Building a Smart Hospital using RFID technologies: Use Cases and Implementation

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Abstract. Technologies of identification by radio frequencies (RFID) experience a fast development and healthcare is predicted to be one of its major growth areas. After briefly introducing the common terminology of the RFID field and its current standards, this paper describes how this emerging technology can be used to build a *smart hospital*. Indeed, used in combination with mobile devices in eHealth applications, RFID helps optimizing business processes in healthcare and improve patient safety.

The second part of this article shows how to use an assets tracking application, called the RFIDLocator, to improve the quality of the hospital services. We developed the RFIDLocator to support the high requirements for scalability and reliability one can expect for such an application. An overview of its distributed software architecture is given. A short cookbook presents the required steps for its configuration to the concrete case of the hospital.

Some critical remarks about RFID technology, the important questions it raises and the barriers it has to overcome to be fully integrated in eHealth applications conclude this paper.

Keywords: eHealth, RFID, EPC Network Standards, smart hospital, workflow optimization in healthcare

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1 Introduction

An alarming statistic from an American healthcare organization [12] is that an average of 195'000 people in the USA died in hospitals in each of the years 2000, 2001 and 2002 as a result of potentially preventable, in-hospital medical errors [14].
[16] asserts that "the problem is not bad people in health care–it is that good people are working in bad systems that need to be made safer".
The goal of this paper is to show how technologies of identification by radio frequency (RFID) can be used to build a *smart hospital* which optimizes business processes, reduces errors, improves patient safety and enhances the quality of service.
This section starts by a short introduction to the RFID technology and define some of its main concepts and standards. Then a rough description of the settings and equipment needed to "RFID-enable" an existing hospital is provided.
The second section describes some interesting hospital use cases that could benefit from RFID. This section further illustrates that there are already many pilot projects successfully testing this emerging technology.
Section 3 presents the RFIDLocator application and shows how it can be configured to be used in a hospital illustrated by a concrete tracking example use case.
The conclusion summarizes the main achievements of this paper and enumerates some open problems that still have to be solved before RFID is fully adopted by the healthcare community.

1.1 Terminology and Standards

Radio Frequency IDentification (RFID) is a method for remotely storing and retrieving data using devices called RFID *tags* or transponders. An RFID tag is a small object, such as an adhesive sticker, that can be attached to or incorporated into a product. RFID tags are composed of an antenna connected to an electronic chip. These chips transform the energy of radio-frequency queries from an RFID *reader* or transceiver to respond by sending back information they enclose[1]. Finally, a computer hosting a specific RFID application or middleware pilots the reader and processes the data it sends. RFID has great characteristics: 1. it is possible to scan tags in motion; and 2. since radio waves can pass through most solid objects, the tags don't need to be in direct line of sight of the RFID reader.
Having labeled or tagged objects being identifiable in an ubiquitous and flexible manner is already a good start. Building a network out of these objects, so that with a unique number one can easily retrieve information about them, would enable much more interesting use cases. In order to make the dream of a *seamless global network of physical objects* come true, an open standard architecture has been defined: the EPC Network (aka "The Internet of Things").
The *Electronic Product Code* (EPC) uniquely identifies objects and facilitates tracking throughout the product's life cycle. The EPC is the fundamental identifier of assets in the so called EPC Network. It basically contains information about: 1. the manufacturer of the tagged object; 2. the product class or the nature of the tagged object; 3. the actual unique item. EPCs are often represented as Uniform Resource Identifiers (URI) in order to be used on large networks and to be easily manipulated and exchanged by software applications. An example of pure entity representation of an EPC is: `urn:epc:id:gid:25.1.12`.
The *Physical Markup Language* (PML) defines a standardized generic markup language for information interchange modelling and encapsulating the data captured by the RFID readers.
The *Object Name Service* (ONS) provides URLs to authoritative information relevant to an object, as for instance the web site of the object's manufacturer.

[1] In fact this is only true for passive tags. There are also active tags, which have batteries and initiate the communication to actively emit radio signals in order to send information to readers.

1.2 Towards Smart Hospital

As mentioned before, we aim to describe how the RFID technology can help in medical facilities and hospitals. Thus, this subsection describes an example RFID enhanced hospital, a *smart hospital*. To start with, many assets and actors of the facilities have to be "tagged":

- The medical equipment must embed RFID tags. In the best case the tags should be placed *into the devices* by the manufacturer and should contain a standardized world-wide unique identifier.
- The doctors, nurses, caregivers and other staff members wear a "smart badge"[2] storing their employee ID number.
- On arrival, each patient receives a wristband with an embedded RFID tag storing a unique identifier, and some information about him (e.g. a digital picture, a unique patient code, etc.)
- All the patients' medical histories (aka paper medical files) and other important documents are tagged with self-adhesive RFID labels containing a unique number.
- The blister packs and other drugs' packages all contain RFID labels. These transponders should preferably be EPC compliant.
- The bags of blood are attached with a self-adhesive RFID label holding a unique identifier, the hospital tracking number and some important information about the contained type of blood.

Furthermore, RFID readers are placed at strategic places within the hospital:

- RFID gates are disposed at entrances and exits of the hospital.
- Each operating theater contains a least one RFID reader.
- RFID sensors are placed in strategic galleries and important offices. In the best case, every office should contain an RFID reader: either placed next to the door or under the desks.
- The staff members (doctors, nurses, caregivers and other employees) each have a handheld (PDA, mobile phone, etc.) equipped with an RFID reader and possibly with a wireless (e.g. WiFi) connection to the web.

Eventually, while not mandatory for most use cases, EPC Network standards should be used as much as possible. This is especially true for the unique identifiers (EPC standard), the readers (Gen2 EPCGlobal standards) as well as for the application queries for authoritative information (PML and ONS standard).

2 Use Cases in a Smart Hospital

This section emphasizes how the use of the RFID (and its related standards) can contribute to create the hospital of the future. It offers a "state of the art" of the RFID technologies enrolled in healthcare applications.
We envision hospitals and medical facilities where using the identification technologies can improve the patients' care, optimize the workflows, reduce the operating costs, help avoiding severe mistakes (such as patients' misidentification) and reduce costly thefts. This section demonstrates not only that several researches goes towards this direction but also that some sophisticated RFID systems are already being successfully tested (or deployed) in a number of hospitals.

[2]Another project developed at the DIUF (Department of Informatics, University of Fribourg, Switzerland) explores the possibilities of so called "smart badges" focusing on providing location-contextual services to the members of an institution (e.g an hospital) or to the visitors of an event. See [2] for more information.

2.1 Patient Identification

Many health professionals are concerned about the growing number of patients who are misidentified before, during or after medical treatment. Indeed, patient identification error may lead to improper dosage of medication to patient, as well as having invasive procedure done. Other related patient identification errors could lead to inaccurate lab work and results reported for the wrong person, having effects such as misdiagnoses and serious medication errors [25].

In order to cut these clinical errors, to improve patient care and security and also to improve administration and productivity, several RFID-based patient identification and tracking pilot projects have been launched during the last two years. For instance, in New York's Jacobi Medical Center [30], in the Birmingham Heartlands Hospital [5] or in the German Saarbrücken Clinic Winterberg [3].

Concretely, as mentioned in Subsection 1.2, all patients admitted to the hospital are given an RFID-based wristband resembling a watch with a passive RFID chip in it[3]. This chip stores a unique patient ID number and some relevant medical information such as the patient's blood type, in order to speed treatment. To ensure patient privacy and to avoid that medical records are improperly disclosed, further medical data are not stored on the devices but are rather stored in a secure database that links the unique patient's ID with its data.

The caregiver uses a handheld computer with an RFID interrogator (an RFID-enabled PDA) to read the data encoded on the patients ID bracelets. Over a wireless LAN connection, the hospital staff can access the patient's encrypted confidential medical history as well as treatment record and can obtain information on which drugs and what dosages the patients will require.

Patients will also be able to check their own records by scanning their wristbands using information terminals.

Such patient identification and tracking systems are especially useful for patients suffering from Alzheimer's disease, diabetes, cardiovascular disease and other conditions requiring complex treatment.

2.2 Blood Tracking

A recent report [7] points out that mis-transfusion errors (i.e. blood transfusion of the incorrect type or blood given to the wrong patient) are unacceptably frequent and serious. As quoted in [1], "in the transfusion environment, misidentification is the most prevalent cause of transfusion errors that result in death".

According to [26], mis-transfusions typically result from an error made during the bedside check just prior to transfusion. Studies have documented [22] that such errors are most likely to occur among surgical patients. Currently the bedside check is done by humans using eye-readable information, and in operating rooms this task is particularly difficult. Indeed, blood is often given under circumstances of extreme urgency and distraction. Patients are unconscious during the transfusion and cannot state their name, and caregivers in the operating rooms may not "know" the patient as well as nurses on non-surgical floors.

To address the issue of the bedside transfusion check one should take advantage of new technology. Two machine-readable technologies are candidates for the automation of these checks: bar code technology and RFID. Barcodes are unsuitable for bedside checks because they require line-of-sight so that a handheld laser can read a flat surface with the code. This constraint represents an important practical obstacle, especially in operating rooms where the patient is covered with surgical drapes.

RFID technology does not have the practical problems of bar codes, and recently several hospitals[4] have deployed pilot programs using this technology to track bags of blood to record transfusions and ensure

[3] In other projects [19] the computer chips, which are about the size of a grain of rice, are designed to be injected into the fatty tissue of the arm.

[4] Examples are the Saarbrücken Clinic Winterberg in Germany [4] or the Massachusetts General Hospital and its START (Safer Transfusion with Advanced Radiofrequency Technology) project [6].

that correct blood is given to each patient.
In our smart hospital as described in [29], each bag of blood arriving at the hospital gets a self-adhesive RFID label. This chip has memory for storing a unique identification number and information on the contained blood type. These numbers are also saved in a secure database containing details about the blood's origin, its designated purpose and, once dispended, its recipient. When a nurse wants to prepare a blood transfusion, she uses an reader-equipped PDA to read the data encoded on the blood bag's RFID chip and on the patient ID bracelet. The data from the patient and the bag must match before the blood can be used. With this solution the overall process of managing blood bags is eased and less time-consuming. Moreover the risk of patients receiving the wrong type of blood is minimized.

2.3 Smart Operating Theatres

As mentioned in [13], surgical identification can raise significant problems, according to recent federal reports. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) declared that the most commonly reported surgical errors involved surgery on the wrong body part or site, the wrong patient or the wrong surgical procedure [23].
The Birmingham Heartlands Hospital [5] is currently running a pilot[5] of the RFID technology on patient undergoing ear, nose and throat surgery [17]. The aim of the system is to ensure the correct operations are carried out on the right patients.
In the smart hospital the patients get a RFID-tagged wristband containing relevant information and a digital picture of them. The photograph allows the clinical team to easily confirm they have the right patient, and the electronic record ensures they perform the correct procedure. If the wrong patients enter the operating room, the medical staff is automatically and instantly warned of the mismatch.
Thus radio tagging makes the operating theatre safer and more efficient. Moreover the risk of litigation resulting from surgery mistakes and the costs they generate should be significantly reduced.

2.4 Anti-Counterfeiting

Drug counterfeiting is an increasing problem: 1. counterfeit drugs reduce patient safety, as they can contain dangerous substances; and 2. pharmaceutical companies lose tens of millions of dollars to the counterfeit drug trade each year.
This problem is being taken seriously and in February 2004 the U.S. Food and Drug Administration (FDA) published a report [18] encouraging the use of RFID to combat it and urging the drug industry to adopt the technology. Coinciding with the FDA's announcement, several major pharmaceutical manufacturers announced pilots to incorporate RFID into packaging of prescription drugs.
For example Pfizer, the producer of Viagra[6], plans to spend about € 4 on a project for supplying RFID tags for bottles, cases and pallets.
The goal is to assign a unique number (the Electronic Product Code or EPC) to each pallet, case and package of drugs and to use this number to record information about all transactions involving the product. This provides an electronic pedigree through the whole drug supply chain, from the point of manufacture to the point of dispensing [21].
According to [18], by December 2007 all manufacturers, all wholesalers, all chain drug stores, all hospitals, and most small retailers should have acquired and be using RFID technology (i.e. antennas, tag readers, and appropriate information systems). Thus they will be able to retrieve the product codes and verify their authenticity by checking the manufacturer's database via the web.
All these measures should make sure that the drugs patients take are safe and effective.

[5] This project follows a smaller "pre-pilot" of the RFID tracking system that began in November 2004.
[6] Viagra is one of the major target for counterfeiting. Five millions of counterfeit pills were seized by authorities in year 2005 [10].

2.5 Tracking Equipment, Patients, Staff and Documents

Amongst all the imaginable use cases, RFID is certainly best suited for *tracking* applications. The technology enables an automated and fast tracking of assets, animals or people. Efficient tracking in a hospital offers plenty of interesting perspectives.
First of all, remember that our smart hospital is equipped with RFID readers at strategic places: e.g. main doors, entrances of operating theaters, recovery rooms, exits of the medical histories library, important galleries, etc. Together with the fact that all the medical histories (and other important documents) are tagged, it enables us to locate them through the use of an assets tracking application like the RFIDLocator (see Section 3). This fact can already help *reducing the medical files' losses*. It is worth noting that, according to a small survey we conducted (see [11]) such losses are not so infrequent and may sometimes have bad consequences, both in terms of costs and patients safety. Several documents tracking applications have already been successfully deployed. Most of them lead to a positive ROI (Return On Investment) such as saving 2500 man-hours a year for the district attorney for Marin County (USA) [27].
Furthermore, using an assets tracking application within the infrastructure deployed for our smart hospital gives us the possibility to locate and trace staff members as well as patients efficiently. This can help *improving the workflow* of doctors, nurses and other caregivers [13]. It can also help to *locate* them in real-time which is especially worthy for huge buildings such as hospitals.
Additionally, being able to trace all the tagged equipment introduces an *efficient and accurate inventory system*. Again, a number of corporates have already successfully introduced RFID systems for real-time inventories. The most often cited positive effects are the reduction of assets loss. As an example Metro Group, the world's third-largest retailer, reported a improvement of about 18% in goods loss thanks to the RFID technology. Besides, tagging and tracking equipments offers many other use cases such as finer maintenance scheduling, usage statistics of equipment, placement optimization and fast localization of important material.
Eventually, RFID *tracking also helps avoiding thefts*. This latter fact is the subject of the next subsection.

2.6 Avoiding Theft of Medical Equipment

It is well-known that hospitals own a great number of expensive medical equipments. What is less known about it is that part of this equipment is stolen on a regular basis[7]. As an example, according to a survey [20], more than € 155'000 of material were stolen in 2005 in eleven hospitals of the United Kingdom. Another survey completed by Harvard Medical School reported that the Beth Israel Deaconess Medical Center (USA) was loosing about € 333'000 a year because of stolen and misplaced equipment [26]. Yet, these surveys do not take into account the sidecosts of thefts. Firstly, before being identified as stolen, a piece of equipment would have been searched for hours by hospital's employees. Secondly, the missing material has to be re-ordered by some employees, diverting them from patient care or management tasks. Waisted money is not the only effect of these thefts. The stolen equipment is sometimes vital and its lack may have sever consequences. According to [20], these facts lead the U.K.'s National Health Service to explore new ways of protecting high value material.
Once again, the Radio Frequency IDentification can help towards the finding of a solution to this serious problem. Indeed, as RFID tags are embedded into the medical equipment of our smart hospital, we are able to *track and trace* it (see Subsection 2.5 for more considerations about assets tracking within the smart hospital). This fact already reduces risks of the thefts as the hospital's technical staff is always *aware of material's whereabouts* within the buildings. Furthermore, as for *anti-counterfeiting* (see Subsection 2.4), electronic tagging has a preventative effect and can help identifying stolen material. Additionally, RFID gates at the hospital's exits can help notifying the security services that medical equipment is taken out of the building. Nevertheless, *access control* methods (a very common use of RFID) can also help by introducing identification procedures for accessing the equipment or running it.

[7] Items such as wheel chairs and intravascular pumps often disappear from emergency rooms or intensive care units [13].

However, it is important to note that similarly to anti-counterfeiting (see Subsection 2.4) the most embedded in the material the tags are, the most efficient the RFID infrastructure will be at preventing thefts. Indeed, if the tags can be removed easily (and without consequences) by the thief the presented methods loose part of their value. As a consequence, the producers of medical equipment should embed the tags at the factory (on demand or as a standard), or the hospital should have the ability to tag its assets with hard-to-remove electronic identifiers.

2.7 Smart Medicine Cabinets

The benefits of RFID in healthcare are not confined to hospitals. Since we made the assumption that all the blister packs were tagged many applications improving patients care even when they are out of the hospital can be thought of. The smart medicine cabinet, is one of these. First imagined in 1999 [28], the project was further developed by many other computer scientists [24] and influenced by researches on smart boxes such as in [15].

Basically, the idea is to construct a smart medicine box that would enable the patients to achieve their own medicine management. Using the RFID tags pasted onto blister packs and RFID sensor coils, a computer connected to the Internet and embedded in the cabinet can help the patients in many ways.

First of all, the system can detect when a patient takes a package out of the cabinet. The retrieved unique identifier can then be used to obtain authoritative information about the drug such as the prescription. Furthermore, using this information the system can schedule the patients cell phone (via Bluetooth) [24] to notify him when he has to take his medicine during the day. If no Bluetooth connection is available the system could also schedule the transmission of SMS (Short Message Service) reminders.

Secondly, the proposed infrastructure can offer various other services through the screen of the smart medicine cabinet. For instance, if the system is aware that the patient has allergy problems it can advice her to take a drug when the pollen count in her area is getting dangerously high [28]. Still by detecting the RFID tags on the blister packs, it can also check that the patient takes out the correct package and warn her if it turns out not to be the case.

It is worth noting at this point that these use cases make much more sense when using EPC Network Standards (see Subsection 1.1). While the use of proprietary RFID standards within an hospital is acceptable (but not recommended as it reduces the power of a number of use cases), it should be avoided at all costs for public or cross-organizational applications. Indeed, in order for smart medicine cabinets to be widely deployed, all the blister packs should be tagged with standardized tags. If this were not the case then the identification of the blister packs would be obviously far more complicated. Furthermore, the use of ONS (another EPC Network standard) permits an efficient retrieval of information (such as the prescription) about the detected blister packs using the Internet.

2.8 Other Applications

This list of use cases is not exhaustive and many other applications of RFID within a *smart hospital* can be imagined. They can be related to healthcare as for instance the tagging of meal plateaux to ensure patients get the appropriate diet according to their treatment, allergies and tastes. The hospital laundry can also be greatly optimized. Nowadays, tags attached to clothes and uniforms can resist extreme conditions both in terms of chemicals products and temperature. Thus, the whole business process could be automated from the collecting of dirty clothes to the redistribution of cleaned ones. We do not want to conclude this section without mentioning one of the first application domains of RFID, i.e. access control. Indeed, in a hospital building the issue has to be addressed. The tagged badges of the hospital staff provide a good solution.

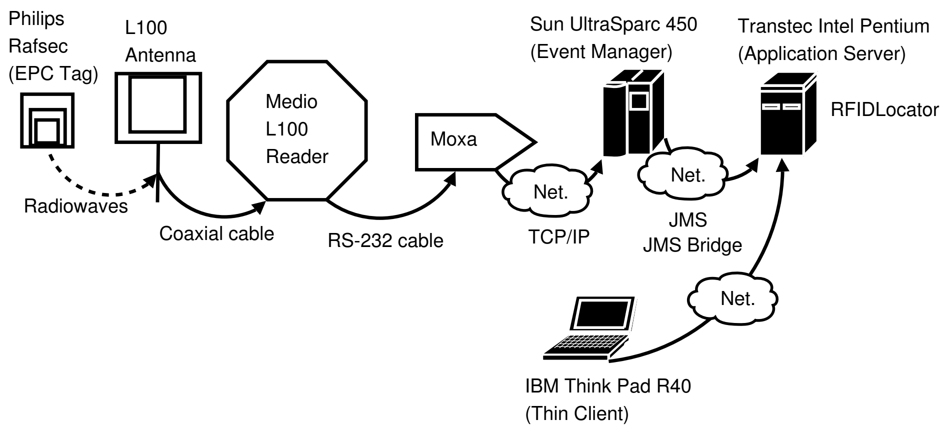

Figure 1: Components of the RFIDLocator infrastructure

3 Implementing the Tracking

As mentioned in Subsection 2.5, efficient tracking in a hospital offers plenty of interesting perspectives. Thus, this section is a so called "cookbook" intended to give an overview of the configuration required in order to enable assets and people tracking in an hospital using the RFIDLocator.
The RFIDLocator is a web-based application we developed at the Software Engineering Group of the University of Fribourg (CH) in collaboration with Sun Microsystems. It is an enterprise application allowing the tracking of assets within a predefined area, such as a building. Special care has been given to use the EPC Network Standards introduced in Subsection 1.1). As a result, the RFIDLocator is a scalable and robust distributed application whose different components are depicted on Figure 1. The global software architecture is presented in [9] and more details as well as a detailed manual can be found in [11]. Let us mention that RFIDLocator is well documented and released under GPL (General Public License), thus one is allowed to freely use and further tailor the application.

3.1 Placing the Readers

We start by defining a plan describing the readers' placement. Indeed, as the RFIDLocator is able to track and trace an object within a predefined area equipped with RFID readers, one first need to specify and parse a plan of the readers' placement into the application.
Let us imagine we want to setup the application for an hospital specialized in brain and heart surgery. In order for the application to work efficiently, we should *include all the RFID enabled rooms and galleries* of the building in the plan. However, for the sake of simplicity this cookbook contains the definition of the following places only:

- An operating theater (for brain surgery) corresponding to the room number: `SH_A1_OPERATING_01`. Within the RFIDLocator such internal location identifiers are called `BusinessLocationNumber`.

- A main gallery at the department for heart surgery corresponding to the number: `SH_A1_GALLERY_06`.

Next, we place the antennae connected to the two RFID readers in "strategic" places as shown on Table 1.

Antenna's ID	Reader	Location	Aim
25.1.10 25.1.11	Medio L100	At the door of the operating theater for brain surgery.	Detecting objects entering and going out of the operating theater.
25.1.12	Medio L200	In the middle of the gallery heading to the department for heart surgery.	Detecting passing by the gallery.

Table 1: Placing the antennae

This is now translated into a formalism the RFIDLocator understands, namely the *Reader's Configuration Formalism*. This XML formalism defines a syntax and a semantics that models the placement of RFID readers within the environment. An extract of the resulting XML document is shown on Table 2[8].

3.2 Define the Users of the System

Now that the application is aware of the readers' whereabouts, we can go on with the definition of our environment. The step is to define the "objects" to be traced. These are called `TraceableObjects` within the RFIDLocator. A `TraceableObject` is virtually "anything" that can be tagged with an RFID transponder, ranging from equipment or medical histories to patients and employees.
For this cookbook, we "tag" the patient Irene Blue with a wristband containing an EPC compliant (see Subsection 1.1) unique identifier: `urn:epc:id:gid:35.5.18`. This number has to be attached with the `BusinessNumber` of the patient, i.e. its hospital-wide unique identifier: `SH_06_IRENE_BLUE`. This matching is achieved using the web frontend of the RFIDLocator and it creates a new `TraceableObject`. Additionally, we "tag" the patient Josh Green in the same manner.
It is worth noting at this point that the web interface of the RFIDLocator is decoupled from the core of the application. Thus, the RFIDLocator core could be integrated with a legacy medical system, enabling the patients' registrations and tracking as `TraceableObjects` (i.e. objects we can locate) directly through the existing system.

3.3 Using the Application

As the readers' configuration has been parsed and EPC identifiers have been bound to `BusinessNumbers` we are ready to use the application:
Let us imagine Josh Green is driven by a nurse to the operating theater for brain surgery. When entering the smart theater Mr. Green is identified by the EPC number sent to the reader by his RFID wristband. The system of the Smart Theater (see Subsection 2.3) detects a mistake: Mrs. Blue was scheduled for operation, not Mr. Green! Immediately, the nurse notifies the Doctor of the mistake and *queries the RFIDLocator*, as shown on Figure 3, *to find Mrs. Blue.* The application informs her that Mrs. Blue was last seen in the gallery on the way to the operating theater for heart surgery (i.e. on the way to the wrong operating theater). She can now contact the heart surgery department to inform that the patients where switched.
This simple example already shows the RFIDLocator can serve for patients tracking and locating. However, it is not limited to this particular use case. For instance, using the application we may as well:
1. Track the medical equipment in order to locate it quickly, to prevent theft, and to optimize its usage

[8] A `LogicalAntenna` can be composed of several `PhysicalAntenna` to be able to detect the direction of motion.

```
[...]
<Reader brand="TagSys" model="Medio L100">
   <LogicalAntenna fiability="80">
      [...]
      <Location>
         <BusinessLocationNumber>
            SH_A1_OPERATING_01
         </BusinessLocationNumber>
         <Description>
            Main operating theater. Brain surgery.
         </Description>
      </Location>
      <PhysicalAntenna id="urn:epc:id:gid:25.1.10">
         <Action>IN</Action>
      </PhysicalAntenna>
      <PhysicalAntenna id="urn:epc:id:gid:25.1.11">
         <Action>OUT</Action>
      </PhysicalAntenna>
   </LogicalAntenna>
</Reader>
<Reader brand="TagSys" model="Medio L200">[...]</Reader>
[...]
```

Figure 2: XML extract of the Reader's Configuration Formalism

and maintenance. 2. Trace the medical staff to optimize their workflows. 3. Track medical histories to be able to locate them as quickly as possible and optimize their management.

4 Conclusion

Healthcare is predicted to be one the major growth areas for RFID. A recent analysis [8] reveals that the RFID in healthcare and pharmaceutical applications markets earned revenue of € 306 million in 2004 and estimates to reach € 1'916.6 million in 2011.

This paper describes some interesting applications with promising perspectives. It also presents an open-source application and shows how it could be used to directly implement some of the use cases.

However, it is worth noting that there are still some open problems to be solved before the healthcare community fully embraces the RFID technology.

One must be sure that the deployment of radio frequency devices does not interfere with pacemakers, heart monitors or other electrical devices that are common in an hosptial. Furthermore, the consequences and side-effects of radio waves on the exposed humans have to be clarified. When talking about pasting radio frequency tags on drug packages, there are concerns that exposure to electromagnetic energy could affect product quality.

Furthermore, any technology implementation in healthcare must deal with privacy and security issues. But RFID presents unique concerns because of the possibility of unintended wireless transmission of healthcare-related information. Unethical individuals could snoop on people and surreptitiously collect data on them without their approval or even without their knowledge. This could occur even after

Figure 3: Locating a tagged object

completion of healthcare services if RFID tags remain active. Hospital staff has to feel comfortable with the fact that they can be tracked and located everytime. Maybe some "RFID free zones" should be delimited in order to fight the "big brother" effect and to preserve the freedom of individuals. From these concerns, it should be clear that challenging cryptographic issues are raised in relation with wireless transmission and that there is a need for clear laws and recommandations about the tracking of goods and people.

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