Mobile Innovations with NFC

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***Abstract*—This paper - presented at Embedded World Conference 2014 - demonstrate ideas and implementations of innovative applications using RFID readers and/or NFC enabled mobile phones. The latter already have a remarkable market share. All ideas were created and implemented in student projects. This also puts available technologies to the test of feasability under a limited timeframe. The proofs-of-concept of several innovative applications and technical solutions with off-the-shelf electronic parts and commercially available Android smart phones will be presented. After introducing the three modes of Near Field Communication (NFC), examples of projects from more than three years will show capabilities and limits. All applications use NFC with mobile smartphones and off-the-shelf readers.**

Keywords*—android; smartphone; near field communication; nfc; rfid; iso14443; iso15693; embedded system; data logger; dual interface memory; rights management

I. Introduction

New technologies should not only be assessed on their potential applications. From the producer's point of view complexity and even risks of a new implementation are also important issues. Between 2010 and now, we have been able to acquire experience in student projects with *near field communication* (NFC) technologies. In groups of two to four, spending around 40 hours under a teachers supervision in the lab, students conceived smart applications and realized them in hard- and software. Please note that these ideas may be new or inspired by resembling projects that have already been thought up or realized with other or perhaps the same technologies. We used commercially available products and components from different manufacturers with their kind and direct support. Each of these projects was limited in time – the members had consistent development skills. The results thus achieved and any problems encountered may give a feeling of the applicability of the technology used.

Before going into the details, we give a short outline on RFID and NFC technology basics and applications.

A. NFC as an RFID Technology

The classical setup of a RFID system consists of a *reader* and a *transponder* alias *tag*. The reader generates a radiofrequency field – a magnetic or electromagnetic one – feeds the tag with energy and may transmit data upstream. Modulating this field, the tag transmits its data downstream. A so-called reader may also *write* data to the transponder. The roles of the reader and the tag are determined forever.

NFC breaks up the strict separation of these roles. A *near field communication* communication device can be a reader at one time and a transponder at another time. Working in the HF region at 13.56 MHz, it uses the standards ISO 14443 A and B as defined in the interface protocol NFCIP-1 (ISO 18092). Functions together with ISO 15693 are described in NFCIP-2 (ISO 21481), see [1] for further details.

B. Three Modes of NFC

The figures 1 to 3 show a NFC device (*host & NFC interface*) in its three possible roles.

C. Common NFC Application Modes

To illustrate the three modes in section I-B, some commonly used Android applications are given.

1) Card Reader: the NFC enabled phone reads an RFID tag: *Smart Poster Application* with URL or event info, *WLAN or Bluetooth pairing* with connection and login data, *Touch&Travel* [2] for localization etc.

2) Card Emulation: for *mobile payment*, the smartphone acts as an RFID tag, e.g. a credit card.

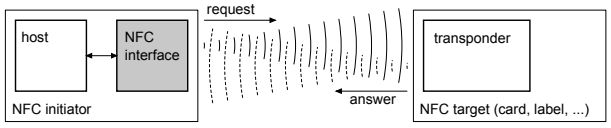

Fig. 1. Card Reader Mode: the NFC interface on the left side acts as an RFID reader, capable to read and/or write the transponder's data.

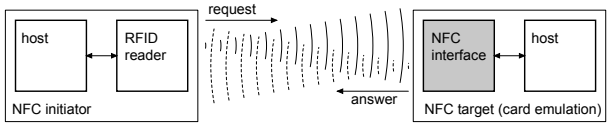

Fig. 2. Card Emulation Mode: the NFC interface on the right side behaves like a tag to the reader.

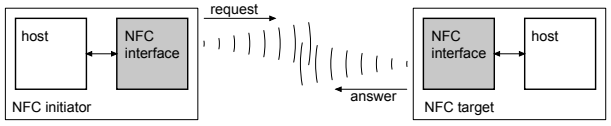

Fig. 3. Peer-to-Peer Mode: two devices exchange data. The transmission may go in both directions.

3) Peer-to-Peer: "beaming" data between two smartphones, e.g. *contacts*, *links* to web sites or applications etc.

D. NFC in the Wireless Market

In the wireless market, NFC closes a gap with the maximum range of 10 cm as well as with its data rate of 106 kbit/s for type A cards and 212 or at most 424 kbit/s for type B, see [3], [1].

Due to the short range, an unintended transmission is unlikely and *privacy* is fulfilled rather well. In this context *security* is high, since sniffing is difficult and quite impossible in real use. Furthermore NFC allows a *low inhibition threshold* for its use, because anonymous, temporary and ad hoc connection is encouraged. Cheap and *vandalism-proof* terminal devices are possible, since both, display and keypad, are in the user's smartphone.

II. Student Projects

The projects were conducted in groups of two to four students, each spending around 40 supervised hours in the laboratory. Voluntary additional time remains uncounted here. One basic principle of these projects is to provide a playing field for the NFC technology and ask for creativity to conceive convenient and handy applications with NFC-enabled smartphones. Much freedom was granted to the groups for implementing their own concepts – if realistic with the allocatable resources. We could notice a high motivation to achieve their ambitious aims.

Corresponding to the communication modes possible with NFC – see I-B – the projects presented are grouped in the following sections.

A. Card Reader

One of the most obvious actions with an enabled smartphone, apart from the known examples in I-C, is to read a tag with a specific content.

1) Games: where tags are the playing cards like memory or are attached to the fields on a playboard [4].

2) Menu Card: or special offers in takeaway restaurants were written on a tag. After getting these data on the phone with a simple touch, the selection and order can be done offline and placed at the counter [5], [6]. Writing e.g. on the fidelity card would only require an ordinary RFID reader at the counter to achieve a highly efficient process.

3) User's Manual: please note that the number of devices and their complexity in the household are constantly increasing - while the small paper manuals tend to get lost. Attaching a small RFID transponder with the required information or the link to manufacturer's service page would only cost a few cents. The project [7] even implemented a very efficient compression of text data on the tag. The users guide is displayed on the phone by means of a smart application.

4) Product Information: entering a shop, the customer gets a local WiFi access by just reading a tag, see figure 4. With a small application or a suitable web page, the customer receives further information of every good just by touching the transponder on the good or the shelf. Getting detailed product information, links, introductional videos or music samples directly on his smartphone is now very convenient to the user [8], [9]. Even smart advertizing with all its potential or analysing customer's interrests is possible – anonymously, only while application is active.

B. Card Emulation

With card emulation, two cases are possible. In the first case, the NFC-enabled smartphone is the target and simulates a card like for mobile payment. This usually requires special software and a secure element or even

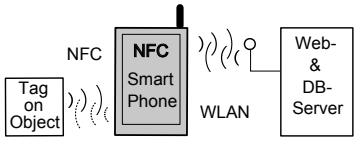

Fig. 4. Product Information [8]: Smartphone in NFC reader mode, gets from a RFID transponder the WLAN pairing parameters. With this connection established, user gets multimedia information for objects, identified by tags.

rooting the Android device. So far, we have not followed this track because all applications were specified to work with unmodified smartphones.

In the second case, the smartphone as initiator acts as the reader and an embedded NFC device as the target, emulating a card. The possibility to create highly dynamic RFID content, inspired several groups.

1) Sensor Box and Logger: tracking the path and environmental conditions of delicate goods during shipment is often a capability desired. [10] realized an embedded system with an AVR-μController [11] for control and logging, sensors for acceleration and temperature and a RFID device making the logs available at any time. The recipient of the packet with the incorporated box just reads the status with his smartphone.

2) Dynamic Content via NFC: in a recent project, the *PN512* is working on a software on a *LPC1227* [12], [13]. The μC may work standalone or as a serial gateway to a PC.

Another group provided a dynamic menu for restaurants [14] and an online and adapted questionary about the actual offer [15].

The project *info points* helps to organize stream of visitors handing over individual information on contact, room, floor etc. It also supports *indoor navigation* [16].

Related to this possibility of creating dynamic tag content is the option of *mission planning* with schedule, address and required actions directly on the phone of the staff [17].

C. Peer-to-Peer

The possibility of exchanging data between two NFC devices in both directions inspired two project ideas.

1) Electronic Pinboard: as a service in shopping malls with local display on a screen. Customers with their enabled phones can search, read, fetch a notice or place adverts. No local keyboard is required, it is already provided by the user's phone [18].

2) Smart Restaurant: with the direct interaction through a peer-to-peer device on each table makes getting the menu, selecting and placing the order very intuitive. Even the payment can be made with the smartphone [19], [6], [5].

3) Digital Rights Management: Smartphones already hold various digital rights. To administer them is the proposal of the project [20] and to provide the share or handover of certain permissions or a subset of them. This can be the *family transport ticket* for example, on weekdays used by the father. On weekends it could be handed over via peer-to-peer to the smartphone of the kids.

Another example could be the teacher, holding access rights for the doors of a whole building on his smartphone. It is conceivable, that from his global permission he lends the access right to a specific room to a student. Defining time windows for keyless entry to cleaning staff, workman etc. is another option. The authors [20] implemented public- and private key and RSA to ensure a high security level.

4) Actual Problems Encountered: P2P actually requires dedicated hardware with quite complex command and software structure. Until now, the required time effort was greater than the available budget.

D. Dual-interface Memory

From our experience, the communication between an NFC-enabled phone and a μController, for example, has not always been easy to realize and required specific reader IC, sophisticated software and time effort. So it seems natural to evaluate dual-interface memories available in the market. From the RFID prospect, they behave like a usual tag with read and write capabilities and passwort protection. From a Controller they can be accessed via I^2C or SPI, see figure 5. The inexpensive chip usually has only a few pins and is quite easy to implement as far as hard- and software is concerned.

1) LightHome: is an actual project [21] demonstrating *smart configuration with NFC*. With an application, ambient settings can be configured on the phone. Touching the NFC point applies these settings. At the same time the actual settings and parameters like temperature, status of air-condition, warm water etc. may be gathered. An embedded system consisting of a *M24LR64E* [22] and *AVR* [11] is used.

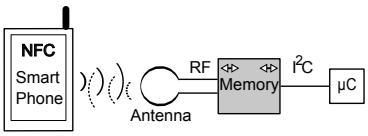

Fig. 5. Dual-interface Memory: the RF interface realizes a passive tag with read and write capabilities. The memory of the tag can also be accessed by a serial interface like I^2C or SPI.

2) P2P and Card Emulation: is replaced by the dual-interface memory in the project *student access* [23] using the *M24LR64E* and an *AVR* as NFC access point and serial interface to a PC.

3) Benefits of Dual-interface Memories: in addition to their compatibility with RFID tags: password protection, low price and the capability of energy harvesting. This allows the configuration of devices even with power off.

4) Drawbacks of Dual-interface Memories: the fact that they do not realize RFID reader functionality. The communication between RF and the μC must go through the memory. The sample described above implements the 15693 standard and is therefore officially not NFCIP-1 compliant as requires ISO 14443 A/B.

III. Conclusion

A. Comparing wireless technologies

In order to compare technologies like GSM, UMTS, WLAN, Bluetooth, QR-Code and NFC in various situations, a master's thesis has been conducted under the supervision of the author: In his work, Tobias Löbermann [24] examined not only the use of these technologies in the human-machine communication, but also how they support the human-human interaction and how their information exchange is assisted. The following criteria, among others, were worked out:

- NFC was found to be most efficient for *communication between two terminal devices*, and
- in this context very effective, efficient, fault tolerant and appropriate for the given purpose.
- assuming one second of acceptable transfer times, NFC allows 13-53 kB of data (see I-D).
- usability and user friendliness ("*joy of use*") will decide over user acceptance.

B. Résumé

The résumé, that can be drawn from our studies outlined above, is that NFC

- is very useful in ad hoc interactions of the user in a terminal device.
- is safe and secure due to a very limited range.
- shows the clear expression of intention of the user to perform a transaction by switching on the phone, unlock it and touch a specific NFC point.
- has the potential to gain a high user acceptance.
- applications are possible now – the market share of NFC enabled smartphones is already high enough.
- usable components implementing the forum standard need to be pushed for viable reader-, peer-to-peer- and card emulation- mode.
- the potential of dual-interface memories must not be underestimated and has the chance of being the admission ticket to a large variety of NFC applications!

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