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Real-time location and inpatient care systems based on passive RFID

Pablo Najera *, Javier Lopez, Rodrigo Roman

Computer Science Department, University of Malaga, Campus de Teatinos 29071, Spain

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ABSTRACT

RFID technology meets identification and tracking requirements in healthcare environments with potential to speed up and increase reliability of involved processes. Due to this, high expectations for this integration have emerged, but hospital and medical centers interested in adoption of RFID technology require prior knowledge on how to squeeze RFID capabilities, real expectations and current challenges. In this paper, we show our lab tested solutions in two specific healthcare scenarios. On the one hand, we analyze the case of a medical equipment tracking system for healthcare facilities enabling both real-time location and theft prevention. Worth-noting aspects such as possible EMI interferences, technology selection and management of RFID data from hospital information system are analyzed. Lab testing of system reliability based on passive UHF RFID is provided for this case. On the other hand, we analyze and provide a solution for care and control of patients in a hospital based on passive HF RFID with the result of a fully functional demonstrator. Our prototype squeezes RFID features in order to provide a backup data source from patient's wristband. It also provides an offline working mode aiming to increase application reliability under network fail down and therefore, improving patient's safety. Considerations regarding lessons learned and challenges faced are exposed.

1. Introduction

Radio frequency identification (RFID) technology enables a seamless link between any physical tagged entity and the business information infrastructure providing lightweight computational and communication capabilities. Due to this, RFID is receiving considerable attention and is considered to be the quintessential pervasive computing technology (Rieback et al., 2006) and the next wave of the IT revolution (Tzeng et al., 2008). As a consequence of the identification, tracking and tracing nature of RFID, organizations can acquire detailed data on property and location information that increases their ability to monitor the history, location and changing states of mobile wirelessly scanned entities. The adoption of RFID technology is being embraced in a wide range of applications; including retail industry, supply chain management, anti-counterfeiting, security and transit systems.

In recent years, high expectations for the integration of RFID in healthcare scenarios have emerged. By exploiting RFID characteristics and possibilities, this technology is considered to have the potential to enable better service to patients and end customers while underutilization of equipment and mistakes in patients' treatment can be minimized. A proper management of RFID technology may improve the quality of medical processes making patient care more reliable and consistent, lowering costs and providing the tools to properly manage and trace material and information flows (Kumar et al., 2009). In spite of recent research interest in the healthcare environment, RFID adoption is still in its infancy and a larger number of experiences need to be collected and studied (Tzeng et al., 2008) in order to better understand how to exploit RFID capabilities.

A highly concerning healthcare application is real-time tracking and location of medical assets. Medical centers have to face continuous losses of high-value assets each year (Bacheldor, 2007). Furthermore, equipment whereabouts are frequently unknown. Medical staff needs to sacrifice patient-care to find assets locations. Moreover, unneeded equipment is acquired or rented while the existing one remains underutilized. In this paper, our first case study focuses on this particular scenario. Our solution for real-time tracking of medical devices in a healthcare center is presented which consider anti-theft capabilities and partial automatic inventory. Beyond the presentation of our approach, several worth-noting and commonly overlooked aspects in the development of the solution are discussed such as electromagnetic interferences of RFID in medical equipment, RFID branch technology selection and management of the data generated by the RFID infrastructure from the healthcare information system. The real-time tracking solution is based on passive UHF RFID technology, a field where few previous results are available in literature. We measured the performance and reliability of the system in a laboratory experimental environment and the conclusions of our tests are provided.

* Corresponding author.
E-mail addresses: najera@lcc.uma.es (P. Najera), jlm@lcc.uma.es (J. Lopez), roman@lcc.uma.es (R. Roman).

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In a different perspective, inpatient care and safety can be greatly enhanced by means of RFID technology. Every step in the patient care process can be seamlessly integrated in the information system preventing manual input mistakes, assisting caregivers in patient treatment and enabling in-depth analysis of medical staff workload to increase efficiency of personnel allocation. But current inpatient care pilots do not make the most out of RFID capabilities. In the common approach, RFID unique identification codes are used as license plates to query and update the backend information system. However, the limited storage resources in staff and patient RFID tags can be exploited as a complementary data source to enhance patient safety and overall system reliability in determined circumstances. In our second case study, the latter approach is adopted where a prototype of a passive HF RFID patient care solution has been implemented. Further than introducing our solution, selected lessons learned and challenges found during the prototype development are discussed.

The remaining of this paper is organized as follows. In Section 2 we present an overview of current applications of RFID in the healthcare environment and existing experiences and pilots gathering their first results and situation compared to our case studies. In Section 3, our first case study is focused on real-time tracking of medical assets. Discussion on relevant development aspects and results of our passive UHF RFID lab experiments are provided. In Section 4, our second case study related to a patient care and control solution for medical facilities is presented. Our approach of exploiting RFID tags as a secondary data source for critical data, as well as lessons learned and discovered challenges are discussed. Section 5 concludes the paper.

2. RFID in ubiquitous healthcare environments

In these scenarios, every single process is critical and must be addressed with the highest level of precaution and inspection to minimize risks and improve patients' safety. In order to achieve this reliability level, implementation of RFID technology may be crucial to accomplish tasks as: ensuring right identification of each patient and his corresponding medical data anywhere in the hospital, guarantying appropriate actions are granted to the right persons (drugs administration, surgical procedures,) regardless the time and place, identifying lab samples (blood, urine, exudations, biopsies, etc), verifying authenticity and origin of drugs and checking their status and expiry dates while they are moved among different departments and sections, etc. Additionally, inventory control of medical equipment or theft prevention of devices and medical utensils is also susceptible to be accomplished ubiquitously by means of RFID technology. In order to control location of medical devices, tracking equipment in real-time by means of RFID technology would allow finding and accessing required material anytime (but in a shorter time period) and anywhere.

Nowadays, there are initiatives and pilot projects that cover these needs in the healthcare environment:

Identification of blood containers: Productivity and safety of the blood product supply chain can be greatly enhanced by means of RFID. In EPCGlobal (2005), authors assessed tag readability and performance in this environment, as well as tested temperature and biological effects of RF energy on blood products. They concluded that HF RFID performs adequately and safely for blood products, RFID has an impact in productivity and quality gains due to less process errors, better inventory management and avoidance of product discards. Moreover, regarding return on investment, authors calculated a pay-back period of four years for a mid-size blood center collecting 225.000 units/year.

Further practical implementation in the area includes a pilot in four Italian hospitals (Swedberg, 2008) where EPC Gen 2 RFID technology has been implemented to track all steps of the transfusion process from taking blood samples to the final blood transfusion. As an output of this practical implementation, human mistakes which could turn into lethal results were dramatically reduced in the processes of drawing donated blood, transporting it and administering it to a patient, reporting an error reduction by 100 percent, as well as work-reduction times.

Identification of drugs: The U.S. Food and Drug Administration (2004) report recommended the use of RFID technology to fight the chronic and expensive problems of drugs counterfeiting. Companies such as Exagera Technologies with his eShepert system that combines RFID and WiFi technology are supporting this goal. Sun Microsystems presented his own solution on this topic called "RFID Industry Solution for Drug Authentication" (Sun, 2009) which provides lightweight EPC-based pharmaceutical authentication comparing EPC data on the RFID tags with available data in a central repository, as well as a supply chain-wide pedigree authentication. RFID has also been applied to anticancer drug management system (Kim et al., 2007) demonstrating its clinical usability. From a different perspective, from 380,000 to 450,000 preventable adverse drug events occur each year in the United States. Due to this, RFID has been integrated in the inpatient medication administration system (ETSI, 2007) reengineering the inpatient medication processes in order to decrease the risk of these adverse events.

Tracking and control of medical equipment: Several pilots based on active RFID technology have taken place with the purpose of tracking medical equipment inside a healthcare facility. In particular, a pilot in San Diego Medical Center (Sullivan, 2009) tracking a wide range of assets (e.g. IV pumps, SCDs, crash carts, gurneys, …) have demonstrated return of investment: infusion pump rental fees were reduced from 8000 USD month rental prior to the pilot to a stabilized 2300 USD/month during the pilot. Considering the complete range of tracked assets saving were estimated to approximately 450,000$ for 2008. Regarding the use of passive RFID technology for tracking medical equipment, very few test results have been published. To the best of our knowledge, the most similar approach to our first study case was the passive UHF RFID trial which took place in the Wright Patterson Medical Center. The results of that trial (Alien, 2007) showed a 85% accuracy rate in location of medical equipment. However, the report was published by a division of a known RFID vendor and they accuracy tests did not specify adverse conditions as the ones exposed in our prototype.

Tracking of medical staff and patients: As a consequence of Severe Acute Respiratory Syndrome (SARS) where 37 patients died and part of the medical personnel was also infected the Ministry of Economic Affairs in Taiwan granted research funds to support the implementation of RFID in healthcare. The experience of five early adopters hospitals has been presented (Tzeng et al., 2008). Authors conclude that future empirical research will be helpful in validating their propositions requiring a bigger number of experiences collected and studied. However they consider RFID useful in enhancing patient care and analyzing workload of medical staff.

A patient- and employee-tracking system (Swedberg, 2009c) based on active 433 MHz RFID technology is currently being tested at Massachusetts General Hospital. The pilot gathers information regarding patient flow and bottlenecks with the expected outcome of gaining a better understanding of how the clinical system behaves. It will potentially reveal aspects such as how long a patient sat alone in an examining room or whether the medical personnel spent the proper time with the patient. An experience of tracking elderly patients suffering from