NFCARE
Possible Applications of NFC Technology in Sanitary Environments

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Abstract: In this paper we discuss the introduction of the NFC technology in the management of the assistance operations in the hospitals. NFC is a new short range communication system based on RFID technology.
NFC systems can work like traditional RFID systems, where a master device reads some information from a slave device, but they can also set up a two-way communication between two items. In particular, NFC devices can be integrated on mobile phones, widely enhancing the intercommunication capabilities of the users.
The introduction of NFC in sanitary environments can help to make safer all the assistance operations. Next to the realization of a NFC electronic case history, we also studied the realization of electronic medical prescription and the use of this technology for the exchange of patient data between doctors and between nurses, in order to avoid errors in the attendance operations.
The final idea is to change a mobile phone into an interactive multipurpose assistant for people working in hospitals or in harness with patients.

1 INTRODUCTION

The acronym NFC stands for Near Fields Communication and indicates a new communication technology directly deriving from RFID identification systems.

Like many RFID systems, NFC works at the frequency of 13.56MHz and is based on the physical principle of inductive coupling.

The main difference between the two systems derives from the fact that, while RFID is strictly an identification technology, NFC has been studied to be properly used as a wireless communication technology between devices brought to a short distance between them.

Nowadays many mobile devices producers are beginning to realize phones and PDAs equipped with NFC circuitry, also providing the software to realize applications using this technology.

The main fields of application of NFC include proximity payments, peer-to-peer communication and obviously, strictly deriving from RFID, access control.

In sanitary environments RFID has found many applications: one of these has been the managing and the identification of patients.

In particular an electronic case history located on passive RFID bracelets has been studied and realized in a previous work (Benelli, Parrino and Pozzebon, 2008), showing the benefits deriving from the chance to get vital information directly form the electronic support, with a reduction of the times of assistance and of the risks deriving from human errors.

The idea of this article is to show how much the performances of RFID systems can be widen moving to NFC technology, which can be used to execute the same operations made by mobile RFID devices, but adding many new functions once unfeasible.

2 NFC TECHNOLOGY

Before talking about how to introduce NFC in sanitary environments it's important to describe its main technological features.
It's obviously impossible to speak about NFC without briefly introducing RFID, which represents a fundamental technological background.
In the second subsection are then described the main characteristics of NFC communication protocol, in order to understand the various ways of interaction

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between different devices.

2.1 The Origins: RFID

The technological structure of NFC systems is quite the same as the one of RFID systems. NFC uses the same physical principles and partly the same kind of devices.

It's therefore difficult to understand the structure and the possible uses of NFC with investigating a little the main features of Radio Frequency Identification technology.

RFID is an automatic identification technology which uses the electromagnetic field as the mean of identification (Finzkeller, 2003). Usually RFID systems are composed by two devices: a Reader, which generates the interrogating electromagnetic field, and the Transponder, which is located on the item to be identified and returns back to the reader the ID (*Identification*) code and the additional information.

When the Transponder comes inside the EM (*Electromagnetic*) field of the reader it can be interrogated and it can send back the data using the same field.

There are many kinds of RFID systems, working at different operative frequencies. In particular we can find Low Frequency (125-135kHz), High Frequency (13.56MHz), Ultra High Frequency (868-915MHz) and Microwave ($> 2GHz$) systems.

Every different RFID application needs a particular care in the choice of the right technological solution: for example even if Ultra High Frequency systems can provide large read ranges, they have a lot of problems od electromagnetic compatibility.

The same happens for the powering methods of the transponders: in fact we can find passive, active or semipassive transponders, offering very different features. While an active transponder can be read from a distance ten times wider than a passive one, his higher price can make it unsuitable in applications in which the number of items to be identified is very high.

2.2 NFC Technological Features

NFC belongs to the family of RFID, but it has specific technological features (Innovision, 2007).

It only works at the frequency of 13.56MHz, that is an unregulated band. This means there aren't any licenses required and restrictions concern only the electromagnetic emissions, in order to limit the impact of the system on human body.

Differently from traditional RFID technology, passive and active devices can be integrated into the same system.

NFC can reach a maximum read range of around 20cm but common devices are not able to read from distances larger than 4 or 5cm. The decision to create products with low read ranges comes not only from the physic limitations of the technology but also from the fact that short ranges ensure a bigger protection from outside intrusions. These requirements mainly come from the aim to use NFC to implement proximity wireless payment systems.

NFC devices can currently communicate at three different speeds, 106kbit/s, 212kbit/s and 424kbit/s but in the future higher rates will be probably achieved.

NFC protocol differentiates the device initiating and controlling the communication, called *Initiator* and the device answering the request from the initiator, called *Target* (ECMA, 2007).

NFC protocol also presents two different operative modalities: a passive mode, with a single device generating the field and the other one using this field to exchange the data, and an active mode, in which the two devices generate their own EM field.

As a consequence NFC devices have studied to integrate on the same support the functions covered by the Reader an the Transponder. This means that we can have three different types of communication:

- The traditional communication protocol of RFID systems, in which the NFC equipped device acts as a Reader and it can get the information stored onto a Transponder and can also write on it.
- A bidirectional communication, in which two NFC devices exchange data between themselves. This case is particularly interesting because, even if the bit rates currently available are not too high, the particular protocol implemented makes the establishing of the communication very easy.
- A communication between a turned on device and a turned off one. In this case the second item is seen by the first one simply as a Transponder, making it suitable for identification and access control purposes.

All these different methodologies of data exchange have brought to the realization of many kinds of systems covering a wide range of applications not only in the field of identification but also in the one of personal communication.

Moreover, the short reading range of the devices makes NFC systems considerably safe, because intruders should arrive too much close to the devices to steal the data.

The large number of possible applications has finally led to the integration of the NFC technology onto the most common communication devices cur-

rently available on the market: the mobile phones. NFC phones can then be used as keys, credit cards or business cards and the number of possible applications is virtually infinite.

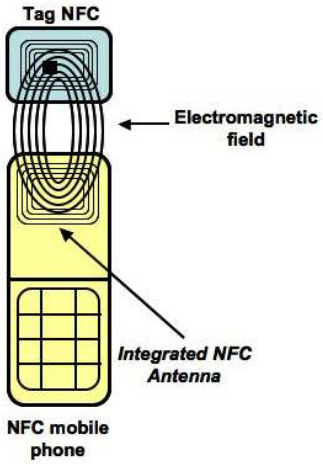

Figure 1: An NFC system.

3 NFC IN THE REAL WORLD

Even if quite new, NFC is a technology whose introduction is supposed to be very fast. In this sense the number of possible devices and applicative fields is growing day by day, making necessary a deep knowledge of the possible technological solutions.
In the following sections we describe briefly the most important typologies of NFC devices and the main applications.
The last subsection describes all the work that has been made in order to create worldwide accepted standards for NFC systems.

3.1 NFC Devices

NFC systems can integrate three different kinds of devices:

1. Fixed Read/Write or Read Only terminals;
2. Mobile Read/Write or Read Only devices;
3. Read Only Tags.

The fixed terminal can be common RFID readers working at 13.56MHz ISO14443 compliant or can be specifically studied devices created to perform specific actions deriving from the particular operation they have to execute.

Some examples of ad-hoc devices can be the NFC POS systems or the electronic ticketing terminals.

Mobile devices are mainly represented by phones or PDA, even if in this case too specific platforms can be studied to satisfy particular requirements.

Many mobile phones producers, including big companies like Nokia, Samsung and Motorola are studying and realizing particular phones with NFC technology integrated, and specific studies assert that by the year 2010 half of all mobile devices will support NFC.

In particular, while many companies have begun to sell specific versions of common phones equipped with NFC infrastructure, Nokia has been the first brand to put on the market a totally NFC phone.

The last kind of devices is represented by Tags. In this case common ISO14443 RFID tags can be used, even if specific products have nevertheless been realized.

Currently four different types of tag can be used in NFC systems:

- Type 1 is based on ISO14443A, is produced only by Innovision Research & Technology and has a 96-byte memory. This kind of tags are very cheap;
- Type 2 is based on ISO14443A, is produced only by Philips (MIFARE UltraLight), and has only a 48-byte memory;
- Type 3 is based on FeLica (a specification compatible with the ISO18092 standard for passive communication mode) and produced only by Sony. These tags have higher memory capacities (up to 2 kbytes) and reach the 212kbit/s rate;
- Type 4 is compatible with the ISO14443A/B standard and is produced by several manufacturers. It has a large addressing-memory capability and reaches rates up to 424kbit/s.

These four kinds of tags represent four strongly different products, and every time that an NFC application has to be realized, the choice of the right kind of tag has to been made extremely carefully.

3.2 NFC Applications

NFC can be used in several different fields. Three different categories of possible applications have been identified (Innovision, 2007):

- Service initiation;
- Peer-to-Peer;
- Payment and Ticketing.

In the ‘Service Initiation’ scenario NFC is used in a way similar to RFID. The NFC device reads the ID code or the saved data from a tag and uses them in many different ways.

In this case the NFC reader can be a fixed terminal or a mobile device, while the Identification device can obviously be a transponder, but can also be a turned-off mobile device. In fact the ID code of the internal tag of NFC phones can be read even if the device is off, allowing for example the use of the phone as an electronic key.

The information retrieved from the transponder (stored data or UID code) can be simply read and displayed, can be used to set up a connection (in this case data can be a URL or a phone number) or can be used for access control in the same way as RFID keys.

One example of this kind of applications can be the 'smart poster'. In this application an NFC tag is located near an informative point: the user brings an NFC phone near the tag, reads an URL stored on it and uses it to connect to the Internet site providing the information requested.

The 'Peer-to-Peer' category is something totally different from RFID systems. In this kind of applications a two-way communication is set up between two devices working in Active mode.

If the amount of data to be exchanged is not too large this can be done using directly the NFC channel. If the amount of data is too big (for example an image), NFC channel can be used to set up another wireless connection (Bluetooth, Wi-Fi) in a way totally invisible to the user, and then send the data through this connection.

In this case NFC is used exclusively to set up the connection. For example in an Internet Point the user can get the Wi-Fi settings touching a specific hot-spot with the NFC terminal and then transfer them, also with NFC, to the device to be connected to Internet.

The last scenario 'Payment and ticketing' is currently the most studied due to high the interest of many banking companies in this technology (Smart Card Alliance, 2007).

The idea is to turn a mobile phone in an electronic wallet or in an electronic credit card. While nowadays a card can be used for a single payment function, with NFC will be possible to collect many different functions on a single multimodal platform.

As we told before NFC is implicitly safe due to its short ranges.

The possible payment operations can be divided in two main groups: micro-payments and macro-payments.

Micro-payments are represented by the electronic wallet. An amount of virtual money is loaded onto the phone and the user can pay various services like tickets or car parks simply bringing the phone next to payment terminal.

Macro-payments can be a little more complicated because they necessarily involve the collaboration with banks. In this case the phone will replace the Credit Cards or Bancomats in payment operations working with POS system. In macro-payments it's mainly used the identification capability of NFC.

3.3 NFC Standards and Organizations

The high interest in NFC technology has brought many companies, coming from very different business areas, to join together into an organization called NFC Forum (NFC Forum, 2007).

In particular the Forum is composed by manufacturers of devices, developers of applications and financial institutions. Among the most important we can cite Hewlett-Packard, Microsoft, Sony, Texas Instruments, Nokia, Motorola, Samsung, IBM, MasterCard, Visa and AT&T, but the most important fact is the the Forum has been joined by companies from all over the world.

The forum has the main purpose to promote the introduction of NFC technology in common applications on a worldwide scale and tries to do this by proposing standard-based specifications, interoperable solutions, and providing stable frameworks for application development.

Being basically an RFID technology, NFC systems are compliant with the ISO14443 standard for proximity cards used for identification.

Next to this specific standards for NFC have been developed. In particular the following standards have been published:

- ISO18092: *Near Field Communication - Interface and Protocol - 1 (NFCIP-1)*: this standard basically specifies the modulation schemes, coding, transfer speeds and frame format of the RF interface of NFC systems;
- ISO21481: *Near Field Communication - Interface and Protocol - 2 (NFCIP-2)*: this standard specifies the mechanism to detect and select the communication mode out of the possible NFC communication modes;
- ISO22536: *Near Field Communication Interface and Protocol (NFCIP-1) - RF Interface Test Methods*: this standard defines the test methods for the RF-interface of NFC systems;
- ISO23917: *NFCIP-1 - Protocol Test Methods*: this standard complements the previous one and specifies the protocol tests;
- ISO28361: *Near Field Communication Wired Interface (NFC-WI)*, this standard specifies the digital wired interface between two components, a

Transceiver and a Front-End, including the signal wires, binary signals, the state diagrams and the bit encodings for three data rates.

4 NFC IN SANITARY ENVIRONMENTS

Even if currently the most studied application field regards the payment scenarios, the versatility of NFC technology encourages its use in many other fields not directly involved in commercial operations.

In particular the availability of common mobile phones equipped with NFC hardware encourages its wide use in applications with high interactivity and security requirements.

In sanitary environments the assistance operations usually involve a high number of actors, including doctors, nurses and obviously patients. Moreover all these operations require a high level of reliability in the interaction among different people because a wrong medical prescription can cause big problems to the patients while in the assistance operations in Emergency Rooms 5 minutes can make the difference between life of death.

The informative and communicative capabilities of NFC can be therefore used to reduce all the errors or misunderstandings deriving from wrong data exchanges or from slow information access.

If the NFC Forum predictions on NFC devices diffusion will demonstrate to be true in the next years many people all over the world will be provided with NFC devices and, due to the standardization of the technology, simply downloading a specific software on their phone they will be able to access at some services modeled on the needs of their particular working environment.

The final idea is to turn the personal mobile phone of doctors and nurses into a multipurpose device joining the personal uses with the common working activities of these categories of people. The phone may therefore become a key, a pen, a sheet of paper, an organizer and, obviously, a communication device.

In the specific case of sanitary environments we studied and developed a set of applications deriving from the first two applicative fields, i.e. *Service initiation* an *Peer-to-Peer* because the *Payment and Ticketing* field is evidently more distant than these two from the specific needs of an hospital.

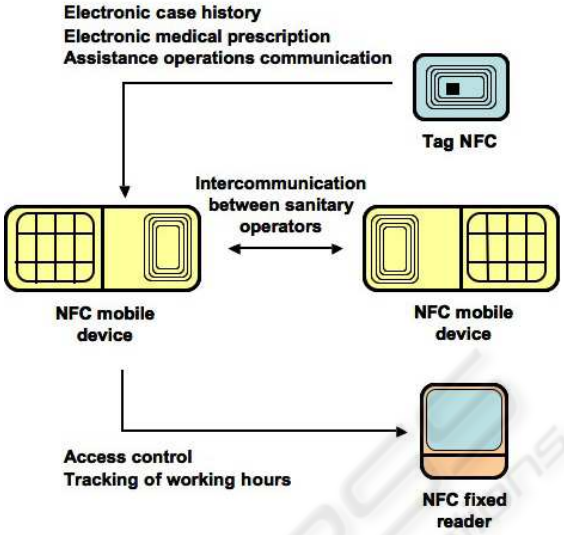

Figure 2: NFC applications in sanitary environment.

4.1 *Service Initiation* Applications in Sanitary Environments

Service Initiation doesn't mean only identification or access control. In this applicative field are included all the applications which use transponders as contactless memories to be read from mobile or fixed devices.

What can be read is not only the UID code of the transponder, but also the information stored on it, which can be codified in order to use in the best possible way the small amount of memory available, and can be ciphered in order to make it unreadable from external users.

Taking care of patients means the performing of a lot of different activities, from the care of wounded people in the Emergency Room to the administration of medicines. Some of these activities can be made safer an faster with the use of NFC phones as reader devices.

In particular the following applications have been studied and developed:

- Access control: entrance in reserved areas and tracking of the working hours of employees;
- Electronic case history;
- Electronic communication of assistance operations;
- Electronic medical prescriptions.

The first application is evidently the closest to the original target of RFID, the automatic Identification. In fact, as we said before, NFC phones can be identified from NFC readers exactly as transponders, even when they are turned off.

This allows to use phones as key to obtain access to restricted areas in the same way as magnetic strip cards. Moreover, the phone can be used to record the accesses and the exits from the working place, a function currently managed in italian hospitals with cards.

In this case the main advantage derives from the incorporation of these functions on the mobile device, preventing the employees to bring with them the requested cards.

The Electronic Case History application derives from a previously studied similar system based on RFID technology (Benelli, Parrino and Pozzebon, 2008).

In many assistance operations the quickness of intervention is one of the most important features to be achieved. Next to this there are some vital information concerning the patient that must be provided to the doctor before performing the intervention: data like blood type, allergies or vaccines are fundamental to avoid dangerous errors.

One of the best ways to ensure a correct and fast reading of the information is to store them into an electronic device and retrieve it with a multimedia support. In this sense the idea is to provide to patients an electronic bracelet concerning mainly of an NFC transponder, where data can be stored and read quickly with a phone in case of need.

Obviously NFC transponder cannot store large amounts of data. As a consequence a severe choice has to be made between strictly vital information, which has necessarily to be provided to the doctor and will be then kept directly on the bracelet, and less important data, like for example the chronology of all the medical interventions made on a patient, which can be stored into a remote database and then retrieved only on request using Wi-Fi, GPRS or UMTS connection (Bing, 2002).

Even if our application has been studied and tested using MIFARE 4K transponders, which provide a 4 kbyte EEPROM, we studied an organization of the information to make it storable also into 256 byte transponders.

This is the bytes subdivision chosen in our application:

- 40 bytes for first name and family name;
- 16 bytes for the tax code, whose decoding allows the recover of birth date, place of birth and gender;
- 10 bytes for the sanitary code;
- 8 bytes for allergies: every byte is a flag indicating the presence/absence of the corresponding allergy;
- 8 bytes for vaccines: every byte is a flag indicating the presence/absence of the corresponding vaccine;
- 8 bytes for infectious diseases: every byte is a flag indicating the presence/absence of the corresponding disease;
- 8 bytes for various information like blood type (1 byte encoding), HIV positivity or smoking/non smoking;
- 100 bytes with a specific codification for the 10 last hospitalizations. Every hospitalization is codified with 10 bytes where the first to bytes are a code corresponding to the specific medical ward, the third and the fourth indicate the kind of intervention and the last six bytes are the date;
- 50 bytes for textual accessory information.

Once the NFC device is brought in proximity of the bracelet, it reads the string of bytes, decodes it and shows the data into a grafic interface. It also gets the UID code of the tag in order to use it as the identification mean to retrieve the information stored inside a remote database.

The application which manages the reading, decoding, recover and reproduction of the information is a Java Midlet, also incorporating simple read and write tag functions.

These functions will be used in the third application, in which transponders are seen as the means to communicate the type of assistance operations performed on a specific patient.

The idea is that every bed in the hospital will be equipped with a transponder. Every time that an intervention is made, before performing the operations the doctor or the nurse reads on the transponder the previous treatment made to the patient, in order to avoid dangerous errors like repetitions in drug administration.

After the assistance has been made the operation performed is written on the transponder with the NFC phone, in the same way as are written SMSs, in order to inform the ones who will make the following intervention.

In the last application we studied the realization of an electronic medical prescription where sheets of paper are replaced with transponders.

The technological infrastructure is the same of the former task, allowing then to incorporate its functionalities into the same software developed for all the other applications.

Instead of writing the medical prescription on a paper, the doctor writes it into a transponder in the same SMS way of the other application. Usually the length of a prescription is less than 200 characters so usually there are no problems of shortage of memory.

Anyway 4kbyte cards can be used in order to avoid any risk of incomplete descriptions.

Once the prescription has been written the transponder can be brought to the chemist who can read it with its own NFC phone.

In many cases handwritten medical prescriptions are very difficult to be read: such a kind of system will help to avoid errors in the administration of medicines, making safer the treatment of patients.

Figure 3: Electronic case history - allergies and electronic medical prescription.

4.2 *Peer-to-Peer* Applications in Sanitary Environments

As described before the *Peer-to-Peer* scenario is the one in which the most interesting innovations are introduced.

The phone is in fact used as a short range communication device allowing people to exchange data simply bringing close to them their mobile phones. The absence of direct interaction from the users to set up the communication channel makes very fast the beginning of the process of information exchange.

This functionality can be joined with the system described in the previous section in order to make the information about patients retrieved with the reading of the electronic bracelets transferable among the people operating around a specific patient.

In fact, usually many different people attend at the assistance of people in a hospital, and in some cases the operations can last even some hours.

Every time that a doctor replaces another one he can download the electronic case history simply bringing his phone close the one of the former doctor.

This operation can be performed for every kind of data that has to be exchanged between two different employees.

For example a doctor can download from a remote server a particular information about a patient like an image of an x-ray and then he can send it to all the other doctors operating with him simply using the NFC channel.

As described before, if the amount of information to be exchanged is too big to be transferred with NFC, this technology can be used to set up a connection in a fast way with other technologies like Bluetooth which can then be used as the real transfer channel.

Figure 4: Phone menu interface.

4.3 NFC Devices used in the Realization of the System

The devices used in the realization of this study are a mobile phone provided with an ad-hoc development kit, a set of transponders and a reader.

The mobile phone used is a Nokia 6131 NFC: it's a particular version of the common 6131 phone with the NFC circuitry embedded. Nokia sells this product in a particular 'Experimental' version, which allows the developers to use all the features of the telephone without the need to validate their applications.

Moreover Nokia provides a Java Development Kit with all the APIs needed to realize NFC Midlet and with a Simulation Environment which can be used to test the applications but can also work as an emulated phone interacting through a NFC reader, connected to the computer, with an external phone.

The Simulation Environment also provides some different simulated transponders in order to fully test several kinds of applications.

In the real testing phase we used MIFARE transponders of different types. In particular we used a MIFARE UltraLight transponder, which is very thin (like a sheet of paper), but it has a small memory (only 512 bit), and a MIFARE 4k, which is thicker but can store up to 4 kbytes of data. Both these transponders are ISO 14443 compliant.

Finally we used a common RFID reader to study the access control application because, once turned off, the phone is read like a common RFID transponder and no specific hardware is requested.

5 CONCLUSIONS AND FUTURE WORK

The aim of this work was to show how much NFC technology can increase the quality of service in situations very distant from the standard payment scenarios.

The performances of NFC systems have proved to be extremely high for what concerns the reliability of the communication channel.

During the reading of the transponder no error has been recorded, especially in the case of the electronic case history, which involved the largest amount of data to be moved.

In addiction the reading and decoding of the data took only some fractions of second, making the information immediately available when the phone was brought in proximity of the transponder.

The modularity of this system, due to the fact that single tasks can be easily integrated into the same software, makes it upgradeable simply adding the new functions to the underlying structure.

Among new applications to be studied we can find some ones deriving from already existing RFID systems, but now made simpler from the presence of mobile phones. In particular we can list the following fields:

- The identification between mother and baby with the use of transponders located onto the cradles or with electronic bracelets.
- The tracking and identification of blood sacks.
- The assistance operations inside the ambulance, which can be made safer using the traditional GPRS and UMTS connections available on mobile phones.

Next to these in many other situations NFC can be used to increase the level of reliability without the need to enlarge the number of devices to be bought. This fact is extremely important because in many cases the introduction of a new service is prevented due to the high costs.

The only expenses to be made to introduce such a system are basically the ones for the mobile phone and for the readers to control the accesses, because currently transponders can be bought with few euro cents, making this expense virtually unimportant.

If the NFC Forum valuations will demonstrate to be true, in the next years we will see a vast diffusion of NFC phones, making the applications described before simply downloadable and executable on the personal phones of doctors and nurses, without the need to buy specific devices.

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