the item level and the distribution at pharmacy store is basically through carton boxes. And this will also reduce the tag cost as item level tagging is the costliest solution [12]. However, the cost of RFID tags was expected to be 5 cents by 2007 [14]. According to RFID journal, the volume, amount of memory on the tag and the packaging determines the cost of cost tag; thus this cost would much lower for high volume requirement [15].

C. The Potential of RFID Technology in the 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 [16] [17], and Taiwan [18] [19]. In our review, we found that [13] 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 [18], 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 [14] 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.

III. Current Drug Management issues in Public HospitaLS in Tanzania

The significant cost of purchasing and storing pharmaceutical products and their respective control requirements largely contributes to the healthcare industry costs [15]. Although the health industry is seen as one 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. 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 [5] 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 [16] 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.

IV. 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

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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.

A. *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 [15] 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 revel 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 [17][10][18][19]. The RFID based anti-counterfeit drug tracking system is designed to provide a drug verification mechanism. Figure 8 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.

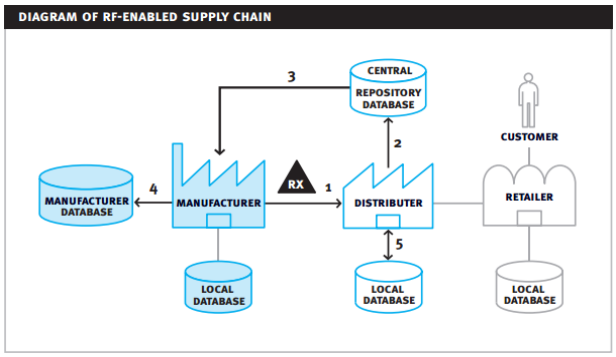

Figure 2: RFID enabled pharmaceutical supply chain [17]

B. *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 [20]. The major challenge on the effectiveness of this system is that the remote health centers 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 center 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.

C. *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

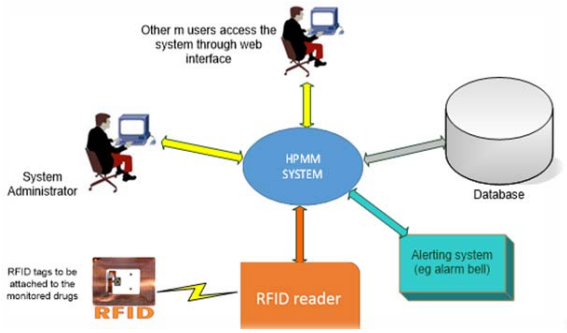

Figure 3: Proposed system architecture

health care provision [21]. Study by [22] 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 [23] 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.

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V. Proposed Drug Monitoring and Management 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 [2]. Receiving, storing, sorting, and shipping processes will all benefit from this wireless technology and become more efficient and effective [24]. Our proposed system intends to 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 to tag the drug 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. Figure 3 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 [9]. This study investigated the use of RFID in healthcare service delivery, especially 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.

VI. 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 proposed system intends to be of low cost by utilizing passive Ultra High Frequency 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.

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