A Mobile Patient Monitoring System Using RFID

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Abstract: In the last decade, Radio Frequency Identification (RFID) has become popular in so many fields from military to industry applications. RFID tags have been embedded into many various products especially in logistics sector. A tag stores individual information of its attached object and an RFID reader communicates with the tag in radio frequencies to identify the object. This object to be monitored may also be a human. In our work, RFID technology is applied in health care systems. The system supports wireless mobile communication between the RFID tags and readers. Each patient available in the system is inherently mobile and wears a bracelet integrated with a unique tag, and the readers are mobile PDA devices each including a wireless RFID reader card. The proposed application can be used to identify and monitor the patients.

Key–Words: Patient monitoring system, RFID tag, RFID reader, RFID communication standards

1 Introduction

Radio Frequency Identification (RFID) is a communication technology which allows for defining some unique characteristics of an object or a living being, usually its identification information, by relating it to a numeric serial number within a tag, and ensures that this number is conveyed by using radio waves. RFID provides a communication infrastructure at the radio frequencies between a special tag and reader device that can detect the tag, and allows for establishing communication between devices within the system without any physical contact, or even without seeing each other. In this regard, communication comfort can be provided with RFID technologies in environments where technologies which require that the devices must exactly see each other, like the case in barcode systems, cannot be used.

One common disadvantage of inexpensive RFID systems is that the computing resources of main elements which support RFID technology are limited [1]. However, RFID tags have various structures, and according to need, memory limitations can be overcome by using systems where RFID tags can also be used as storage of electronic data, and different information on the objects to which they are related can be written and read. Moreover, as allowed by costing considerations, the power constraint may not be an issue when the data obtained by using RFID systems are processed within information systems with high resources.

In recent years, RFID technologies are used in a number of fields including military, logistics, education, production, security, and health. For these different areas, passports with embedded RFID-tagged chips with identification purposes [2], RFID systems used by locating tags with antennas in library books, systems with tags for tracking objects and human beings, automated processes used for product identification and monitoring in stock warehouses, authorized entry and exit systems to and from certain territories, applications in hypermarkets in shopping industry, and several similar applications can be given as examples. Due to its low cost, RFID technology is becoming widespread throughout the global world.

There are different applications of using RFID technologies in health industry [3, 4]. In addition, member communities of RFID in Healthcare Consortium [5] assert that wireless Technologies should be used in an efficient and safe manner in health care industry. When the significance of human health is considered, it is necessary that information is transferred in a correct and fast manner to rapidly perform the first aid to the patient. By using RFID technologies as integrated with patient information systems, it will easily be possible to identify patients with the RFID tags that they carry and to rapidly process the previously recorded information about that patient. Based on this reasonable motivation, an RFID-supported patient monitoring system is designed. The proposed design and the implementation of the system are dissected in this paper.

In this attempt, the objective is to transfer the identification information of patients who use RFID tags in a safe manner and preserve them in a digital environment so that communication between authorized doctors and patients could be improved by means of RFID technology. In this regard, another purpose is to present a running solution example with RFID applications in systems which perform patient monitoring.

The rest of the paper is organized as follows: Section 2 surveys the main features of RFID technology. Section 3 presents the design and the implementation details of our patient monitoring system. Finally Section 4 concludes the paper.

2 RFID Communication

In this section, main components of RFID communication and standards used in communication are presented and the topology used for RFID communication is explained. In addition, the privacy issue, which is seen as an important social fact in realizing RFID based applications, is also indicated.

2.1 RFID Tags

As a general category, RFID technologies can be seen as a kind of Auto-ID [6] technology. MIT-centered Auto-ID laboratories [7] are developing network infrastructures similar to Internet so as to monitor in global environment the products which carry Electronic Product Code (EPC) [8]. In this regard, attempt is made to develop RFID networks along with EPC-inclusive RFID tags. Devices which are called RFID tags basically include a microchip which includes EPC code in its memory and an antenna. They can be in a number of shapes and they can be embedded on products in various ways. For example, an RFID-tagged bracelet, which is considered for making the patients wear, as explained in Section 3, is shown in Fig. 1.

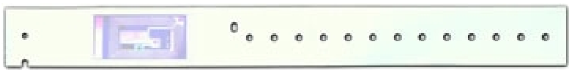

Figure 1: An example bracelet with RFID tag

EPC is used for identifying the object on which it is embedded via RFID tag by giving it a serial number. An EPC at Auto-ID standards is a piece of data with 94 bits, where the first 8 bits are title, following 28 bits are manufacturer of the product, the next 24 bits are the type of the product, and the last 36 bits are the serial number which identifies the product (or object) [9]. This piece of information which is included in the memory of RFID tag can be read by an RFID reader device via radio communication through the antenna in the tag.

Although they can be defined in different standards according to their features, there are basically 3 types of RFID tags in terms of the characteristics used in applications; namely active, passive and semi-passive. Active tags can send signals to RFID readers through a power source like a battery that is embedded in them. Passive tags do not have any power source and they reflect the data in their memory with the power created in the tag with the signal sent by RFID reader; therefore, they are in passive state when there are no readers in the environment. Semi-passive tags are active when sending signals through the use of their embedded power source, but they are passive during reading stage and they reflect the information in their memory with the energy created in the tag with the signal sent by reader.

2.2 RFID Communication Standards

Previously, RFID tags were used by being supported by physical interfaces with many different standards. Then EPCglobal [8], which played an active role in determining a common standard for RFID tags, categorized them into classes and generations in numeric manner. In this regard, Class 1 - Generation 2 standard [10] was approved by EPCglobal in 2004 for RFID readers and tags. This standard was organized by ISO as international ISO/IEC 18000-6 [11]. For RFID communication in several frequencies, EPCglobal standards are adopted as ISO/IEC 18000 standards. In Europe, RFID communication has been organized as ETSI EN 302 208 [12] by ETSI.

In Table 1, frequency intervals, tag reading distances, and data transfer rates in communication are shown for major RFID communication types which can be used at different frequencies according to these standards.

RFID	Low frequency	High frequency	Very high frequency
Frequency interval	125-134 KHz	13.56 MHz	433 MHz 865-956 MHz 2.45 GHz
Reading distance	<0.5 m	<1.5 m	<100 m
Data rate	<1 kbps	<25 kbps	<100 kbps

Table 1: RFID communication features [9]

2.3 Topology in RFID Systems

An application which takes the radio communication between related RFID tag, embedded to an object in order to identify it, and RFID reader, where several tags are read by using at least one RFID reader, can be made integrated in a number of systems so that the information in tags can be processed in an information system. In such RFID systems, basic components in the section where RFID communication is realized in application are readers and tags, and the topology in a network environment formed by them is generally in the shape of a star. In this structure, there is an environment where the reader is in the center and this device can communicate with the tags around it directly through one hop. If the distance between reader and tag is far such that communication cannot be established, all tags in the network can be reached by keeping the reader mobile.

On the other side, by using multiple readers, a tree topology can be established where the devices, to which readers are connected, are interconnected through a wireless or wired line and each reader in the tree transfers the information that they read in their environment to the parent reader in the tree; thus, all information are transferred to the reader at the root of the tree and the root is used as the exit point of the knot. By this way, all information is transferred from this root node to an information system. However, when computation resources of the nodes, which include reader elements, are powerful there may not usually be needed such a structure, because the first node that include a reader may already have the ability to communicate the world outside the network. Structures similar to tree topology where clustering is made and cluster leaders are communicated, or all nodes are communicated without any clustering can be needed in cases where devices that include reader elements are very small in size and have limited resources, for example when an attempt is made to integrate Wireless Sensor Networks and RFID systems.

In an RFID system used in either star or tree topology, one-hop data communication between tag and reader can be considered as a graph, which consists of two vertices as different types of nodes, and one edge as a directed communication between those nodes, and the communication infrastructure of the system can be designed such.

2.4 Privacy in RFID Applications

Today, security is a matter which should be examined in all kinds of new technologies. In terms of data security, privacy concept means hiding personal information or not displaying any individual information. In monitoring and tracking applications where RFID tags are embedded to living beings, for example when patients are monitored through RFID-tagged bracelets, if the communication between tags and readers is performed in wireless environment and without any encryption, people with ill-intentions can have access to the system. If the transferred information is private, this act can constitute a violation of privacy. In case the transferred information is only an EPC code, there can be an adversary in the environment with illegitimate access to the computer where this EPC code and relevant information is preserved. In addition, wireless environment naturally includes a number of security threats.

For such above reasons, in RFID applications which can be the target of social reactions, privacy may not be totally protected but systems which allow maximum security can be preferred. The first solution which comes to the mind is encrypting the data communication. In addition, authentication might be considered as well. Due to cost considerations, additional procedures might be chosen depending on the importance of the application.

3 Patient Monitoring System with RFID

In this study, an RFID-based patient-monitoring system has been considered. This system, which can be created by integrating a probable patient information system and proposed RFID application, is seen as a proper solution in cases when doctors want to have fast and automatic access to patient information and in particular when patients are not able to establish healthy communication. From this point on, after the information of patients who come to the hospital is recorded in the system, a bracelet is worn by the patients which includes an RFID tag, and the relevant doctor who is assigned to the patients can read the tag in the bracelets with authorized access to an RFID card reader-supported PDA device, and, as a result of this definition, PDA device can reach the server and withdraw relevant health information from database and submit them to the doctor.

3.1 Infrastructure of the System

In Fig. 2, communication infrastructure of the designed system is shown. In this system, network structure of the RFID application was envisaged to have star topology and using passive tags the radio frequency communication can be seen as a single directed graph. The base server of the system may be connected to many of different local stars, each including a mobile reader and a number of tags. The wireless reader cards are integrated to mobile PDA devices, and the tags are embedded into bracelets. Taking into consideration the issue of privacy in RFID applications, it is decided to use symmetric encryption in data transfer to the server during the communication between PDA and the server so that the transferred tag information can be protected.

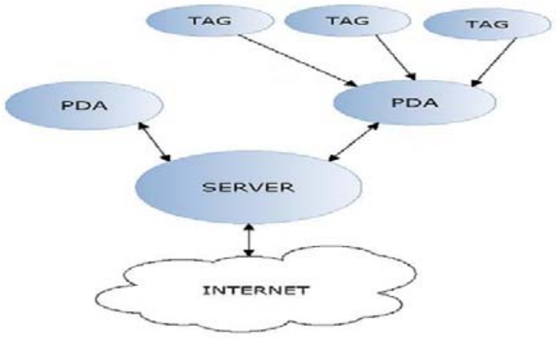

Figure 2: Communication infrastructure of the system

As a similar system model, in their work where they examined the possible attacks against applications performed by using Wireless Sensor Networks in health industry, Misic et al. [13] located sensor nodes to the patients in a patient room and pointed out the communication based on CSMA-CD protocol on IEEE 802.15.4 [14] data link layer standard in beacon effective mode between the leaders in clusters and the base station of the room. In their study [13], it is stated that the efforts to support devices in health industry at IEEE 1073 [15] as wireless communication, as regards the communication established by these devices within personal area, there is a tendency to support it as low data speed wireless personal area network protocol at IEEE 802.15.4 interface standard. In this regard, RFID devices can find themselves a place in IEEE 802.15.4 infrastructure since their frequency intervals can be supported and they can work in personal domain network environment. As a matter of fact, SGrfid [16], an IEEE work group, has been conducting examinations on standard effort at data link layer level so that RFID devices and sensor nodes can work in common applications.

SGrfid also discusses whether there is need for standardization by IEEE 802 in a sub-group. Taking this into consideration, in our application which we tried to conduct by using existing radio communication, no special IEEE 802 standard has been determined as a data link layer. As specific to our application, no additional amplifier antenna was used when reading RFID tags, and it is performed not within personal domain area but within the 10 cm distance between the reader and the tag. If required, it is believed that these parts can be modified later and an antenna can be added to the system or the system can be used as integrated with other systems in the same infrastructure; but that work has been excluded from this study.

3.2 Software Design of the System

Software design of the system mainly consists of the patient information system. Once tag information is obtained by RFID communication, they can be processed in the information system in the application. In the designed system, tasks of the persons in the patient monitoring system where these data are processed is depicted as a use-case diagram shown in Fig. 3.

The database tables which will be used in the software are designed by using the roles of the three basic actors shown in Fig. 3 as counseling (advisory), patient and health official (doctor). In this regard, as can be understood from Fig. 3, there are 7 main tables considered, 4 of which also include sub-tables.

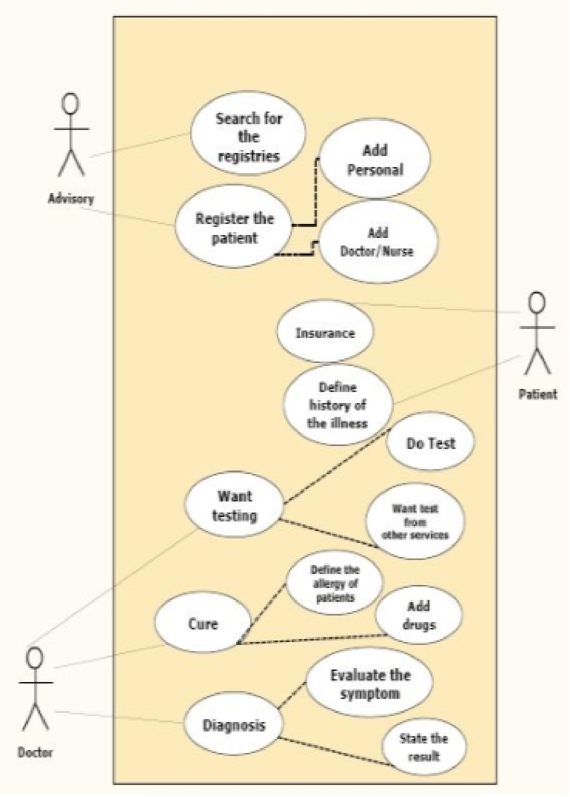

Figure 3: Use-case diagram based on the roles

Flow process operated in the inclusion of patients in the designed patient monitoring system is shown in Fig. 4. Before the patient is taken to the hospital, a file is opened which is related to the patient and the records of the patient are controlled. If the patient is recorded in the system, newly acquired information is updated in the database; otherwise, the patient is given an RFID-tagged bracelet and information related the unique tag number in this bracelet is recorded in the database. Then, the patient can be directed to the relevant health official.

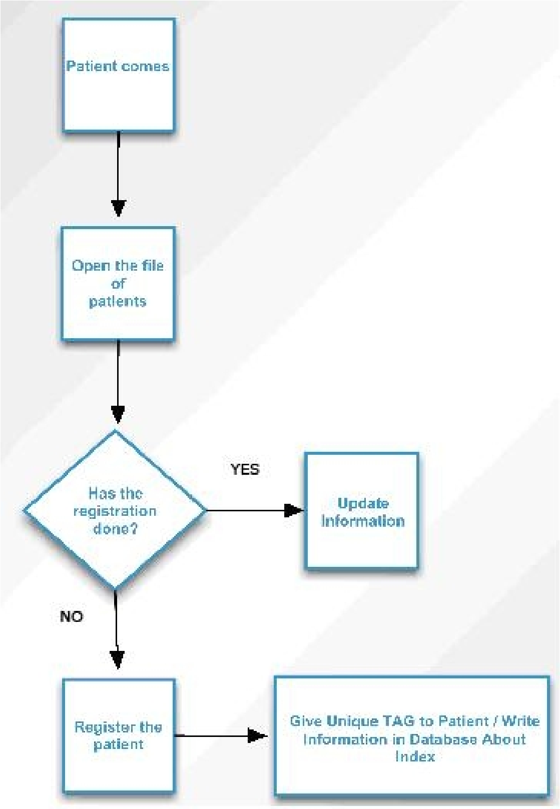
Patient comes
Open the file of patients
Has the registration done?
YES
Update Information
NO
Register the patient
Give Unique TAG to Patient / Write Information in Database About Index

Figure 4: The process of patient entrance into system

A sample process for the health official (or explicitly the doctor) using a PDA while checking-up a patient in monitoring system is illustrated in Fig. 5. The doctor first gets the related RFID tag information from bracelet of the patient by a PDA. After having examined the patient, the doctor records the related information updates within the PDA. Finally the updates are saved in the database server through the background communication between the PDA and the server.

3.3 Implementation

Software development technologies used in realization of the system are basically MS Visual Basic.NET, MS Visual Studio 2005 C#, Developer Express 2007, MS SQL Server 2005, and SmartDraw 2008 programs. It was aimed that the chosen software tools would provide interfaces which could make things easier for the programmer and be user-friendly in terms of the server.

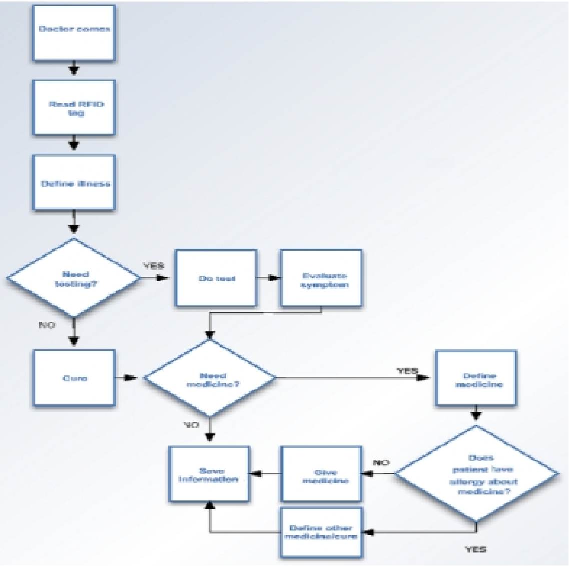

Figure 5: Sample use of system by a doctor owning a PDA

Syscan RFID tag reader card which is inserted to PDA palm device is used for reading the tag data. This reader device can communicate at 13.56 MHz high radio frequency with additional antenna support and in an area with a diameter of 5 meters. Unless an additional antenna is used in the applied system, communication can be performed between the tag and the reader card in a distance of 10 cm.

Another issue which is seen important in RFID patient monitoring system is safety. Taking into consideration the privacy of the patient, in order to be able to operate the RFID-supported patient monitoring program in the PDA of the doctor, password authentication is the first precondition. The purpose here is to protect the system from unauthorized persons. Only the authorized persons can operate the system. Based on the clarity of the authentication process, the login screen has a basic interface as simple as shown in Fig. 6.

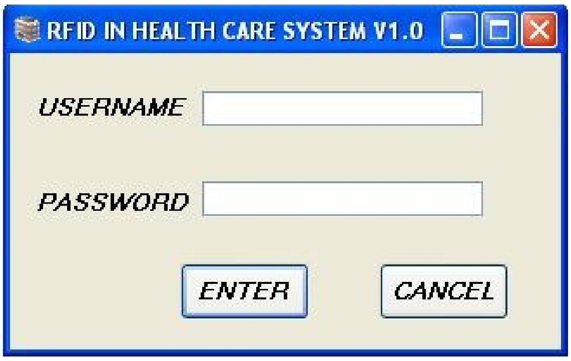

Figure 6: Simple login screen on PDA

After the health official or doctor enters both his/her user ID and password correctly, he/she can operate the system. Fig. 7 shows a sample screenshot for the initial menu of the system software prepared to be easily operable by a doctor. After that moment, the doctor should make sure that the RFID tag within the bracelet of the patient is read by PDA device. By this way, the doctor can have access to the health information of the patient in the database through the serial number in the tag. In addition, the doctor can immediately record the necessary updates to the database through wireless connection between PDA and the server. Wireless and mobile communication between PDA and server is ensured by IEEE 802.11 cards in both devices.

In order to make sure that the communication between PDA and database server is performed safely, the RFID tag number read from the bracelet of the patient can be encrypted by RC5 [17] block cipher algorithm and sent to the database. Instead of RC5, any block cipher may also be used; the choice can be made based on the security analysis of the algorithm, however RC5 is easy to implement. In the database the encrypted data is to be decrypted and patient information can be accessed which are related to the obtained identification number. Alternatively, to stregthen the system privacy, the data encrytion within the communication may also be performed through an asymmetric protocol, which will cost more expensive than RC5 in both implementing and running times of the application.

In the current status of the system, patient information taken from the database server is sent to the PDA device without any encryption. In such cases where identification information of the patient are not sent, privacy may not be an issue, as the owner of the information related to health in this environment seems anonymous. If it is planned to transfer also the identification information of the patient to the doctor through the database, it would be proper to encrypt the information replied from server to PDA device and decrypt them on PDA and submit to the doctor.

4 Conclusion

RFID technologies have rapidly been developing and it is envisaged that systems that support RFID applications will be used in several fields of industry for making life easier.

In this study, concepts in RFID technologies are explained and relevant standards are examined. Elements considered in the design of RFID systems are identified and as an example application, RFID communication is used for patient monitoring purposes in health system. As regards the proposed system, the qualifications of the software and the infrastructure designed for communication at radio frequencies to be performed between bracelets that include RFID tag and a PDA device which includes RFID reader are described.

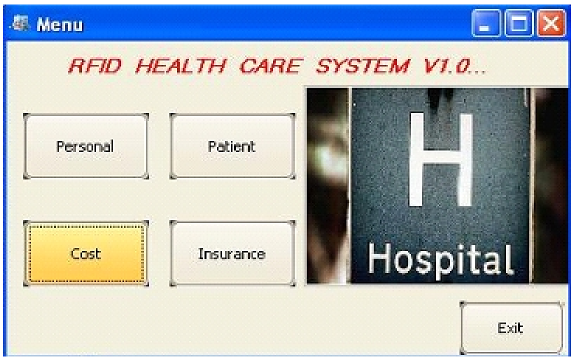

Figure 7: Initial menu screen after the doctor logs on the system

Encrypted communication during transfer of tag information read by PDA in the system to the server is supposed to be based on RC5 block cipher method so that it could be performed rapidly and easily. However, in terms of system safety, using encryption in both-ways communication between server and PDA and making this encryption algorithm asymmetric would be more secure. Its effectiveness may be considered by the system designer by taking account the system resources. It may be a future work to develop another patient monitoring application code in that direction.

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