45

NFC TECHNOLOGIES IN MOBILE PHONES AND EMERGING APPLICATIONS

Diogo Remédios, Luís Sousa, Manuel Barata and Luís Osório
GIATSI research group at ISEL,
Instituto Superior de Engenharia de Lisboa, PORTUGAL
dremedios@deetc.isel.ipl.pt, lsousa@isel.ipl.pt,
mmb@isel.ipl.pt, aosorio@deetc.isel.ipl.pt

The main purpose of this paper is to introduce some new non-conventional applications to allow the exploitation of today's mobile phone resources, namely their connectivity capabilities to other devices. There is a great potential for applications to take advantage of these available resources, to perceive and interact with the world around us, namely to serve as a user interface to interact with controlled devices. Recently beyond the necessary speaker and microphone, cell phones incorporate more sensing, processing and storage capabilities as well as alternative communication systems, e.g. digital camera, Bluetooth. This paper addresses, in particular, the Near Field Communication (NFC) incorporated in cell phones and enumerates some of its main promising applications like in device monitoring and control.

1. INTRODUCTION

In today's world, where everyone walks around with a mobile phone in their pockets, one question arises: Are we taking advantage of their full potential?

Mobile phones are becoming ubiquitous, in the sense that they are everywhere, making it possible and easier to develop non-conventional ubiquitous applications. Traditionally Ubiquitous Computing (UbiComp) is divided into several areas of expertise (Weiser, 1993) trying to solve different problems like: Context Awareness (Yau, 2002); Location Awareness (Hightower, 2001); Data availability and Storage (Bindel, 2000).

On the other hand, Mobile computing (Forman, 1994) – the use of a portable computer capable of wireless communication – consists on applications for devices that are mobile having wireless connectivity, or at least having to deal with some of the following problems: Disconnection without warning (Frequent loss of connectivity); Low Bandwidth; High Bandwidth variability; Heterogeneous network; Security risks; Mobility (address and location migration); Low Power restriction; Risk to data Small user interface; Small storage capacity.

A mobile phone, a PDA and a LAPTOP are some examples of this kind of devices. In this category of devices one can also include sensors and actuators, for

Please use the following format when citing this chapter:

Remédios, D., Sousa, L., Barata, M., Osório, L., 2006, in IFIP International Federation for Information Processing, Volume 220, Information Technology for Balanced Manufacturing Systems, ed. Shen, W., (Boston: Springer), pp. 425–434.

example, in a smart building there can be sensors spread across the entire area keeping measure of the temperature, lighting, personnel presence, surveillance cameras, access control mechanisms, etc.

Mobile computing experienced a great evolution since its birth, and still continues to, due to the fact of the ever-growing resources available in mobile devices. These include: Photographic camera; InfraRed (IrDA); Bluetooth; NFC (Near Field Communication); High resolution Color Displays; Generating computer Graphics; Speaker and Microphone; Growing storage capacity; Growing computing capacity; Human Machine Interaction – HMI.

Some of these resources confirm Moore's law (Moore, 1965) (which says the size and cost of electronics shrinks by a factor of two every eighteen months) will provide for more processing power, memory, and storage space. Though, the progress in batteries technology does not follow Moore's law (it improves only perhaps 10% each year), Gene Frantz's law (Pulli, 2003) states that the power consumption of integrated circuits decreases exponentially; hence the batteries will last longer.

However, mobile terminals are already in many ways equivalent or even superior to home computers of ten or fifteen years ago.

These resources extend the ability of the devices to interact and perceive the surrounding environment. As they evolve, so will the applications capacity to help people in their every day tasks. Near Field Communication (NFC) in concrete allows, just by touching or holding a mobile phone within a range of few centimeters of a tag or reader, to be turned into a cashless wallet, an information source, a privileged human machine interface to monitor and control embedded devices or a tool to help make business more effective.

The range of applications that can be developed taking advantage of this privileged interaction is enormous. Keeping those as goal objectives in the horizon let's not forget today's limitations and walk one step at a time in the long walk ahead of us.

A cell phone can be used not only to make phone calls, but also to interact with the environment controlling and monitoring surrounding entities providing services of authentication and control. For example, the cell phone can provide a universal interface to open garage doors, yard gates, front door and turning on/off alarm systems. Moreover the integrated functionalities for the support of human to machine interface can be exploited for implementation of monitoring and controlling functions in manufacturing environments, like the use of the screen and keyboard of the cell phone as small portable contact less terminal.

These kinds of applications have to deal with problems like integrating different systems and security issues, namely, guarantying that the communication is secure and not replicated by an intruder.

In this paper we will address, in particular, how the use of NFC can enhance and facilitate every day tasks, presenting several different usage scenarios and describing in detail an implementation of one case study where a cell phone using its NFC capabilities is used to pay a parking meter (P&D machines).

NFC technology is not at a point where it is feasible to implement all these usage scenarios because it is not available to the major public, yet. Hopefully it will get as widespread as Bluetooth is today, and much quicker. Nokia is being very aggressive in the promotion of NFC technology and is engaging in several field tests like in the

Atlanta stadium and in some commercial environments like fast food restaurants and pharmacies (Nokia, 2005).

The next chapter explains the NFC technology and why we believe that in the near future a major part of all mobile phones will be equipped with it.

Chapter 3 presents several examples of applications where NFC can be a facilitator of everyday tasks.

Our case study is an evolution from a system that enabled the payment of services using the mobile phone Bluetooth connectivity (Remédios, 2005). In this first approach, several problems were identified due to the distance of the communication that can range from 10 to 100 meters. The main problem is the association of the cell phone and the service being paid; if there is more than one service and cell phone, in a limited area, an ambiguity problem arises due to the several possibilities of combinations. An example of this problem is a highway toll where the user through the mobile phone using Bluetooth makes the toll payment, but the system doesn't know in which lane he is to clear his passage. Another identified problem was the initial time needed for the discovery of the surrounding devices. With NFC the proximity requirement solves all of the identified problems.

2. NFC (NEAR FIELD COMMUNICATION)

NFC is the worldwide standard (ECMA, 2003; ECMA, 2004) for mobile phone short-range communication, with the leading mobile phone manufacturers as members of the industry committee (panel includes Nokia, Philips, Samsung, and Sony) (Forum, 2004).

Near Field Communication (NFC) is a wireless technology for short-range communications designed to enable interaction between electrical devices, allowing the exchange of data between NFC enabled devices, assuring interoperability between vendors.

Although NFC has many advantages and solves problems exposed in other wireless communication technologies, its main goal is to simplify communications.

NFC devices operate under the 13.56 MHz frequency, thus allowing interaction between NFC devices and existing contactless cards, since the underlining protocols are those used by FeliCa and Mifare (ISO, 2000) Cards. Expected data rates range from 106 kbps, up to 424 kbps.

This standard (ECMA, 2004) started as a joint effort from Phillips and Sony, to provide a unified interface between electrical devices and also Smart Cards. Nokia joined one year later. Together with Phillips and Sony founded the NFC–Forum. Nokia quickly introduced the technology in Mobile Phones.

NFC is now starting to be deployed in commercial devices. Nokia, for instance, introduced NFC as an add-on shell for Nokia 3220 phones. Philips is producing microcontrollers with NFC capabilities built in that, although not yet stable, it is already being integrated in embedded devices.

3. APPLICATIONS

In this chapter, we present a survey of several emergent applications made possible by the NFC connectivity. This chapter is divided into four subsections, each representing a different type of usage scenario.

3.1. Authentication

Authenticity is very important whether we are authenticating a person or a product. The authentication of a person has great potential, imagine if you could approach your cell phone to a NFC reader and instantaneously the system knows who is trying to use a specific resource allowing or denying access depending on the predefined permissions.

This could be used for access control to the workplace, home, building, garage, etc. This application could replace the use of keys, cards and passwords.

Another example is the authentication of products with an NFC tag. This could lead to better tracking of goods and possibly identify vulnerable points in the supply chain, either detecting damaging or theft hazards. Additionally there is the possibility of the final consumer being able to read from the product relevant information, such as, its authenticity and validity dates. As the tags get cheaper the number of products labeled with them will increase. As an example of this tendency, in Florida, it has been approved a law requiring tagging on all pharmaceutical products starting in 2007. (Kanellos, 2006)

3.2. Interface with the environment

A mobile application running on the mobile phone has the potential to be a privileged access point to interact with systems in the surrounding environment. This could provide monitoring and control to every kind of systems from a device the user is already familiar with. There are several usage scenarios that fit in this category:

The first example is home automation where we don't have to use several different remote controls for different systems like stereo, television, air-conditioned, illumination controls, etc. The only device needed is our mobile phone that we already carry voluntarily everywhere.

Another kind of application is for enabling the collecting of particular data/information relevant for a person like, for instance, description about a monument, a tourist path, museum's visit, advertisement poster, etc. In these situations, the NFC technology will make easy the transfer of the detailed information wanted, and display it on the mobile phone screen, by merely approaching the device near the information supply device installed in these places.

3.3. Token Storage

This usage scenario implies the transfer of a token that by itself represents a digital ticket. The idea is when you buy a plane or a concert ticket instead of receiving a paper ticket, receive a token representing the digital ticket stored in the mobile phone. This allows the token to include some extra information that can be viewed

at any time, like detailed information about the event, etc. NFC should act as the communication medium between the mobile phone and the tickets machine.

After use the ticket expires, it can be deleted or maintained as a customer relationship card where information about the client can be stored to offer future discounts and promotional offers.

3.4. Payment Service

If the mobile application has the ability to guarantee the authenticity of a person then why not use that information in a monetary transaction for a service payment to a given clearing company like *Via Verde (www.viaverde.pt)*, *VISA* or *MASTERCARD*. Security concerns are of the utmost importance and must be guaranteed, just like in the first usage scenario for authentication. The mobile application must have mechanisms to become disabled when copied to other devices. The communication between the mobile phone and the point of sale must be secure.

We choose this usage scenario for our case study to evaluate the technologies and issues involved. The next chapter will describe in detail the architecture of our proposed solution and the developed prototype to provide the users of *Pay & Display* (P&D) machines the possibility to pay with the mobile phone, dispensing the always problematic coins.

4. PROTOTYPE

4.1. Overview

The proposed application displayed in **Error! Reference source not found.** consists in a new method for paying street parks, using a NFC enabled mobile phone to interact with the P&D machines. This gives users a more convenient and comfortable payment procedure. Current P&D machines accept only coins or credit cards as the payment method.

This new approach to street park payments allows the user to specify the exact amount they want to pay and, gives the park operators a great advantage by reducing the amount of coins in P&D machines safe. This leads to less vandalism but also to a cost reduction by decreasing the cash collection rate, from the P&D machines.

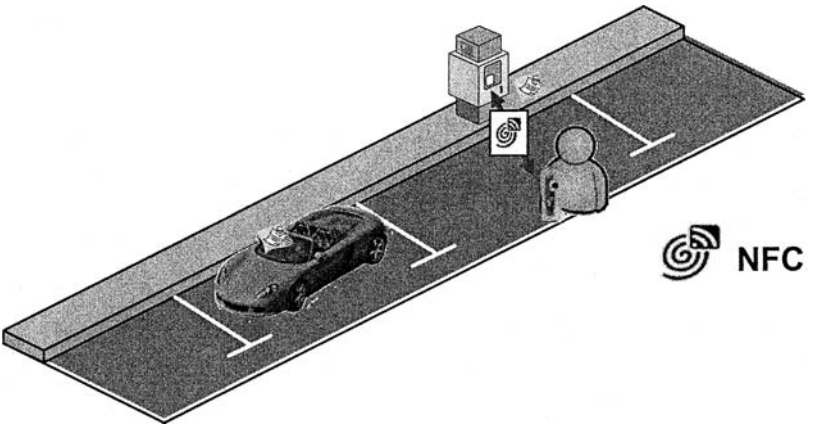

Figure 1 – NFC enabled phone performing a P&D parking payment.

4.2. Architecture

The proposed architecture will use a third party entity as money broker. This model is adapted to the Portuguese scenario where such an entity already exists and is present in every national toll, providing electronic payment alternatives (www.viaverde.pt) based in DSRC technology (CEN, 1999).

The payment scenario presented uses a mobile agent that will be installed in mobile phones, trough the broker's web site. This agent will handle the communication with the P&D machine.

RF communication in the mobile phone side is handled by the phone shell; this shell is connected to the mobile phone by its expansion bus. On the park equipments, an embedded device with NFC capabilities has been added.

The mobile agent has to be installed in the mobile phone. Since this is a piece of software that contains personal user data, and authenticates the user before the system, there are security issues that should be taken into consideration. The most important are: mobile phone theft; mobile agent theft; user ID replacement; mobile ID replacement; and all of the previous combinations.

The mobile agent has to be personalized in a per user basis, to insure that only the subscribed user can use the mobile agent with its user ID. Each agent must contain the unique user ID, assign by the broker, the mobile phone unique identification and the SIM card unique identification.

All this information has to be bound in a single file, and signed using Public Key Cryptography. The signed file will be stored inside the mobile application package. This way the combined user information can be validated by the mobile phone and the P&D machine.

With the schema presented it is ensured that, if the agent is cloned to another mobile phone, it won't work because the mobile phone ID won't match the one in the file. Even if the attacker manages to replace its mobile phone ID to match the one in the file, the SIM card ID will fail to match. The user ID has to be stored in a signed location to assure that a misbehaved user does not change its user ID, trying

to impersonate some other user. All this information must also be sent to the P&D Machine allowing for it to validate all the information and its signature.

4.3. Deployment

With the schema presented above, the application must be packaged on a per user basis. Nevertheless the application installation should be done with the minimum user intervention. Ideally the user should be prompted for his login in the broker's site and based on this information the security file should be generated and signed; the mobile agent should be packaged and then deployed to the user Over the Air (OTA) like demonstrated in Figure 2 and Figure 3.

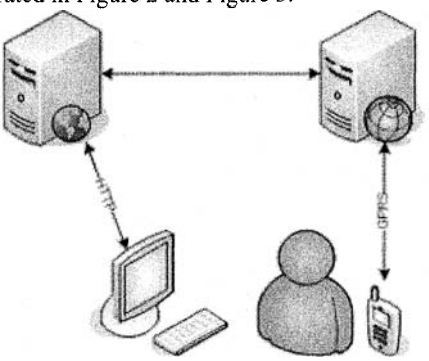

Figure 2 – Submission via PC

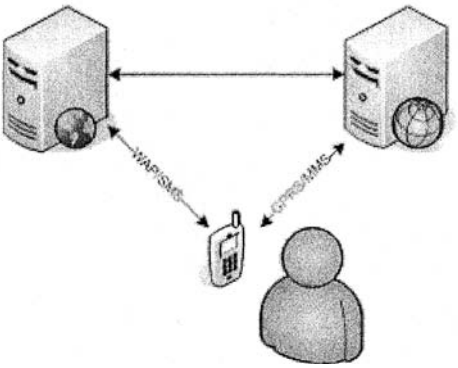

Figure 3 – Submission via Mobile Phone

Over-The-Air deployment, allows the application deployment without user intervention on the mobile phone. Since the user is required to have the mobile agent to interact with the P&D machines, it should first visit the brokers website, login, optionally enter his mobile phone information (all other relevant user information should already be stored in the broker's database) and then receive on the cell phone the mobile agent. Ideally the user should be able to visit the broker's web site in his

WAP enabled phone and start the submission procedure without the need of any other device.

4.4. Test Results

Our current implementation demonstrates the feasibility of the concept and allows users, equipped with NFC enabled phones, to pay their parking. NFC proved to be a good alternative to the Bluetooth implementation solving the setup time problem (Remédios, 2005), reducing the user interaction time with the P&D machines radically.

Using a Nokia 3220 with a NFC shell the total setup and communication time is an average of 600 ms for each transaction. This translates to data transfer rates of around 1 kbps. For the prototype application the observed transfer rates were sufficient despite of according to the NFC specification it can go up to 106kbps.

In a monitoring and control context where we might use the NFC enabled cell phone as an interaction terminal to other devices this transfer rates also seem adequate.

This observation clarifies that NFC has a fast setup time, but a slow data transfer rate. On the other hand Bluetooth has a slow setup time, mainly due to the service discovery protocol taking up to 14 seconds to discover surrounding devices. With the connection established the data transfer rate is much higher than NFC, and with every new version of the BT specification the maximum data transfer rate increases.

Communication with passive equipments showed even slower data transfer rates but its accuracy is not good enough to be quantified.

5. RELATED WORK

The Atlanta pilot launched by *VIVOtech*, *Nokia*, *Phillips*, *Visa* and others demonstrated, in December 2005, how NFC could ease and speedup monetary transactions in a full Hockey Stadium where a test case involving 250 consumers, 150 points-of-sale contactless readers and about 60 smart posters equipped with NFC.

Philips started in 2005 a project to use NFC in the public transport system of Frankfurt, using the mobile phone to access an exiting contactless smart card infrastructure.

6. FUTURE WORK

The next step will be to combine the NFC technology with other already common technologies like Bluetooth. Alone each has disadvantages, but combined together they solve many of the obstacles existing today preventing the realization of the earlier mentioned emergent applications.

Another interesting project would be to implement a mobile application with a consistent look and feel and user interface to use in a manufacturing environment allowing authentication, monitoring and control over different kind of machinery.

To simplify the deployment process on the mobile phone, NFC deployment of the application should be investigated. Although this would require changing the submission process, allowing for the P&D Machines to generate and package the mobile agent application, user experience would be greatly improved.

7. CONCLUSIONS

NFC (Near Field Communication) proved adequate to exchange information at very small distances guaranteeing that the communication is being done only by the interested parties. The location problem now solved with NFC was initially detected when implementing a mobile application to pay services via Bluetooth (Remédios, 2005). Another problem was the time it took for the discovery of neighboring devices. To solve this problem and the NFC limited bandwidth, it should be considered a combined use of NFC with other communication protocols like Bluetooth. Exchanging through NFC only the necessary setup information to establish a broader band communication channel. This setup information for Bluetooth could be the Bluetooth address and encryption keys, etc.

Our experience tells us that in the future, when mobile devices permit it, we will see a symbiotic combined use of several different technologies like NFC, Bluetooth and Wi-Fi to provide the described mobile applications. These usage scenarios refer to authenticity of people and products, interaction with the surrounding environment, token transfer and storage allowing the procurement of digital tickets, and finally the possibility to make service payments.

A big driver leading people to use these applications will be the ease of use of the touch and go philosophy. The added value that we see for the future is the combined use of different technologies to provide in a single mobile application all of the services described before.

8. ACKNOWLEDGMENTS

We acknowledge the valuable contributes of Rogério Rocha, with the base code of the first prototype.

9. REFERENCES

1. Bindel D, Chen Y, Eaton P, Geels D, Gummadi R, Rhea S, Weatherspoon H, Weimer W, Wells C, Zhao B, and Kubiatowicz J. "Oceanstore: An Extremely Wide-Area Storage System". Proceedings of the Nine International Symposium on Architectural Support for Programming Languages and Operating Systems (ASPLOS IX), November 2000.
2. CEN. "Road Transport and Traffic Telematics". CEN/TC 278, 1999.
3. Ecma International. "ECMA-352: NFCIP-2 Interface and protocol". Geneva, 1st Ed. December 2003. http://www.ecma-nternational.org.
4. Ecma International. "ECMA-340: NFCIP-1 Interface and protocol". Geneva, 2nd Ed. December 2004. http://www.ecma-international.org.
5. Ecma International. "Near field communication (NFC)". ECMA/TC32-TG19/2004/28; ECMA/GA/2004/67, June 2004. http://www.ecma-international.org/activities/Communications/2004ga-067.pdf.

6. Forman G, Zahorjan J. "The Challenges of Mobile Computing". IEEE Computer, vol. 27, no. 4, pp. 38-47, April 1994.
7. Forum NFC. "Near Field Communication (NFC) Forum". 2004. http://www.nfc-forum.org.
8. Hightower J, Borriello G. "A Survey and Taxonomy of Location Systems for Ubiquitous Computing, Extended paper from Computer". 34(8), pp.57-66, August 2001.
9. ISO/IEC. "Identification cards - contactless integrated circuit(s) cards - proximity cards". part 1 to 4, .ISO/IEC 14443, 2000.
10. Kanellos, Michael. "RFID tweaked for item-level tracking". CNET News.com, 2006. http://news.com.com/RFID+tweaked+for+item-level+tracking/2100-1008_3-6041718.html.
11. Moore, G. "Cramming more components onto integrated circuits". Electronics 38, 8, 1965. ftp://download.intel.com/research/silicon/moorespaper.pdf.
12. Nokia. "Nokia Says Look for New Phone, Busy Stores in '06 NFC Payment Pilots". December 2005. http://www.digitaltransactions.net/newsstory.cfm?newsid=809.
13. Nokia Corporation. Nokia Mobile RFID Kit and Nokia NFC (Near Field Communication). http://www.nokia.com/rfid and http://www.nokia.com/nfc.
14. Pulli K. "The Rise of Mobile Graphics". Featured article of Nokia Mobile Phones, May 2003. http://www.nokia.com/nokia/0,,53718,00.html
15. Remédios D, Barata M, Osório A. "EXTENDING MOBILE PHONE USAGE FOR NON-CONVENTIONAL APPLICATIONS - WIRELESS IDENTIFIER". Proc International Conference on Electrical Engineering - CEE'05, Coimbra, Portugal, Vol. I, pp. 39, October, 2005.
16. Weiser, M. "Some computer science issues in ubiquitous computing". Communications of the ACM, vol. 36, issue 7, pp. 75-84, July 1993.
17. Yau SS, Karim F, Wang Y, Wang B, Gupta SKS. "Reconfigurable Context-Sensitive Middleware for Pervasive Computing". IEEE Pervasive Computing, IEEE Computer Society Press, pp. 33-40, July-September 2002.