RFID-Based Information System for Preventing Medical Errors

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Abstract

A report by the Institute of Medicine of the National Academy of Sciences estimates that as many as 98,000 people die in U.S. hospitals each year because of medical errors. In this project, we propose an innovative IT-based approach to prevent errors in various medical processes by utilizing advances in Radio Frequency Identification (RFID) and wireless communications. The goal of the study is to perform an in-depth study of existing RFID technologies for patient care in medical facilities. In the paper, a new system architecture that integrates various wireless technologies such as RFID and Wi-Fi was proposed. In the pilot study, *we primarily focused on the limitations and shortcomings of passive RFID technologies in medical settings. Our experimental results show the reliability challenge in the current passive EPC Gen 2 RFID systems for use in a dynamic medical environment.*

1. Introduction

One of the defining trends of the 1990's was the explosive growth of mobile devices and wireless technologies. However, the penetration of these technologies into a number of domains has been limited. One of the areas in which such integration has been particularly slow is the medical domain. This can be attributed to the perceived dearth of sufficient reliability, security, and performance in new technologies. This, in turn, has prevented high performance wireless networks from replacing traditional networks in critical medical applications.

For many years, critical medical information has been transmitted with traditional methods such as paper, medical charts and voice communications. This has proven to be labor intensive and prone to human errors. A related study estimated that as many as 98,000 people die in the U.S. hospitals each year due to medical errors [10]. The study also indicated that the number of casualties caused by medical errors can be substantially reduced by a system that provides medical personnel with accurate information. For example, a wireless network can be deployed for detecting medical errors while administering medication to patients. This can be achieved by having each patient wear a wireless tag that carries private medical information which helps avoid medication errors.

In this paper, we address one of the most important problems in medical applications: everyday, commonplace medical errors that are responsible for severe medical cases including fatal incidents. We introduce a comprehensive attempt to address this problem by utilizing recent advances in medical knowledge and IT technologies. We also develop a blood bag management system to prevent errors in blood transfusions. The rest of this paper is structured as follows: Section 2 surveys related work, Section 3 briefly discusses the architecture of the proposed medical error prevention system, and Section 4 presents the developed passive blood bag management system and the results of our experimental study. Finally, concluding remarks are given in Section 5.

2. Related Works

A Radio Frequency Identification (RFID) is a short-range wireless technology one technology which has great potential in varied fields. It is an automatic identification mechanism with its main application in location and asset tracking. In hospitals, RFID tags can be planted on patients and medical staff to track their location within the medical facility. This technology can also be beneficial for short-term visitors as well as patients to be directed towards their destination such as the diagnostic center, doctor's clinic, and casualty ward in the hospital such that there is no delay especially in cases of emergency.

A RFID system comprises of a RFID Reader, RFID tags, a communication infrastructure. RFID tags are usually affixed to the objects of which the information is to be captured or manipulated, and they contain a unique identifier which may optionally hold the information about the objects. RFID tags in particular contain two parts: the first one is an integrated circuit for storing and processing information, modulating and demodulating radio frequency signal; and the other part is the antenna for receiving and transmitting the signal. A RFID reader wirelessly communicates with a number of tags to capture the information of the object in which the tag is

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embedded. Besides, the RFID readers are capable of reading and writing the information stored in the tag.

Wireless tracking of mobile objects is a field that has been growing rapidly and steadily for several years, and there have been a number of studies investigating the development of RFID-based tracking systems [2,3,6,8,9,11,13,14,17,18]. Here, we review several wireless tracking systems available in the literature. In [7], Mike Ingamells et al. studied a methodology of tracking, validating, and managing probe cards using RFID, and A. R. Al-Ali et al. in [1] described the development of kid tracking system based on an active RFID technology. The proposed RFID system would allow us to monitor the location of "tagged kids" from a sufficiently large distance by implementing an application that reveals the position of a kid at anytime and anywhere in the coverage area.

In [5], an RFID based track and trace solution for supply chains was proposed by the research group at the Singapore Institute of Manufacturing Technology and Institute. The system stores the EPCglobal number in the RFID tags to identify a specific object as it moved through the supply chain, and captures all events to make them shareable among other participants in the supply chain. The Geographical Location Based RFID Tracking System introduced in [16] integrates a wireless sensor network and RFID technologies. Ningcong Xiao et al. [12] has proposed a localization system based on RFID and GIS for underground moving targets, the goal of this project was to develop an efficient and reliable equipment monitoring and control system for the mine business.

Despite the fact that RFID technology has brought a revolution in tracking and capturing objects, the privacy concerns have hindered the commercial implementation of it. Besides, the cost of the RFID tags and readers is also one of the factors behind it. In addition to that, research has shown that the technology is not matured enough to be implemented commercially because the tags are less than completely reliable [15]. However, we believe that it is just a matter of time because the evolution of RFID technology will address these issues in the near future, and RFID tags will be everywhere from your clothes, to the tires of your car.

3. Architecture of the Proposed Medical Error Prevention System

In this section, we propose a comprehensive IT-based approach to detect medical errors in various medical processes while supporting a high level of reliability, security and system compatibility. The system utilizes advances in Radio Frequency Identification (RFID), wireless communications, databases, and Graphical User Interfaces (GUIs). The proposed system innovates by incorporating the advances in IT with the advances in medical knowledge. The system is designed for a dynamic paradigm that allows incorporation of new discoveries in both IT and medical domains.

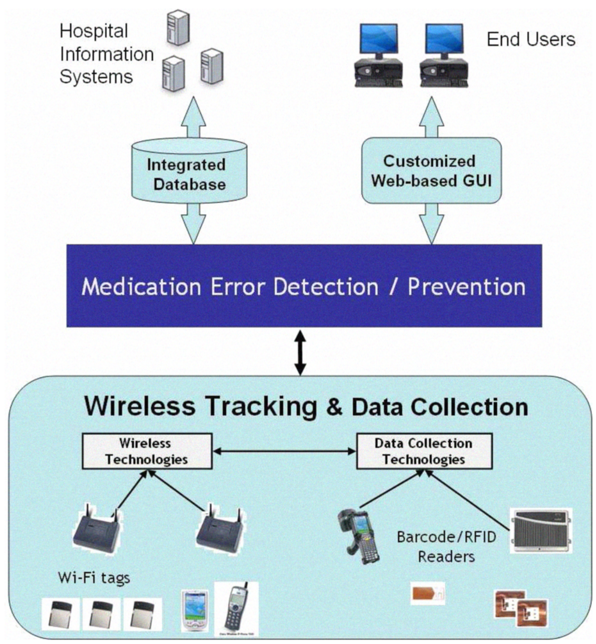

Figure 1: Architecture of the proposed system

The proposed architecture of medical error prevention system is shown in Figure 1. In order to achieve maximum modularity, the system is broken into several cooperative subsystems. At the base of the system, the flexible data collection and tracking module enables the system to integrate various state-of-the-art input devices such as barcode scanners, RFID, PDA's, cellular phones, laptops, and wireless sensors. Note that the proposed architecture is not tethered to current wireless technology restrictions. The flexibility of the system is derived from the capacity to absorb any data collection technology into the wireless tracking and data collection subsystem. The tracking module also gains flexibility through combining a wireless and wired infrastructure.

Building on the information gathered and collated by the tracking subsystem is the core of the system. The core consists of a flexible middleware, several monitoring applications, and data source interfaces. The proposed system also includes database interaction software that handles interfacing with individual medical databases. This software interface presents a unified database to the system that facilitates the detection of potentially harmful reactions. The interface is designed modularly, allowing components

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to be easily added, subtracted and updated from the system as necessary.

All authorized medical personnel can access the system via a sophisticated Graphical User Interface (GUI) which provides a common-sense Web interface that makes it easy to find assets and make everyday operations more effective and stress free.

4. Pilot Study: RFID-based Blood bag Management System

Blood management is a complex process that contains a number of manual steps, which can potentially introduce human errors. Recently, RFID tracking has also been a keen subject of interest in the health care industry since this technology has found a lot of potentials in critical medical scenarios like alerting the medical personnel in case a wrong blood-bag is delivered to the operating room during surgery or treatment. This section discusses a pilot study on the blood transfusion management system which integrates the RFID technology to alert an authorized medical staff in case of a blood type mismatch.

In the proposed system, when a patient is admitted, a nurse gives him/her an RFID wristband, so that the patient can be identified individually. The nurse also has his/her identification tag, and every medical treatment will be logged in the system. The proposed RFID system makes the entire process of blood transfusions absolutely safe. The staff in the transfusion center would be able to receive real-time information from the patient's beds about the transfusions performed and to monitor the status of delivered blood bags. The main distinction of the proposed model for other RFID-based systems is that it is based on the passive RFID tags and it does not require any human intervention. Whenever the RFID tags are within the read range of a given RFID reader, the reader can automatically capture the identity of the blood bag, as well as the identity of the employee who is moving into the room.

A testbed comprising of RFID readers, RFID tags, a wireless network, a server and a piece of application software was incorporated together to model a scenario and how such a system could be used to detect the blood mismatch was studied. In this study, we also address critical and potential errors in the blood transfusion and handling process: the possibility of administering the wrong blood to a patient. The system uses UHF-RFID systems to address the sources of human errors all the way from the selection of bag to the completion of a transfusion. The configuration of our testbad as follows: Symbol XR450 Fixed RFID Reader along with two high-performance AN400 RFID Antennas[1], and a number of single-dipole EPC Class 1 Gen 2 tags printed by a Zebra R/Xi series printer.

Figure 2 gives a pictorial description of the testbed deployed in our lab. The RFID reader (module 1 in Fig. 2) is located at the center of the ceiling and connected to two RFID antennas that capture the location of RFID tags with high accuracy and efficiency. The module 2 in the figure denotes the arrangement of two antennas in the testbed. The module 3 and module 7 represent the wireless access point connected to both the computer and the RFID reader. RFID reader has its own IP-address so that the server can communicate with it via the wireless access point. The module 4 represents a patient who has an RFID wrist band that stores the patient's unique ID and some additional medical information as needed. The module 5 denotes the configuration of multiple blood bags in the Blood Facility Room (BFR). Each blood bag in the blood facility room has a UHF RFID tag attached to it, which contains the information about the blood group that it is associated with. The module 6 denotes a server with a piece of software installed in it which wirelessly communicates with the RFID readers to collect the information about the objects and present to the users in a human intelligible form.

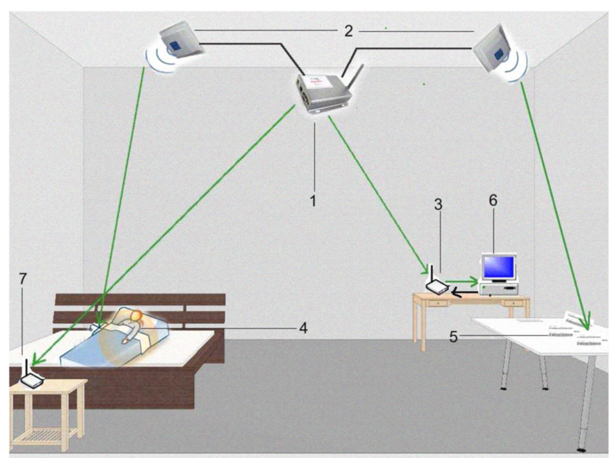

Figure 2: A pictorial illustration of the Testbed

A scenario was modeled, in which a collection of blood bags were placed in the BFR Room (module 5, right side of the testbed in Fig. 2) with different blood groups embedded in their respective tags. A patient was placed in the Patient's Room (left side of the testbed in Fig. 2) with an RFID wristband which contains information about his blood group. The RFID antenna near the Patient room periodically polls the patient tag. After detecting the RFID tag, the

[1] http://www.motorola.com/Business/US-EN/Business+Product+and+Services/RFID

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reader wirelessly sends the location of the patient tag to the server application in the module 6. The authorized medical staff can retrieve the location of the patient as needed. An RFID tag is also attached to each blood bag and kept in the blood bag facility room. The tags attached to the blood bags are also continuously tracked and monitored by the system in the similar fashion.

When a medical personnel enters the patient's room, the RFID tags attached to the medical staff is captured by the reader, and the system logs the details of each individual activity of the staff like- 'Who deliver which blood bag to which room at what time?'. Upon the blood mismatch, a warning alert sound was played accompanied by a warning display as well.

Another benefit of tagging the blood bag with an RFID is that the system can inform medical staff when the inventory of the particular blood type in the blood bank drops to a certain level. Also, it would be possible for an authorized medical staff to monitor the exposure period of the blood bag into the outside environment. This would help prevent a spoiled blood bag from being used.

4.1 Reliability of Passive RFID Systems

A passive RFID tag has no battery but instead derives its power from the reader. These tags are smaller, cheap, and have a long life, however they have their own set of drawbacks. One of main problems is the reliability of reading passive tags. Although the tags can be read if the antennae are pointer directly at the label, it has also been observed that, if blood bags aren't stacked properly or if one bag is blocking the line of sight of the reader and another tag, the tag will often not be captured. The purpose of this experimental study is to investigate and test the performance and reliability of reading passive UHF RFID tags. A number of experiments were conducted under various configurations to test the reliability of the RFID system based upon a number of factors such as the number of RFID tags stacked together, the distance between the tag and antenna, and the speed of movement.

In the first experiment, we studied the relation between the reliability of the RFID system and the number of passive tags. The average distance between the reader and passive tags is between 3- 4 meters. The reliability was measured in terms of the number of tags captured by the reader. Figure 3 plots the number of captures tags among 10, 25, and 50 tags, and Table 1 summarizes the results. For the scenario with 10 passive tags, the passive RFID system is quite reliable. The reader captures about 9 tags on average. However, with 25 or 50 tags, the reliability drops considerably. This is because, as the number of tags increases, the inter-tag distance decreases and the tags interfere with each other.

Fig 3: Number of Tags Captured Vs Time

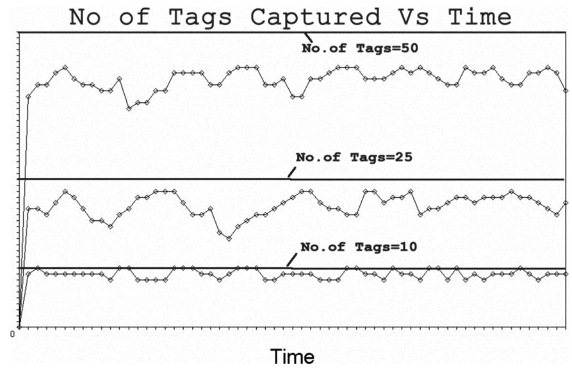

Table 1: Number of Tags Captured

	Number of Tags Captured			Avg. Reading Rates
	Maximum	Minimum	Average	
10 Tags	10	8	9.1	91%
25 Tags	23	15	21.3	85%
50 Tags	44	37	41.8	83.6%

The second experimental scenario measured the reliability of the RFID system with various distances between the RFID antenna and tags. Measurements were taken by putting the tags at the same horizontal level of the antenna at a distance between 1 m and 8 m. Figure 4 shows the average numbers of captured tags for 60 seconds.

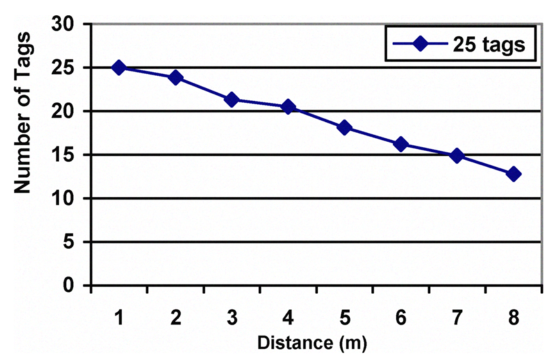

Figure 4: Reliability vs. Distance

In the last set of our experiments, we studied the impact of the speed of movement on the reliability. Three different speeds of movement were tested. The first one is approximately 1.35 m/sec., which is corresponding to the average walking speed of a man, the second one is around 3.5 m/sec., which is similar to

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the slow running speed of a man, and the last one is about 5 m/sec., which is the fast running speed of a man. Although, for a small number of tags, the speed of movement did not make a visible difference in the reliability, we observed some noticeable changes with 25 tags, as the speed of movement increases. The average reliability of the RFID readers with 25 tags is shown in Table 2.

Table 2: Reliability vs. Speed

Speed of movement	Reliability of the reader
1.35 m/sec	81.7%
3.5 m/sec	76.4%
5 m/sec	74.6

5. Conclusions

RFID can provide a number of benefits to the healthcare industry. Accurate visibility data allows the hospital to improve patient care while simultaneously cutting cost and improving utilization. Hospitals will gain directly from the reduction of equipment leases/purchases costs and maintenance expenses by improving asset utilization and increasing operation capacity. In this paper, we presented a compelling argument that healthcare can benefit significantly from integrating various new IT advancements with wireless technologies. A new system architecture was proposed by integrating various wireless technologies such as RFID and Wi-Fi.

As a pilot study, we developed a passive RFID-based blood transfusion management system that prevents blood transfusion-related problems such as given a wrong blood type during blood transfusion. The proposed system represents an important step towards the goal of improving healthcare by utilizing recent advances in Information Technologies. The results of our experimental results clearly demonstrate the reliability challenge in current passive UHF Gen 2 tags for use in a dynamic medical environment where hundreds or even thousands of patients and support staff are moving through a hospital with a number of RFID tags attached to operating tools, medical equipment, drugs and more. As a future work, we will study how to improve the reliability of passive RFID systems through analytical and experimental studies.

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