RFID and NFC in Healthcare: Safety of Hospitals Medication Care

[1]Antti Lahtela, [1]Marko Hassinen, [2]Virpi Jylhä
[1]Department of Computer Science, [2]Department of Health Policy and Management
University of Kuopio
P.O.Box 1627, FIN-70211 Kuopio, Finland
Email: antti.lahtela@cs.uku.fi, marko.hassinen@cs.uku.fi, virpi.jylha@uku.fi

***Abstract*— Use of information technology has become commonplace in healthcare. In an ideal world a patient always gets first class treatment and everything goes smoothly and as planned. Applications of information technology are created to help the hospital staff achieve this. However, hospital staff is often working under a heavy workload and minimal workforce. This may contribute to human error, for example, in medication that may have adverse effects on patient's treatment.In this paper we will demonstrate how to improve patient's safety in healthcare and especially in medication care by using RFID (Radio Frequency Identification) and NFC (Near Field Communication) technologies. We will concentrate on the technologies itself and how they could be used in different parts of healthcare. Earlier research results concerning this area are also evaluated.**

I. Introduction

In the future, the development of information technology will inevitably affect the healthcare system and its practices. Healthcare practices must adapt to the challenges of expenses vs. assets well as ageing people [1]. Use of information technology in different operations can improve patient's safety and nursing efficiency and therefore decrease healthcare expenses [2].

Enhancing patient's safety internationally and nationally is one of the essential targets in healthcare development. In Finland, the Ministry of Social Affairs and Health, has set up a working group (at the beginning of 2006) to investigate this matter. The aim of this group is to coordinate and evaluate the development, reporting, and feedback of adverse events and be networked internationally. [3]

Mistakes in patient care can cause humane suffering and additional expenses to the healthcare system. Different types of international estimates show that 2-5 % of all expenses of a fairly large hospital are caused by adverse events or the appropriate care being late. In case of medication errors this would mean about 40 million euros of additional costs in Finland, if the amount of mistakes were same as in the United States. [4]

According to international studies, adverse events in nursing happen to about 10 % of patients that are in hospital care. The diciest operations are medication care and surgery [4]. Medication errors occur predominantly with medication orders (49 % - 56 %) or administering medication (26 % - 34 %) [5]. A research, made by Peijas Hospital (Finland), supports these international reports: 33,6 % of all medication errors was related to documentation, 31,1 % was related to medication administration, and 19,5 % was involved with medication prescription [6]. Developing and using a new technology for administering medication would help prevent these errors and bring safety to patient's care.

One part of healthcare and patient safety is identification: patients need to be identified when they arrive at the hospital, different kind of materials and devices need identification as well as medications and patients under medication. There are many targets for identification in healthcare for monitoring and registration purposes. For example, medication care includes several stages where misidentification can be fatal. The Benner's working group, which investigated errors in nursing, created a taxonomy for different medication errors. Seven types of errors were identified in their study: 1) incorrect dose of medication; 2) wrong time of administration of medication; 3) too fast IV rate; 4) wrong concentration or dosage of medication delivered; 5) wrong route of administration; 6) wrong medication administered; 7) wrong medications delivered due to misidentifying a patient [7].

II. RFID and healthcare

RFID (Radio Frequency Identification) is a technology for identification using radio waves. Its main parts are: an RFID identifier (a tag, also called a responder), an RFID reader and a data system for handling the information. RFID tags, which include an antenna and a chip for information storage, are commonly installed on targets that need to be identified. The content of the chip can be read and written with an RFID reader. The technology is comparable to the bar code system, where a reader reads the information from a bar code. In RFID identification systems reader can read and write tags information without a line of sight. Also, the information of a tag can be rewritten, where the bar code is unchangeable and an RFID reader can read several tags simultaneously. [8] Other great benefits of the technology are its reusability, reading range, security, and the data's easy transmission between the tag and the reader [9].

Figure 1 shows RFID's main parts and how they are connected with a simple data system. The figure represents how a tag is placed to an object to be identified. This tag includes information about the object. The information is read

by a reader that sends them into a data system for further processing and investigation.

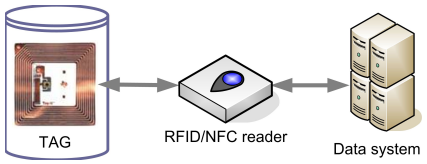

Fig. 1. Simple RFID/NFC system.

RFID tags can be classified into different groups depending on their features. Their power source (active, passive, semipassive), frequency band (below 135 kHz, 13,56 MHz, 860-930 MHz and 2,45 GHz), physical size (almost for every size), and storage capacity (from bits to kilobytes, even megabytes) bring each one a characteristic to a single tag. In proportion, there are two kinds of RFID readers: fixed or mobile. Both of them have an antenna for sending and receiving information, and a reader for reading the information from tags. [8]

The RFID technology shows a way to move from manual identification processes to automatic identification. This way, especially the data entry, is far more reliable than using, for example, handwritten information. The RFID automation also increases productivity even when working in difficult environments and certain tags are hard to counterfeit and/or break which increases security. [9]

Using RFID in healthcare has mainly been studied in the U.S. and methods have been tested in a hospital environment. Next we will discuss some of the discovered research results:

RFID has been used in different access control systems for improving hospitals safety. A tag sends an alarm when a patient is leaving the department without permission. The cost of hospitals lost equipments can decrease by using RFID. Tagged equipments are identified and found quickly without any further use of time. Tagging medical instruments is also a good way to decrease expenses and save time for finding those. With this method the medical staff can monitor use of instruments, improve billing, and give information for the people working in maintenance. [10]

RFID can be used for monitoring temperatures in different situations. Transporting blood is a one event, where RFID is a useful help for observation. A tag, responsive to temperature, enables a real-time follow-up for assuring proper transport conditions. [10]

Organizations in healthcare believe that RFID will bring savings and development for present identification systems well as improvement to patient care. Identification systems in geriatric and hospital care have been under development, where tags have been placed to patients for identification and information. A tag, placed on a wristband when patient arrives to the hospital, can be used to store information about the person (name, blood type, allergies, medication etc.). In case the patient has previous records, a reference to those records could also be stored into the tag. This way patient records are up to date and their identification is much easier in future. Also, a tracking system for hospital equipment and materials has been under development. [10], [11], [12]

In the Orthopedic and Trauma Operating Unit of Töölö Hospital, Helsinki Finland, a system for tracking patients with a decision for urgent surgery, was build and tested. At the hospitals emergency department, after the decision, each patient was given an active RFID tag to wear. The patients were monitored throughout the hospital, where the tracking system was available and data from patients' movements were gathered. [13]

In reference to previous studies, we can find that in healthcare it is possible to build and develop RFID identification systems for almost every situation, where something must be identified or monitored. This way the risk of different kind of errors decreases and identification is more secure than with present systems. Using RFID can improve patient safety especially in medication care. [10], [11], [12]

The safe medication care is based on five "rights": right medication, right patient, right dosage, right way of taking medication, and right time [14]. With the help of RFID, giving the right medication and the right dosage to the right patient can be done safely. The tag could also include information about the patient's medication allergies and possible data of medication combinations. In addition, RFID can help with identifying outdated medication [10].

Figure 2 shows how RFID could be used in medication care combined with the electronic patient record and a data system. Tags are placed onto the patient and onto the medication, which information the nurse reads with RFID reader. Next the information is transmitted to the data system for handling, from which the data finally continues to the electronic patient record and to the nurse. The information, which is automatically read from the medication and from the patient to the electronic patient record, improves the surveillance of medication care. This is where international studies have noticed some deficiencies [15].

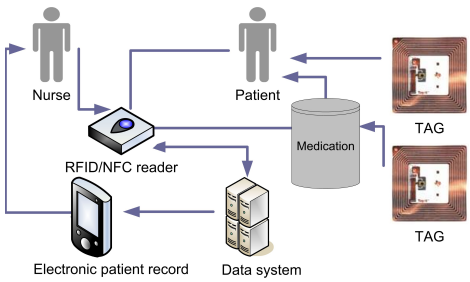

Fig. 2. Using RFID/NFC in medication care combined with electronic patient record

III. NFC AND HEALTHCARE

NFC (Near Field Communication) is an RFID based technology that enables short-range wireless information exchange. The communication range is typically 0-20 centimeters facilitating touch-to-launch applications that are intuitive and easy to use by all user groups regardless of their ability to

cope with modern technology in general. The range, however, also enables contactless action as the action can be launched when a device is in close proximity.

The NFC technology uses reader/writer devices and tags (responders) as in the RFID technology (see figure 1) and magnetic induction to power the tag which may not have a power source of it's own. The frequency NFC operates in is standardised 13.56 MHz, which is an open frequency. The data transmission rates avalable to date are 106 kbits/s, 212 kbits/s and 424 kbits/s with higher rates expected in the future. The tags vary considerably in their properties such size (the smalles being ¡ $0.5mm^2$), memory capacity (from a couple of kilobytes to over 1 megabyte) and price. [16]

It is also possible to have data interchange between two NFC devices so that both devices generate their own radio fields (also called the active operation mode) in comparison to the passive mode in which only the reader/writer device generates the radio field and the tag merely responds.

NFC technology relies heavily on international standards, such as the smartcard standard ISO 14443, which makes NFC compatible with a large number of existing contactless smartcards. Compliance to standards facilitates cross-vendor solutions enabling the user to choose the best combination of tags and readers for a particular task at hand.

One clear advantage making NFC technology a lucrative choice is the availability of reasonably priced, compact NFC devices. Several mobile phones on the market contain NFC readers, such as the Nokia models 5140i (see Figure 3) and 6131. Such devices are small in size, have rather long battery life, can connect to the internet and can be used as ordinary mobile phones.

Fig. 3. Nokia 5140i and a tag.

In healthcare NFC is a newcomer. While many application of RFID in healthcare are described in the literature, not many articles discuss uses NFC this domain. NFC usage in healthcare has been much similar to other areas identification. Facilitating data transfer from patients suffering from chronic diseases was described in [17]. Using NFC the patient could initiate of data transfer by touching a medical measurement device with a mobile phone. Also NFC could be used in medication care as RFID (see figure 2).

IV. RFID vs. NFC

Both of the RFID and the NFC technologies have their own benefits and qualities to perform automated identification in different situations. RFID has been used for several years but NFC is making its entrance to the industry. Especially in various mobile systems, e.g. in mobile payment systems, NFC is a prospective technology. RFID on the other hand has proven very usable in identification tasks where things move fast, quantities are high, and reading range should be rather long.

The demanding identification in healthcare needs high reliability and functionality from the system that performs this task. One function that needs acute attention is security. RFID is not as secure as NFC because an eavesdropper using an RFID reader within the reading range can read the tags if they are on the same frequency and if the tags aren't secured in any way. NFC has a very short reading range compared to RFID making eavesdropping much harder.

The terminal devices of the RFID and the NFC technologies are similar for the readers operations. RFID's terminal is ordinarily a laptop or a PDA with an RFID reader. NFC is also available in mobile phones where the reader is placed in to the phone's shell. This gives to NFC a big benefit because now the "reader" can be used also for communication.

The NFC technology is also more concrete than the RFID technology. With NFC the user must perform more physical work in order to use the technology because the tag and the reader must come very close for reading. In RFID this isn't necessary because RFID can perform its task from a distant range.

V. Case KUH (Kuopion University Hospital)

The Kuopio University Hospital is one of the five university hospitals in Finland. Our future project is to build a pilot system for the KUH. In this system we are going to investigate how with automated identification technologies (in this paper RFID and NFC) the hospitals medication care can reach a level where there will be less medication errors or different kinds of complications in medication care so that the patient safety will not be threatened. This system will be integrated into an automatic medication dispenser (AMD), which will be acquired to the hospital's pharmacy in year 2008. Figure 4 shows how the system will work at the hospital's pharmacy. First the hospital's ward, e.g. maternity ward, sends a list of needed medication to the order processing system. The order processing system will send the list to the hospital's pharmacy and to a pharmacist there. The pharmacist orders the medication from the AMD, which informs the automated identification data system. The data system tells the automated identification reader to write the required information to the tag. This information includes details of the patient who needs the medication and the ward's identification data. Finally, the tag is attached to the medication, which the AMD has generated. After that the medication is transported to the ward, where it will be distributed as shown in figure 2.

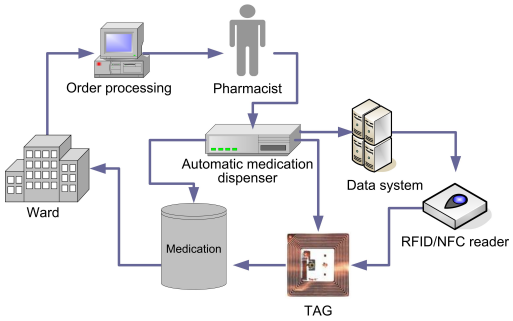

Fig. 4. Medication distribution.

The automated identification system for the KUH has some problems that need consideration. One problem is to find out how the tags could be placed to the medication container? For now, it seems that the medication will be put into a plastic bag after the AMD has handled the medication order. This means that the tag must be placed in or to the bag, but this needs some of evaluation because all of the bags are disposed of after the medication has been given to the patient. The problem is to sort out how tags could be collected from bags afterwards for reuse. This entails more work and expenses, because someone has to collect the tags from wards and clean them up before they can be reused. If the tags aren't collected back, they go to waste, which probably isn't an economical way to handle them. But is this cheaper than collecting the tags? This needs some investigation when the exact expenses of the system are accessible.

VI. Conclusion

The role of information technology in healthcare will be emphasized at same time as operation models and patient safety are developing. New identification technologies can be used to facilitate healthcare and medication care processes.

The RFID and NFC technologies bring needed functions for developing and building a modern identification system for decreasing mistakes in healthcare. With these technologies, controlling different materials and patients can be improved. Also, payment systems for paying the services are one thing that the automated identification has been used for [18] and this possibility seems also tempting in certain areas of healthcare.

Some changes with the work processes are needed to be done. The benefits of the technologies won't be fully utilized by just installing tags and using readers. The processes need to be changed so that they take full advantage of the technologies as well. Also, connecting medical records to the electronic patient record with automated identification is a task that needs development from present systems. With this the validity of information improves substantially compared to existing medication management processes and documentation.

The project for building the automated identification pilot system for the KUH is not a simple task to perform. It needs a lot of planning and research before the system is fully functioning. One of the main challenges for the project is to investigate how the automatic medication dispenser could be integrated with the automated identification technologies. Also, the system has to be easy to use and highly dependable so that the nursing staff and the pharmacists won't make errors in the medication care. Working properly, the system gives a great way to do medication care without confronting medication errors and lack of patient safety.

References

[1] O. Ryynanen, J. Kinnunen, J. Lammintakanen, and O. Kuusi, *Suomen terveydenhuollon tulevaisuudet. Skenaariot ja strategiat palvelujarjestelman turvaamiseksi*. Tulevaisuusvaliokunta. Teknologian arviointeja 20. Eduskunnan kanslian julkaisu 8 ,Edita Prima oy, Helsinki, 2004, in Finnish.

[2] R. Perrin and N. Simpson, "Rfid and bar codes - critical importance in enhancing safe patient care," *Journal of Healthcare Information Management*, vol. 18(4), pp. 33–39, 2004.

[3] Sosiaali- ja terveysministerio, "Potilasturvallisuuden edistaminen," 2007, in Finnish, referred 10.9.2007, available http://www.stm.fi/Resource.phx/hankk/hankt/potilasturvallisuus/index.htx.

[4] U. Idanpaa-Heikkila, "Turvallinen hoito on yhteinen asia. ehdotus potilasturvallisuutta edistäviksi valtakunnallisiksi linjauksiksi ja toimenpiteiksi," 2007, in Finnish, referred 10.9.2007, available http://www.stm.fi/Resource.phx/hankk/hankt/potilasturvallisuus/index.htx.i639.pdf.

[5] R. Hughes and E. Ortiz, "Medication errors. why they happen, and how they can be prevented," *The American Journal of Nursing*, vol. 105(3), pp. 14–24, 2005.

[6] P. Mustajoki, "Hoitoon liittyvät virheet ja niiden ehkäisy - peijaksen sairaalan projekti," *Laakarilehti (Finnish Medical Journal)*, vol. 60(23), pp. 2623–2625, 2005, in Finnish.

[7] P. Benner, V. Sheets, P. Uris, K. Malloch, K. Schwed, and D. Jamison, "Individual, practice, and system causes of errors in nursing," *Journal of Nursing Administration*, vol. 32(10), pp. 509–523, 2005.

[8] RFID Journal, 2002-2007, referred 6.8.2007, available http://www.rfidjournal.com.

[9] L. Cheng-Ju, L. Li, C. Shi-Zong, W. Chi Chen, H. Chun-Huang, and C. Xin-Mei, "Mobile healthcare service system using rfid," in *Proceedings of the 2004 IEEE International Conference on Networking, Sensing and Control*, 2004.

[10] A. Wicks, J. Visich, and S. Li, "Radio frequency identification applications in hospital environments," *Hospital topics*, vol. 84(3), pp. 3–8, 2006.

[11] S.-W. Wang, W.-H. Chen, C.-S. Ong, L. Liu, and Y.-W. Chuang, "Rfid applications in hospitals: a case study on a demonstration rfid project in a taiwan hospital," in *Proceedings of the 39th Hawaii International Conference on System Sciences, IEEE*, 2006.

[12] A. Holzinger, K. Schwaberger, and M. Weitlaner, "Ubiquitous computing for hospital applications. rfid-applications to enable research in real-life environments," in *Proceedings of the 29th Annual International Computer Software and Applications Conference, IEEE*, 2005.

[13] A. Marjamaa, P. Torkki, M. Torkki, and O. Kirvelä, "Time accuracy of a radio frequency identification patient tracking system for recording operating room timestamps," *Anesthesia and Analgesia*, vol. 102(4), pp. 22–24, 1183-6.

[14] D. Benjamin, "Reducing medication errors and increasing patient safety: case studies in clinical pharmacology," *Journal of clinical pharmacology*, vol. 43(7), pp. 768–783, 2003.

[15] S. Eguidanos and R. Brumley, "Risk of medication errors at hospital discharge and barriers to problem resolution," *Home health care services quarterly*, vol. 24(1-2), pp. 123–135, 2005.

[16] Innovision Research and Techology, "Near field communication in the real world. turning the nfc promise into profitable, everyday applications."

[17] J. Morak, A. Kollmann, D. Hayn, P. Kastner, G. Humer, and G. Schreier, "Improving telemonitoring of heart failure patients with nfc technology," in *Biomedical Engineering (BioMED 2007), Austria*, 2007.

[18] S. Garfinkel, A. Juels, and R. Pappu, "Rfid privacy: An overview of problems and proposed solutions," *IEEE Security and Privacy*, pp. 34–43, 2005.