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SECURITY SYSTEMS ON HEALTHCARE ORGANISATIONS: RFID TECHNOLOGY APPLICATION

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Abstract

Healthcare organizations are looking to RFID as a way to maximize their use of equipment, boost patient volume and plug gaps in patient safety. The RFID technology is actually considered a hot topic in all scientific areas and has been described as a major enabling technology for the automation of many processes. Although it is not a new technology it has only recently come to the awareness of the public and widely used in many sectors and particularly in the healthcare.

This paper aims to illustrate the utilization of the RFID technology in healthcare, more precisely in infant security system inside the hospitals. To attain this objective a case study about the experience of Portuguese hospitals in this system is presented and highlighted the main advantages and contributions to a better performance in terms of infant' security.

Keywords: Healthcare Organizations, RFID Technology, Security system, Case Study

1 Introduction

The Radio Frequency Identification (RFID) is the generic name attributed to the technologies that use the waves radio (Jones *et al*., 2005) for the automatic identification of objects, positions or persons through electromagnet answers and at a considerable distances (So and Liu, 2006). It allows that firms produce, store and deliver a high quantity of data quickly (Bange, 2006).

RFID is an emerging technology that intends to complement or replace traditional barcode technology to identify, track, and trace items automatically (Wilding and Delgado, 2004). RFID is

claimed to add intelligence and to minimize human intervention in the item identification process by using electronic tags. The tags are significantly different from printed barcodes in their capacity to hold data, the range at which the tags can be read, and the absence of line-of-sight constraints (Meyerson, 2007). This has justified the increase on use of this technology in the healthcare sector. A recent study reports that the global market for RFID tags and systems in the healthcare industry will increase steadily from $90 million in 2006 to $2.1billion by 2016 (Harrop and Das, 2006).

This paper aims to illustrate the utilization of the RFID technology in healthcare, more precisely in infant security system inside the hospitals. That is, it seeks to emphasize the importance of this technology to the healthcare organizations highlighting the main advantages that hospitals reach with RFID in infant security systems. To attain this objective, a Portuguese case study about the application of this technology mainly as part of an infant security system in the hospitals is described. The main characteristics of the infant security system, functionality and advantages are presented.

The paper is structured as follows; first, we offer the characterization of the RFID System in terms of the elements that constitute it (readers, tags, software, and security programs). The following section focuses on the main advantages and disadvantages associated with the use of the RFID technology to the organisations in general and to the healthcare ones in particular. Next, a case study is presented about the Portuguese application of the RFID in an infant security system in the hospitals.

2 The RFID Technology

A RFID technology is composed by several elements: readers, tags, software, and security programs for the readers (Atkinson, 2004). Instead of visible light used in ordinary bar code labels, these tags use radio waves to communicate with the readers. The readers generate signs that are able, by one hand to supply energy to the tag in order to generate data and, on the other hand, to send a sign of interrogation.

To produce radio waves tags require some source of energy to power its electronics. Active tags use a tiny battery, a microchip, and a tiny antenna built into them. The operating frequency of radio waves employed also varies. Low-frequency RFID tags operate at 125 to 134 kHz, for US and international use. High-frequency systems use 13.56 MHz. Frequencies of 866 to 960 MHz are used in UHF (ultra-high-frequency) systems, while microwave systems operate at 2.4 to 5.8 GHz (Dipert, 2004).

The key component of an RFID system is the tag itself. Tags come in a large variety of forms and functional characteristics. One useful way of classifying tags is to divide them into active and passive classes. Active tags whose read/write range is longer and passive tags with shorter range. However, passive tags are much cheaper than the active tags and are therefore more widely used. The active tags have more possibilities and bigger flexibility than the passive ones. This is because, they have their own internal power source which is used to power the integrated circuits and broadcast the signal to the reader.

To distinguish tag types from each other, Electronic Product Code (EPC) Global has established five tag classes to indicate capabilities a tag can perform. For instance, Class 0 tags are factory programmable. The EPC number is encoded onto those tags during manufacture and can

be read by a reader. Class 1 tags can be programmed by the retailer and supplier. They are manufactured without the EPC number which can be encoded onto the tag later in the field (i.e., by retailer and supplier). The Class 3 tags have the Class 2 capabilities plus a power source to provide increased range or advanced functionality. The Class 4 tags have the Class 3 capabilities plus active communication and the ability to communicate with other active tags. The Class 5 tags have the Class 4 capabilities plus the ability to communicate with passive tags as well (Meyerson, 2007).

Antennas also come in a diverse range of form and technical factors. They are used in both the tags and the reader. The size could vary from under a square centimetre to several square meters. Technically speaking, UHF reader antennas can be classified as circular-polarised or linear-polarized antenna. The former emit and receive radio waves from all directions, while the later work best in one particular direction. Therefore circular-polarized antennas are less sensitive to transmit readers could come in four types: handheld, vehicle-mount, post-mount, and hybrid (Meyerson, 2007). The first three are dedicated to reading of the tags, active or passive. The fourth type has the active/passive mode allowing it to switch from the passive to active mode and vice versa. Both handheld and hybrid readers are more expensive than the vehicle-mount and post-mount. Next generation readers are expected to have less power consumption and fewer voltage requirements.

Passive RFID readers create a radio frequency field when they are turned on. When a reader detects passive tags, it activates them. These tags draw their power from the radio frequency field; they do not require battery power. Because they have no battery, the passive tags are smaller and lighter in weight than active tags (Meyerson, 2007).

When the active tags with power come into the reader's field, the reader switches to the read mode and interrogates the tag. However, the operating range of a linear-polarised antenna is more than that of a circular-polarised antenna (Intermec, 2004). When a tag communicates with an antenna, the radio frequency portion of the circuit between the tag and the antenna is called the air interface. This radio communication takes place under a certain set of rules called air interface protocol. Propriety protocols may cause interoperability problems with equipment from different vendors.

Readers read or interrogate the tags. In reading, the signal is sent out continually by the (active) tag whereas in interrogation, the reader sends a signal to the tag and listens. To read passive tags, the reader sends radio waves to them, which energise them and they start broadcasting their data. The reader reads all the tags within its read range in a quick succession. This automatic process reduces read times.

Software is the glue that integrates an RFID system which depends upon the industry context, but usually a front end component manages the readers and the antennas and a middleware component routes this information to servers that run the backbone database applications. The middleware technologies could be into three levels: (i) software applications which solve connectivity problems and monitoring in specific vertical industries; (ii) application managers that connect disparate applications within an enterprise; and (iii) device brokers that connect applications to devices (RAGMS, 2004).

The enormous advantages associated with this technology, has justified its large application in several functional areas. We can find the RFID technology in different contexts namely in: (i) anti-terrorism initiatives (Albright, 2005); (ii) electronic keys; (iii) warehouses (Meyerson, 2007);

(iv) distribution centres (Borck, 2006); (v) points of sales; (v) security applications in the transport (Kevan, 2004), (vi) demotic (Kelly and Scott, 2005); (vii) retailing (Azevedo and Ferreira, 2008; Jones *et al*., 2005) (viii) e-business (Want *et al*., 1999); (ix) supply chain execution applications; (Lee *et al.*, 1997; Meyerson, 2007).; (viii) healthcare (Hendrickson, 2004; Sini *et al*., 2008).

2.1 Advantages of the RFID Technology

There is a high investment in the development and improvement of the RFID systems because of the important advantages that organisations can reach with it when compared with bar code tags where the reading must be done by a visual contact using optical readers. In healthcare particularly, RFID is considered generally more suitable than barcoding and has many potential advantages such as field reading, as opposed to line-of-sight reading. RFID devices can store more data than barcodes and some RFID tags can have data written to them by the interrogator (Symonds and Parry, 2008). Lee and Shim (2007) identify the following perceived benefits associated with the use of the RFID in healthcare: (i) overhead cost reduction; (ii) reduced error rates; (iii) improved customer service; and (iv) improved hospital image. But the advantage more pointed out by healthcare organizations is the improved customer service.

Healthcare organizations are looking to RFID as a way to maximize their use of equipment, boost patient volume and plug gaps in patient safety. On the plus side, RFID tags are often more durable than the easily smudged bar code' labels (Baldwin, 2005). One of RFID's biggest selling points is that healthcare staff can benefit without much understanding of the underlying

technology. Unlike a complex electronic medical record system, RFID can operate quietly in the background, requiring little attention.

The RFID could be used in patients who are put "on hold," such as those with head injuries or drug overdoses. If these patients try to leave the hospital, a sensor will detect their movement and trigger an alarm. The other costly option was a full-time security guard (Baldwin, 2005).

Brooke (2005) identified several aspects of the healthcare industry where RFID can be beneficial, including the ability to trace high value assets in the hospital and the ability to track assets over time, thus verifying that certain procedures have been completed (in this case, decontamination of surgical instruments).

The management of surgical instruments is a major problem for most healthcare facilities. In addition to the loss issue (ranging from simply lost or misplaced instruments to outright theft), there has been a need to track both the instruments themselves and the entire process associated with them, aiming at optimizing instrument inventory and utilization and patient safety. The surgical instrument cycle includes procurement, assembly, packaging, sterilization, storage, distribution, utilization in the surgical suite and other clinical settings, and the decontamination process (Sini et al., 2008).

In this context, one of the advantages pointed out to the utilisation of the tags is its power of reading. The tags can be read independently of the environment conditions. They can be read in aggressive environments such as fire, ice, ink, noise and different temperatures (Knill, 2002). This system presents also a high, rigorous and simultaneous capacity of reading (So and Liu, 2006). According to Garfinkel and Rosenberg (2005) the benefits of the RFID could be identified in the RFID' tags, non line-of-sight and better information (table 1)

Table 1. Benefit analysis

Area	Benefit
The RFID tag	- small size - uniquely identifiable - memory capacity - reading range - write capability
Non line-of-sight	- penetrate material - independent of tag orientation - read multiple tags - process improvements (speed up)
Better information	- more information (frequent reading) - accurate information - end-to-end view (track & trace)

Source: Garfinkel and Rosenberg (2005)

According to Atkinson (2004), in the U.S.A. billions of dollars are lost annually, with the inefficiencies that occur on organisations motivated, to a great extent, by the incorrect locations of products or by a bad management of the information. RFID technology does not require a line of sight, since it can read many tags simultaneous. RFID will facilitate improved use of warehouse and distribution centre space in that goods will not need to be stored according to product type for manual location, but they can be stored in the most efficient manner. Retailers will be able to know where pallets and cases of goods are to (Coltman *et al.*, 2008), to identify products that may have been recalled, to respond rapidly to unforeseen changes in the supply chain, to react quickly to problems within the supply chain, to check on expiry dates and to determine when products will arrive in store (Jones *et al*., 2004). RFID within a retailer enables a reduction in the number of incorrect manual counts, unreported stock loss, mislabelling, and inaccessible/misplaced inventory (Veeramani, *et al.*, 2008).

Within stores many other benefits are also predicted for RFID. Many manufacturers have indicated as much as a 7% increase in sales because of the greater visibility of the inventory on the shop floor. RFID can not only detect if items are being moved from the store without being paid for but also they can alert security guards if a large volume of particular products have suddenly been removed from store's shelves. It also reduce check out times in that customers will able to push their trolley of carry their basket past a reader and get a complete list of all items purchased automatically charged to the customer's credit card (Jones *et al*., 2004).Retailers will also be able to track products that are selling rapidly and to restock shelves several times a day with such fast moving items. RFID can also be used to promote products and stimulate up selling. It could be also used to trigger an interactive display of related products (Jones *et al*., 2004).

In healthcare the main benefits pointed out are: (i) patient flow management; (ii) Improve productivity; (iii) reduce human errors; (iv) reliable accurate and secure measures for tracking and authentication of pharmaceuticals (Reynes, 2007); (v) a triage system which employs facing massive casualty incidents through the news every RFID tags, which are silicon chips with IDs, radio frequency day. We also position it as a start point for new horizons in function and some additional logic and memory (Want *et al*., 1999, Hewkin, 2004) (vi) speed of data access and multiple item identification without need to have the tags on the line of sight;(vii) safety of electronic matches, item identification and data transfer; (viii) automation of some process activities and information flows; (ix) chance to implement workflow management rules, bounding health workers to follow the implemented procedures; (xi) remote item/people tracking and real time process monitoring (Sini *et al*, 2008)

2.2 Disadvantages of the RFID Technology

As it can be seen, the new application of the RFID technology in an organisation context can bring a lot of advantages in terms of optimization and of efficiency. Despite of the enormous advantages attributed to the RFID technology, some disadvantages are also pointed out. In this context, the main disadvantage attributed to the use of this technology is its cost. It involves a big investment (Borck, 2006) and the return of this investment is only recuperated in a long time (Kinsella and Elliot, 2005). If a short Return-on-Investment (ROI) was verified it could promote the use of this technology because according to Trunick and Williams (2005) this type of technologies presents a great level of obsolescence and innovation. Furthermore, the cost of each electronic tag is higher than the bar code one which leads organisations to think about it.

The future of RFID still remains unclear due to limitations in the form of high implementation and operation costs, the lack of standardization, and unawareness of its importance (Smith, 2005). Another disadvantage of RFID technology according to Lai *et al.* (2005) is the prohibitively high cost of tags. The financial return of using RFID is also a major question in the hospital industry (Hendrickson, 2004).

Coltman *et al*. (2008) make the following questions related with the use of this technology: (i) can the cost per RFID tag reach feasible economies of scale for individual level tagging?; (ii) who will bear the cost of deployment in organisations and how will these costs be distributed in an equitable manner? In this context also Witt (2006) and Veeramani *et al*. (2008) refer that one of the barriers to the adoption of RFID by organisations is the difficulty in assessing the potential return on investment (ROI). Besides a set of authors had analysed the impact of the

implementation of the RFID technology on ROI (Hardgrave *et al*., 2005; Rekik *et al*., 2008), there is a lack of a good understanding of the impact of RFID upper echelons of any supply chain.

The level of security provided by the RFID represents another disadvantage. From the point of view of Atkinson (2004) is relatively easy to have access to the information that flows in a RFID systems in an organisation. It is only necessary to use a radio telescope in a relatively near distance. This can explain the fear of the organisations to adhere to the RFID technology. The complexity of this technology, the lack of know-how and standardisation are some obstacles referred by organisations for not use the RFID technology (Albright, 2005).

Once analysed the main characteristics, advantages and disadvantages associated with the RFID technology, we will focus on the challenges the organisations are facing to implement this technology. There are many technical challenges associated with the deployment of RFID based solutions. Among the main technical challenges faced by organisations could be highlighted the erroneous reads, the read collisions and the cost of handling large amounts of data generated by RFID (Coltman *et al*., 2008).

Despite its potential, RFID has been slow in coming to healthcare since the lack of awareness has worked against RFID. In addition, RFID implementations can be costly, particularly if a hospital lacks the wireless infrastructure needed to support far-flung applications, such as equipment tracking. RFID tags cost two to three times more than barcode labels (Baldwin, 2005).

Some authors (Luckett, 2004; Piasecki , 2005; Heinrich, 2005; Staake, *et al.*, 2005; Gunther and Spiekermann, 2005) highlight the following disadvantages associated with RFID: (i)

Roi uncertainty, (ii) lack of universal standards; (iii) high cost of individual tags, (iv) obstructive materials interface with readings.

3 Case Study: Experience of the Portuguese hospitals with the RFID Technology

The information needed to the development of this case study was gathered from the healthcare' institutions web page, public presentations of the RFID application in this institutions and suppliers' RFID Technology web page.

There are a set of Portuguese' healthcare organisations mainly hospitals that are adopting the RFID technology. Some of them are using this technology since some time ago and are in a maturity phase. Others are testing recently it in a set of healthcare services and medical specialities. Besides all the application' field of the RFID in hospitals, this technology in the Portuguese reality has been used mainly to assure the infant security. This is justified by the statistics associated with the number of babies that are abducted and changed from healthcare organizations. In Europe each year in average twenty 20 babies are abducted and during the same period 2 000 babies are changed[1].

The experience of Portuguese hospitals with the RFID technology is relatively recent and reduced in its scope. Among the seventy tree (73) hospitals that constitute the healthcare system in the country we can observe the application of this technology mainly as part of infant security systems and in the following healthcare organizations (Figure 1): Hospital da Luz, Hospital do

[1] http://www.safesis.com/main.cfm?id=694&Sid=697&l=1

Barreiro (Lisboa), Hospital S. Teotónio (Viseu), Hospital de S. João de Deus (V.N. Famalicão), Casa de Saúde da Boavista (Porto), Hospital de S. Marcos (Braga), Hospital dos Lusíadas (Lisboa), Centro Hospitalar de Trás-os-Montes e Alto Douro (Vila Real), Centro Hospitalar de Trás-os-Montes e Alto Douro (Chaves), Centro Hospitalar do Nordeste (Bragança). The system used by the Portuguese healthcare organizations is named “Hug” and is supplied by Safesis and VeriChip companies. This system is designed to prevent infant abductions and inadvertent child mishandlings.

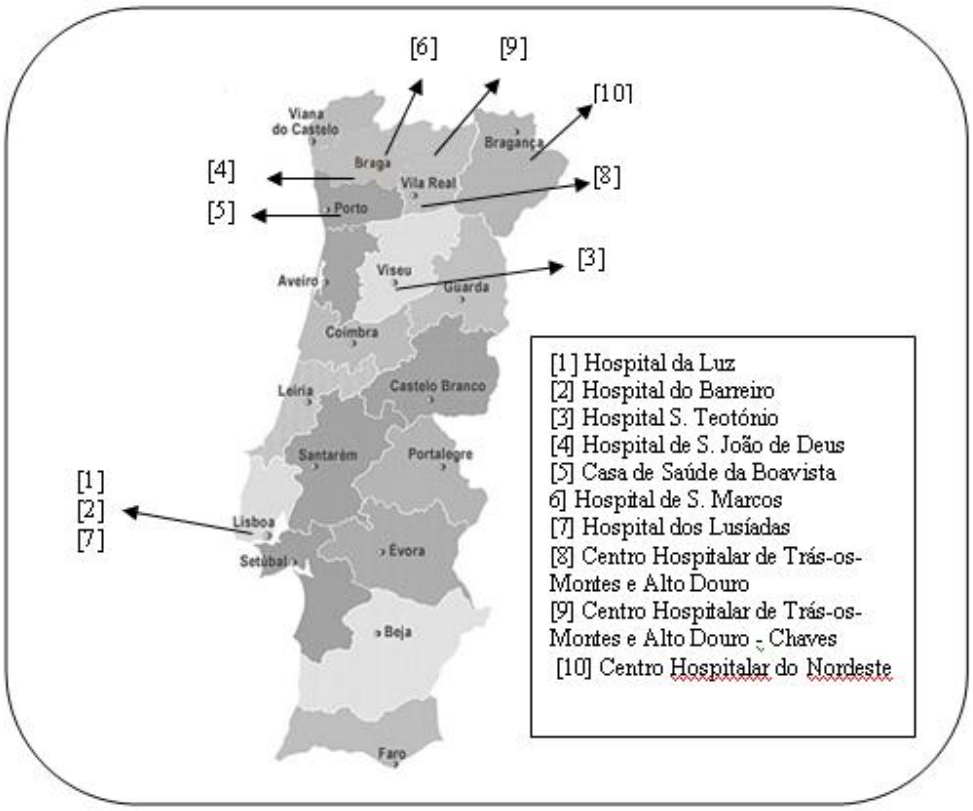

Figure 1- Mapping of hospitals that apply the RFID in its infant security system

As it can be seen in the above figure most of the hospitals that has already invested in the infant' security system focused in this study are located in the north region of Portugal. Only tree hospitals are more to the south in the capital of the country.

How this infant security system works? The security system is based on RFID technology and has as main components the following: (i) exciters, tags, receivers and controller PC (Figure 2). The exciters monitor the exits from the safe area. The hug tags incorporate a tamper mechanism that is enabled as soon as the tag is attached with the tamperproof strap. The receivers receive hugs tag transmissions, time stamp them and relay them to the controller PC. The controller PC contains the Hugs system software and controls the operation of the entire system.

Unlike bar codes, an RFID chip can be sensed from many feet away and without human intervention. Sensors, for example, in the ceiling detect a chip that is embedded in a baby's wristband, triggering an alarm if the child is in an off-limits zone, or prompting a jingle when the baby comes close to its mother's pre-programmed RFID band.

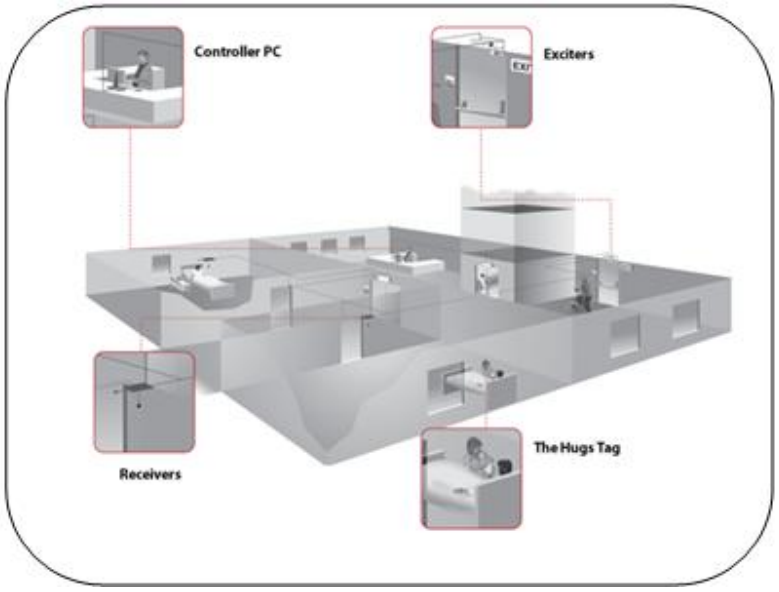

Figure 2 – The infant security system

Every infant in a medical unit wears a tag with a unique ID number on the ankle, and every exit point is electronically monitored to detect the tags. This means staff and family can move infants freely within the protected zone, but no one can remove an infant from the unit without the organisation' staff being alerted. Beyond this superior and active supervision of infants, the system monitors its own functionality and alerts staff of any problems.

In the event of an alarm, the system can automatically activate magnetic door locks or hold an elevator. It can also integrate with and activate other security and access control systems, such as alpha-numeric pagers and cameras. The alarm goes off in the following situations: (i) someone tries to exit via a monitored door or elevator with a protected infant, without authorization; (ii) the strap has been cut or tampered with; (iii) the tag's signal has not been detected by the system for a specified time period, (iv) the tag's battery power is low; (v) an authorized exit has occurred but someone tries to "piggyback" through the protected exit with another infant; and (vi) an

authorized exit has occurred but the infant has not been returned to the designated safe area in the specified time.

For security purposes, all system transactions are password controlled, time and date stamped and logged into the database on the system controller. A permanent record is possible of who is admitted, signed out and discharged of all babies. Also have a record of when and where alarms occurred and who cleared them can be obtained. The system controller itself is equipped with a watchdog timer card to output an alarm signal in the unlikely event of a problem with the operating system, providing an extra level of security. When mother and baby are brought together with a correct match, a pleasant lullaby will sound from tag. An incorrect match generates a buzzing tone.

The Hugs system's advanced radio frequency technology not affects or be affected by other electronic hospital equipment which represents an important advantage. Each tag has a unique code to ensure easy identification of every infant, the strap is easily "snagged-up" to accommodate weight loss and extremely durable and the tags are also reusable and waterproof which allows its permanence with the baby all over the time.

There are some important advantages that could be pointed out to the utilisation of this security systems based in the RFID technology. With the adoption of this systems any unauthorized person trying to take an infant from the bed nursery will set off an alarm 10 feet before they hit the exit door since if the alarm goes off, everyone comes running. In operational terms, it is easy to attach the tag since it is done automatic enrolment. Also no manual checks is needed given that the system software continually monitors the status of all devices, and will generate an alarm if something goes wrong. It also allows an automatic mother/infant matching as

with the kisses option, the system immediately confirms that the right baby is with the right mother. There are no buttons to push, no numbers to match and no wall-mounted lamps to check. Another advantage that could be highlighted to this system is its user friendly given that the users only see the menus and commands they need, all in a standard Windows based PC environment. Finally a full supervision is granted by the system.

The main disadvantage that could be pointed out to the use of this system is its costs. Like was referred by Borck (2006) and also Kinsella and Elliot (2005) it involves a big investment and the return of it is only recuperated in a long time.

4 Discussion

In a business context the RFID technology has reached many adepts by the huge potentials that it presents for organisations. The RFID technology has received also considerable attention from academics and practitioners because of its potentialities and diverse fields of use in organisations such as: manufacturing, transportation, distribution, information systems, healthcare, and others. The increase use of the RFID has been pointed out by several kinds of organisations because of the advantages gathered with its use.

The adoption of this technology allows a quicker flow of information, an improvement in the quality, and a better synchronisation among members of the supply chain. To the healthcare organisations, the RFID permits a better patient flow management, improve the organisation' productivity, reduce human errors, the speed of data access and multiple item identification, the

automation of some process activities, the remote item/people tracking and, so on. The main disadvantage signalled is its cost.

The Portuguese hospitals' experience with the RFID can be found mainly in infant security systems with the Hug system. This system intends to prevent infant abductions and inadvertent child mishandlings in hospitals. This system has been well accepted by hospitals because the number of children abducted and mishandlings in hospitals is excessively large and deserves an urgent solution.

Besides the healthcare organizations had already wake up to the potentialities of the RFID Technology in some specific applications there are however other medical services and valences that could be improved through the RFID technology. The Joint Commission (2007) has signed up some errors that must be avoided in any kind of healthcare organization such as: (i) patient care hand-over errors; (ii) wrong site and procedures; (iii) wrong person surgical errors; (iv) medication errors; and (v) high concentration drug errors. To overcome these errors the RFID technology could be the answer. Being so, we propose as future directions other researches on the application of the RFID in these areas as a way of improving the performance of healthcare organizations.

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