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I'VE GOT YOU UNDER MY SKIN: THE PAST, PRESENT, AND FUTURE USE OF RFID TECHNOLOGY IN PEOPLE AND ANIMALS

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ABSTRACT

Although RFID technology has gained in popularity among businesses for the past two decades, it has been mostly applied to objects such as tangible products, raw materials, and manufacturing parts. Discussion and guidelines for its applications on people and animals are rather limited. Since people and animals can change their locations independently, their use of such technology is far more complex and a proper guideline is needed to ensure higher success. In this study, we brought upon factors that may influence of the success of RFID uses on people and animal by reviewing the past, present, and future use of RFID technology. Factors such as motivation to use, privacy, certainty of carrying, and confidence of identification are synthesized to develop a guideline that can be used by future RFID adopters.

Keywords: radio frequency identification, RFID, tracking living beings, privacy, confidence of identification

INTRODUCTION

Radio frequency identification (RFID) is a technology that can uniquely identify an object using radio frequency transmissions [40, 42]. A basic RFID system consists of three components: Tags, readers, and an application system (see Figure 1). Contrary to public belief, RFID technology is not new; it actually originated in World War II for aircraft identification [15]. Today it is in use for speeding cars through toll booths, marking medicine bottles, and tracking large products as they move around factory floors. RFID tags are attached to products to help reduce counterfeiting and shoplifting [5]. When

used in conjunction with mobile technologies, RFID can enable "process freedoms" and real-time visibility into supply chains [1]. RFID technology is also used to synchronize information flows in a given supply chain, which in turn provides a better level of information integration between supply chain members [36].

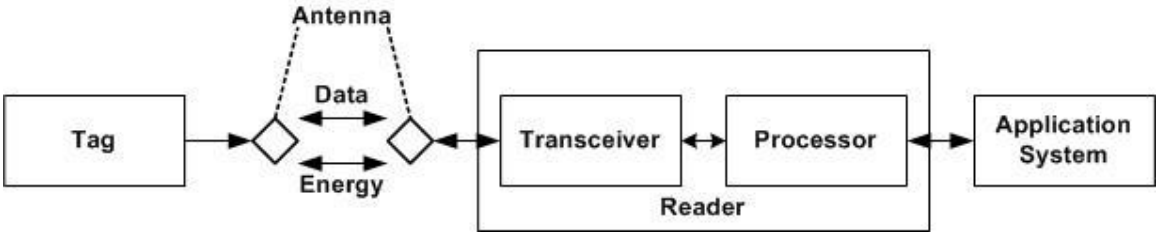

Figure 1: A Typical Block Diagram of an RFID System (from Zhang et al. [42])

RFID was also implemented in fashion retailing in customer relationship management, shop floor management, marketing and promotion, and logistics and inventory management systems [18]. Improved operational efficiency and effectiveness, and increased sales and profits, are the major perceived benefits, while implementation cost, compatibility with current systems, data accuracy, top management attitude, and staff acceptance are the key challenges. In 2003, Wal-Mart started laying out timetables demanding that its suppliers use RFID chips and then the U.S. Department of Defense joined in. While there are certainly technical and cost issues, the prospect of identifying virtually anything without the clear line-of-sight needed by bar codes is too tempting to dismiss. The RFID utilization is found to improve organizational agility and thus operational performance for manufacturing firms [41].

One increasingly intriguing use of RFID technology is to track living beings, i.e., people and animals. Unlike physical items such as automobiles and other consumer products, people and animals can change locations on their own and need to be found from time-to-time for a variety of reasons. There are additional issues associated with people and animals that make the study of RFID tags applications more compelling. First, people are on a unique level when considering an entity's "value." Second, people and animals can move not only independently but also more flexibly than inanimate objects. Third, people are the only entities that may be able to make a decision about whether they will be tracked. That is, motivation and the related issue of privacy enter into it. Will people tolerate being tracked wherever they go? There are three scenarios/motivations that drive the use of RFID tags on people. The first is if users feel that there are measurable and clear benefits, e.g., patients who need to be monitored closely. It is the case of voluntary uses. The second is there are circumstances in which the use of RFID chips may be mandatory/required and the people have no choice in the matter, e.g., criminals on parole who should be tracked continuously. The third is in applications in which the use of the tag is so innocuous especially, when using it is a social norm, e.g., people attending exhibitions or conferences. It is important to note that these are not necessarily mutually exclusive.

A commonality between the use of RFID in people and animals is that an RFID chip can either be implanted under the skin of a living being (at least a mammal) or it can be "carried" by it. We put the word "carried" in quotes because its meaning can differ between people and animals. For an animal to "carry" an RFID chip, clearly it must be attached to the animal, as with ear tags in cattle. For a human to carry an RFID chip, there is a range of possibilities with different degrees of permanence. It can be in a pierced-ear earring, in a bracelet of the type that will stay on until it is cut off, or on a chip that can be literally carried on a card in one's pocket or on a badge attached to one's clothing. While implanting a chip is a more severe act than carrying one, it is also more secure in the sense that a carried chip can be switched from one person or animal to another much more easily.

Clearly, the application of RFID on people and other beings are complex issues and can benefit from having a structured guideline to help facilitate the decision. This study therefore suggest that there are at least four factors to be considered in proposing an RFID application involving people, two of which also apply to animals. First is *motivation*: Why should a person be willing to be tagged? Second is *privacy*: Will being tagged compromise one's privacy? Clearly, these first two elements are related. Third is the *certainty of carrying*: That is whether a person is carrying their chip at any given time. Fourth is the *confidence of identification*: That is whether a person

is carrying the chip that indeed belongs to them. While all four factors are more related to the use of RFID in people, only factors three and four are related to animal applications.

In the following sections, we will summarize the past, present, and possible future uses of the living-being RFID chips. We will divide the subject into three categories: People carrying RFID chips, people with implanted RFID chips, and animals with either carried or implanted RFID chips. We will additionally note the four key factors of motivation, privacy, certainty of carrying, and confidence of identification in each application area, as appropriate. Potential adopters of this technology in living beings will benefit from this discussion in seeing the range of current and future applications juxtaposed with the discussion of the four key elements.

PEOPLE CARRYING RFID CHIPS

RFID-based systems can provide us with a view to human activity that is unprecedented in detail and breadth. Smith et al. [27] described in detail the iBracelet and the Wireless Identification and Sensing Platform that was used to infer human activity directly from sensor readings. In terms of motivation, people might carry RFID for varying reasons including (1) mandatory use, (2) to receive direct benefits/voluntary use, and (3) to use it because others do/social norms. As for the certainty of carrying a tag, it depends on the circumstances. If a person enters an environment and is issued a tag (i.e., attending conferences), the certainty of carrying is high. On the other hand, if the person has been issued a tag for a long-term application, it is possible they do not have it with them at all times. Thus, it is very common to add an extra feature to the tag to promote its use such as using the tag to gain entry to restricted areas. Regarding the confidence of identification, there is no absolute confidence that the tag a person is carrying really is assigned to them. They may have deliberately or accidentally switched tags with another person. Precautions, such as having a person's photo on the tag and a requirement to display the tag on one's clothing can help to promote the confidence.

A good example where carrying RFID tags can be both mandatory and voluntary is in healthcare context, especially in hospitals. Oftentimes patients are vigilant on checking their tags since it may alter the results of their hospitalizations. RFID bracelets worn by patients can provide medical staff with a patient's personal and medical information such as date of birth, blood type, allergies, prior treatments, and the location of any medical appliances installed in their bodies. The data may be on the tag or the tag may be used for identification purposes with the data accessible by a tag/chip reader. Early adopters in the U.S. and Europe include Jacobi Medical Center in New York and Massachusetts General Hospital in Boston [30]. The Palm Beach Florida Orthopedic Institution used to try a variation in which RFID skin labels are attached to a patient's skin near an upcoming surgical location in order to make sure the proper surgical procedure is performed at the right site on the body of the right patient. RFID tags can also be used to control workflow processes in a similar setting. For example, a large hospital in Memphis, Tennessee, has reduced wait times in a pilot study that tags patients in trauma units with RFID ankle bracelets [11]. At a hospital in Charlotte, North Carolina, RFID tags are used to prevent a possible infant abduction. Wang et al. [37] attempt to apply RFID technology to develop a distant medical care service platform (DMCSP) to support home-based medical care. The DMCSP functions include modules such as situation monitoring, diagnosis, prognosis, inventory management, and service scheduling and dispatching. In the proposed platform, patients wearing RFID tags are continuously monitored according to their critical body condition parameters. These monitoring data are interlinked with the prognosis and diagnosis modules in the service center to provide the latest patient physical condition.

RFID chips can be used as electronic wallets to provide customers with speedy and secure payment. In this form of voluntary RFID use, customers simply wave their RFID-embedded tags at a read station which then links to their preferred credit card or bank account without signatures required and with little or no interactions with store clerks. ExxonMobil introduced a version of RFID payment, called Speedpass, in the form of a keychain fob which their customers simply wave over the scanner at a gasoline pump, a convenience store terminal, or a car wash kiosk that says "Place Speedpass Here." McDonald's customers in the Chicago area can pay for their food with PayPass using an RFID-embedded Master Card. Note that while the basic intent here is not about "tracking" customers, it could be used to do so and thus privacy could become an issue. What if such a tag be lost or stolen? In such incidence, users may handle the situation the same way that their credit cards are lost or stolen.

RFID-enabled wristbands can be used by family members to locate each other in amusement parks and other recreational facilities. Each family member tagged with a watch-like wristband can use kiosks located throughout the park to quickly identify where the other members are located on a displayed electronic map. In a variation on the concept, parents can use RFID technology together with their mobile phones to send a text message inquiry and later receive a message indicating the location

of their child in the park [4]. Legoland in Denmark, Wannado City in Florida, Wet'n Wild in Las Vegas, and Steamboat Springs Ski Resort in Colorado are examples of the venues in various stages of introducing this technology. This is an instance of voluntary use of RFID in which privacy is not as much of an issue.

Replacing traditional school ID cards, RFID-enabled ID badges can be used to facilitate a variety of school-related tasks including attendance checking, monitoring which students leave during school hours, paying for cafeteria meals, and checking out books at the school library [4]. A school in Texas has equipped school buses with RFID readers to keep track of when students get on and get off the buses. Tagging students is a mandatory use of carried RFID tags by minors. The certainty of carrying and confidence of identification elements would, presumably be discipline issues. Ervasti et al. [6] developed a location-aware safety service system using both GPS devices ("safety sticks") and RFID tags (attached to keychains) carried by school pupils. Together they were intended to provide continuous and real-time information about the presence or absence of children from certain outdoor or indoor areas. The GPS device was used when the students are outdoors, whereas the RFID tag was used when the students are indoors. Interestingly, people of all the interest groups did not have much privacy concerns as reported in the results of their follow-up study.

Required RFID tags can be used to enhance physical security in a corporate setting by being the "keys" to gaining access to restricted areas and even by tracking an employee's movements in facilities ranging from office buildings to highly sensitive areas such as nuclear power plants. In the public arena, the U.S. Transportation Security Administration worked on a plan to enhance security as well as expedite the security checking process in airports with RFID-tagged boarding passes. The U.S. Department of Homeland Security uses RFID technology in a pilot border-management program. Each visitor entering the U.S. will be issued an RFID tag. This will improve the accuracy of entry/exit records as well as reduce processing time. In 2006, the U.S. government started working on the concept of RFID-embedded passports. As of today, all U.S. passports are issued with an RFID chip. All of these are examples of mandatory uses of the technology. However, there are obvious certainty of carrying and confidence of identification issues, to one degree or another, in all of these applications.

RFID technology can be used to track attendance at events, such as exhibitions and conferences having multiples sessions. This attendance tracking ability would reveal useful information to event organizers, such as which exhibition themes or conference tracks are found most valuable to people with different demographic characteristics and how long attendees stayed in each session. This is an example of an innocuous RFID application in which there is virtually no reason to object. Hsi and Fait [10] explored a custom-designed RFID application called eXspot being prototyped and evaluated at the Exploratorium, a hands-on science museum in San Francisco. The eXspot system consists of a small RFID reader package for mounting on museum exhibits, an RFID tag carried by visitors on a card or necklace, a wireless network, a registration kiosk, and dynamically generated Web pages. After interacting with exhibits, visitors use their ID cards to log onto a museum kiosk and view the exhibit photographs they have captured, either of themselves or of the artifacts they have created. They can then continue their exploration - either from home or at the kiosks in the museum - by logging on to personalized Web pages through their ID card number and email address. While at their personal Web page, they can view the dates they were at the museum, the exhibits they visited that day, and the photographs they took. In this application, some visitors express some concerns of their personal data privacy, including being tracked or scanned remotely.

Finally, in an application that had perceived benefit and was, in any case innocuous, one of the authors was recently issued an RFID tag to attach to his sneaker in a 5K charity run/walk race. This allowed his time to be automatically recorded at the finish line.

PEOPLE WITH IMPLANTED RFID CHIPS

Implanting an RFID chip under a person's skin clearly takes the RFID concept to another level. Either the perceived benefit must be greater than that of just carrying an RFID chip so that people volunteer to get an implanted chip or the circumstances must make it mandatory. And, once the chip has been implanted, whatever the motivation, privacy is clearly waived, or at least minimized. Having said that, when the circumstances are favorable, there is an indisputable advantage to a chip being implanted rather than carried: It cannot be lost, removed, or transferred to another person nearly as easily. Thus, the certainty of carrying and the confidence of identification are very high.

In October 2004, the U.S. Food and Drug Administration (FDA) approved implantable RFID chips for patients' health data. Like carried RFID tags, implantable RFID chips can provide vital patient information (i.e., blood type, age, etc.) and can also be used as an identifying device. The process cost was approximately $150 -

$250. After scanning the chip, authorized personnel can access more detailed information about the person by logging into a password-protected database which is maintained by the RFID chip manufacturer. Further, implanted RFID chips can be used to identify medical devices in patients' bodies such as pacemakers, and implanted tags associated with specially designed sensors can provide current readings of body temperature, blood pressure, pulse rate, and glucose level. Certainly, people can see the perceived benefit in this. Such technology has been adopted in animals to determine whether a pet is ill [7]. Another potential advantage of implanted chips in healthcare is their use in infants and Alzheimer's patients. In addition, the healthcare industry can benefit from the use of implanted RFID to reduce patient fraud. It seems that an increasing number of uninsured people visit hospitals and purposely misidentify themselves pretending to be a relative or friend who has health insurance. However, it is questionable whether implanting RFID tags can be made mandatory for this purpose and doubtful that people will see enough perceived benefit to flock to do it on a voluntary basis.

Starting in 2015, people in Sweden began microchipping [17]. Epicenter, a digital hub in Stockholm that houses 300 start-ups and innovation labs for larger companies, made implanted RFID chips available to its workers and member organizations. Hundreds of people working there volunteered to have a microchip the size of a grain of rice implanted in their bodies (e.g., hands). This would enable them to unlock doors, operate printers, open storage lockers, and even buy smoothies. People with implanted microchips may not need to carry keys, employee badges, credit cards, and even train tickets.

One of the most debatable cases of mandatory human-implanted RFID chips is that of the Mexican government. At the very first phase, one hundred and sixty government officials were equipped with the device so that they were able to enter freely into a new Mexican anti-crime information center in Mexico City [7]. Similar applications of mandatory implanted tags have been discussed for military personnel and firemen in order to improve security control through improved identification [7]. Some correction facilities may implant RFID chips in prisoners to track their locations and movements. Actually, this was tried with tags in wristbands in a California prison, but in this setting and with this population, one would assume that implanted chips, which could presumably be made mandatory, would make sense in terms of certainty of carrying and confidence of identification. With medical-style sensors, correction facility officers may monitor prisoner vital signs which can show the onset of violence. And, what about potential military applications? As advances in RFID tag readers are made, it seems clear that tags implanted in soldiers could take battlefield command and control to new levels.

In 2004, the Baja Beach Club in Barcelona, Spain, became the first nightclub in the world that offers their VIPs a choice of implanted microchips [9]. The microchip is about 1.2 millimeters wide and 12 millimeters long and looks like a long grain of rice. The chip can be injected under the skin, usually in the upper left arm. Clubbers with implanted microchips can jump the entrance queues, speed drink orders and payment, much as in automobile Smartcards. This is a good example of the perceived benefit case for implanted tags. Finally, consider the potential integration of RFID chips with other technologies and devices such as GPS, ATM cards, and firearms. Firearms might only work and ATM cards might only function if they are held by their RFID chip-implanted owners.

ANIMALS CARRYING RFID CHIPS OR WITH IMPLANTED RFID CHIPS

Animals can relate to people as pets, food sources, work animals, and wild animals. RFID chips have also been used to track animals in all of these relationships with both the implanted and "carried" (really attached in the case of animals) approaches employed. There are fewer issues with animals than with people since animals cannot complain about privacy rights, do not have motivation issues, and are not concerned about the aesthetics of an attached tag. The certainty of carrying can vary with the attaching mechanism and how easily a human, or even an animal by biting or scratching, can remove a tag. Similarly, one would also assume that confidence of identification is high. With an implanted chip, the certainty of carrying and the confidence of identification are both very high, subject only to deliberate human acts of mischief.

In addition to being used in the livestock production environment, RFID is commonly used in dogs [16]. When the owner buys a dog he can use the RFID microchip for safety purposes. It can help in finding the dog when it is lost or missing. Microchips are widely used by pet stores, trainers, registers, brokers and breeders. It is also used to record vaccination records in animals. RFID tags are used to track dogs as they enter and leave the Unleashed Indoor Dog Park, the world's first indoor dog day-care center, in Dallas, Texas [31]. RFID tags attached on the dog's collar are used so the animals can enter and exit the facility in a matter of seconds, and the tags allow automatic billing for the animals' owners. The reasons for

the now rapid adoption of RFID in this sector embrace disease control, cost control, safety, crime prevention, and improving customer service. RFID tags are at times punched in the ears of the animals for tracking and for many other purposes.

A prominent pet RFID case is the Portuguese dog application. The Portuguese parliament passed legislation ordering all of the dogs in the country to have implanted RFID chips as a means of identification and rabies control. A contract for the first phase of the work went to Digital Angel Corp. of the U.S. More broadly, the European Parliament enacted a law requiring the eventual electronic identification of pets (e.g., dogs, cats, and ferrets) so that they can be tracked as they travel from country to country. Several European countries already have popular RFID or tattoo pet tracking programs. In the U.S., services with names like Pet-ID and HomeAgain offer pet tagging services through veterinarians and even with do-it-yourself kits, for recovering lost pets [16]. Indeed, California requires its animal shelters to check all lost pets for RFID tags.

The interest in RFID tracking of animals raised for food can be traced primarily to the fear of bovine spongiform encephalopathy or "mad cow disease" [33]. Since the case of the Washington State cow that turned up with the disease in 2003, there have been several attempts in the U.S. to begin a cattle tracking program with RFID chips, generally embedded in ear tags. The U.S. Department of Agriculture (USDA) has proposed a National Animal Identification System (NAIS) for tracking both common and exotic farm animals. The National Cattlemen's Beef Association (NCBA) and individual states such as Michigan are at various stages with their own plans.

RFID tags attached to an individual animal can hold basic information, e.g., its birth date, breeding details, and what inoculations it has received [32]. Sensors can relay valuable information about the animal's eating habits and weight. Also, because RFID tags can detect if an animal is unwell, livestock owners can address any health problems before they get out of control [32]. Scientists at a meat animal research center in Nebraska have developed a new system using standard RFID technology to monitor feeding behavior of feedlot cattle and grow-finish swine in a livestock industry setting [3]. Each animal receives an ear tag that allows the system to identify it, record its presence at the feeder, and thus measure individual animal feeding behavior. Once data are gathered and summarized, people can tell the time spent eating, number of eating events in a day, and timing of the events for each animal. This system can provide valuable management information to aid in animal care. For example, it can be used to detect illness when an animal deviates from its normal eating behavior.

Other countries, such as Australia and Argentina have also shown interest in RFID tagging of food source animals. All Australian cattle are required by law to be "equipped" with RFID tags that provide information to identify, track from farm to fork, and control them [8]. An experimental system in Japan has meat packages in supermarkets marked with unique animal codes which can be entered into a computer that has information about each animal, including its mad cow disease test results (negative, of course). But, this Japanese system brings up an interesting point. Unless very deliberate and expensive procedures are in place to track the cow through its slaughter and butchering, an RFID ear tag is effective only as long as the cow is in one piece. Ordinarily, once butchered, the only effective tracking method is the even more expensive use of DNA as an identification vehicle.

DISCUSSION AND CONCLUSION

Summary of Content

RFID technology enables an organization to significantly change its business processes, not only to increase its efficiency, but also increase its effectiveness [25]. Companies that implement the appropriate business processes and IT infrastructure to leverage the data collected by RFID and its conversion to information, intelligence, and improved decision-making process will accelerate these benefits [25, 42]. In this paper, we have focused on the use of RFID technology in tracking living beings such as people and animals. We have considered RFID usage in three categories, including (1) people carrying RFID chips, (2) people with implanted RFID chips, and (3) animals with either carried or implanted RFID chips. For each category, we have considered four factors, including motivation, privacy, certainty of carrying, and confidence of identification. A summary of the discussion is illustrated in Table 1. The table can be used as a guideline for any businesses to evaluate what type of RFID application to be used. For example, businesses that are operating with highly-private information, they may consider implanted form of RFID to ensure higher privacy, certainty of carrying, and confidence of identifications.

Table 1: Factors to Consider for RFID in People and Animals

Category	Factors			
	Motivation	Privacy	Certainty of carrying	Confidence of identification
People carrying RFID chips	(1) Want to; (2) Have to; (3) Social norms	Yes/No*	Low/High*	Low/High*
People with implanted RFID chips	(1) Want to; (2) Have to	Yes	High	High
Animals with either carried or implanted RFID chips	N/A	N/A	High	High
*Note: * indicating a wide range of the user perception (low/high or yes/no) based on previous literature.*				

Technical and Social Challenges

Even though RFID technology and its applications seem promising and limitless, its ubiquitous adoption and implementation and deployment depends on whether we can adequately address the technical and social challenges it is currently facing. As shown in Table 2, the most cited challenges or barriers to RFID adoption, implementation, and deployment are cost, standards, lack of expertise, privacy and security, and health related issues. Other challenges or barriers include interoperability and compatibility [2], business process reengineering [35], reliability [29], and integration with legacy systems [38], etc. Apparently, these technical and social challenges are not only related to RFID technology used in tracking living beings such as people and animals, but they also are related to inanimate objects such as cargo and merchandise.

Table 2: Major Technical and Social Challenges

Challenge	Source
Cost	Asif and Mandviwalla [2]; Kumar et al. [14]; Ohkubo et al. [22]; Shoewu and Badejo [26]; Smith and Konsynski [28]; Soon and Gutiérrez [29]; Viehland and Wong [35]; Xiao et al. [40]
Standards	Asif and Mandviwalla [2]; Ngai and Gunasekaran [20]; Shoewu and Badejo [26]; Soon and Gutiérrez [29]; Viehland and Wong [35]; Xiao et al. [40]
Lack of expertise	Asif and Mandviwalla [2]; Ngai and Gunasekaran [20]; Shoewu and Badejo [26]; Viehland and Wong [35]
Privacy and security	Asif and Mandviwalla [2]; Neumann and Weinstein [19]; Ngai and Gunasekaran [20]; Ohkubo et al. [22]; Ramos et al. [24]; Soon and Gutiérrez [29]; Viehland and Wong [35]; Weinstein [38]; Xiao et al. [39]; Xiao et al. [40]
Health related issues	Kazmeyer [13]; Neumann and Weinstein [19]; Timmer [34]

One challenge is cost. Xiao et al. [40] discussed five critical research issues of RFID technology, and listed cost control as the #1 critical research issue; other four critical research issues included energy efficiency, privacy issue, multiple readers' interference, and security issue. Smith and Konsynski [28] identified six types of RFID costs: (1) The cost of the tag itself; (2) the cost of applying tags to products; (3) the cost of purchasing and installing tag readers; (4) system integration costs; (5) the cost of training and reorganization; and (6) the cost of implementing application solutions. Apparently, searching for way to decrease the adoption and implementation and deployment costs is critical. Analysis showed that the cost of implementing current RFID technology is too expensive for broad and sweeping implementation within the healthcare sector at this time [14]. Affordable tags and technology simple and secure enough to ensure personal data privacy are required before retailers implement and consumers trust and confidently use them on a mass scale [22].

Another challenge is standards. The initial barriers against widespread adoption of RFID technology include standards, interoperability, costs, forward compatibility, and lack of familiarity [2]. Their analysis suggests that business needs to overcome human resource scarcity, security, legal and financial challenges and make informed

decision regarding standards and process reengineering. The RFID technology is not fully mature and suffers from issues of attenuation and interference. A laboratory experiment conducted by them shows that the middleware is not yet at a "plug-and-play" stage, which means that initial adopters need to spend considerable effort to integrate RFID into their existing business processes. Despite the growing RFID market, the following are some of the major contributing factors preventing the adoption of new RFID technologies across the full range of industries [26]: Lack of standardization, high costs of implementation, slow technology development and deployment risks, and elimination of unskilled labor. Viehland and Wong [35] identified the most important and unsolved issues that may determine the future of radio frequency identification (RFID): Standardization, system costs, business process reengineering, integration, privacy, lack of RFID-skilled professionals, and data warehousing. The most frequently cited barriers of RFID technology adoption are standards, cost, reliability, and privacy [29].

The privacy and security challenge as well as health related issues are mainly tied to using RFID technology in tracking people. "RFID benefits may be negated by numerous opportunities for accidental or intentional misuse of the technology and its supporting systems, along with a wide range of issues relating to system and data integrity, personal well-being, and privacy" [19, p. 136]. Rightfully, people are worried about their privacy and data security. According to Ramos et al. [24], six pieces of information can be stolen from the RFID chip on a U.S. passport: your name, nationality, gender, date of birth, place of birth, and a digitized photograph. To ease people's concern, Ramos et al. [24] proposed several effective countermeasures to protect against RFID privacy risks, two of them being described as follows. One countermeasure requires adding a 128-bit secret, printed on the passport and unique to each passport, to the key derivation algorithm, making it less susceptible to brute-force attacks. Another countermeasure requires installing an enclosure to block RFID transmission outside of the immediate area, minimizing the possibility of intrusion on the communication between RFID tags and readers. Furthermore, Xiao et al. [39] present several mechanisms to enhance privacy such as killing tags, shielding tags, locking tags, re-encrypting tags, silent tree walking, regulating tags, selective blocking tags, anonymous tags, and hash-based anonymous tags.

According to Ngai and Gunasekaran's [20] study, the following are the issues facing RFID adoption: (1) globally interoperable standardization problem, (2) environment, (3) security and privacy, (4) data management, (5) tag failure rate, (6) quality assurance, and (7) RFID expertise for deployment. According to the same study, the current challenges facing RFID adoption include: management commitment, dual systems, cost challenges, legal and patent challenges, operational automation, selection of hardware and software and technology support for adoption.

Health related issues are a big concern. The chip implants could cause "infections or reactions of immune system." Specifically, Kazmeyer [13] says: "As with any foreign object that enters the body, implantable RFID tags could pose health risks. These chips are extremely small to minimize trauma, but injection sites still may become infected, and the chips may also work their way to the surface of the skin over time. In addition, a powerful enough RFID pulse could damage the chip, possibly causing irritation or trauma to the surrounding tissue." According to Timmer [34], "The Associated Press has produced an extensive report on the potential risks of RFID devices, which have been approved for use in humans. The report cites a range of animal studies that have linked similar devices to cancers in experimental animals, such as mice and rats. The report is generally well prepared and raises both scientific and ethical issues." Apparently, more in-depth research studies are needed to verify and validate these results related to health risks to people and animals, especially pertaining to implantable chips. If health risks do exist, research efforts should be focused on how to eliminate or at least minimize the risks that implanted chips pose to people and animals. Technical development to leverage on the benefits of RFID and to address the health concern is still evolving. For example, DuoSkin, a joint collaboration between MIT Media Lab and Microsoft Research, is in the process of developing on-skin interface devices in a form that is similar to temporary tattoos or jewelry [12].

Best Practices for Adoption

There exist some best practices pertaining to the adoption, implementation, and deployment of RFID technologies. Note that these best practices are not related to RFID technology used in people and animals in particular, but are related to RFID technology in general. Niederman et al. [21] suggest that we integrate RFID data into business processes and develop feedback-loops that generate more efficient and effective business processes and decision making. Successful RFID deployment involves changes in firm organization, business processes, and technological applications [21]. Angeles [1] proposed some guidelines for IT and business managers for the proactive implementation of RFID technologies: (1) make the ROI case for RFID, (2) choose the right RFID technology,

(3) anticipate RFID technical problems, (4) manage the IT infrastructure issues including data management concerns and integration with back-end applications, and (5) leverage pilot project learning experiences. In the DOD's case, the expected benefits of deploying RFID in logistics include: reduced shipping losses, reduced inventory losses, reduced duplicate order issuing costs, and reduced duplicate order transportation costs [23]. The best practices discerned from the experience of Wal-Mart, Tesco, Metro Group, and the Department of Defense following the deployment of RFID technology in the supply chain and store operations are: executive support, business case development, pilot testing, performance measures, and personnel training [23].

Conclusion

The list of applications for RFID tags on or in people and animals is literally being updated daily. In a news article, "Apparel Maker Tags RFID for Kids' Pajamas," saying, "Children's sleepwear with radio-frequency identification tags sewn into the seams is expected to hit stores… The PJs are designed to keep kids safe from abductions…" This is yet another method for "carrying" RFID tags. In this twist on the theme, there is perceived need (albeit by the parents) and there is no privacy objection because the carriers are children. The bottom line is that the potential range of applications for the use of RFID tags on or in people and animals is enormous and is limited only by the imagination.

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