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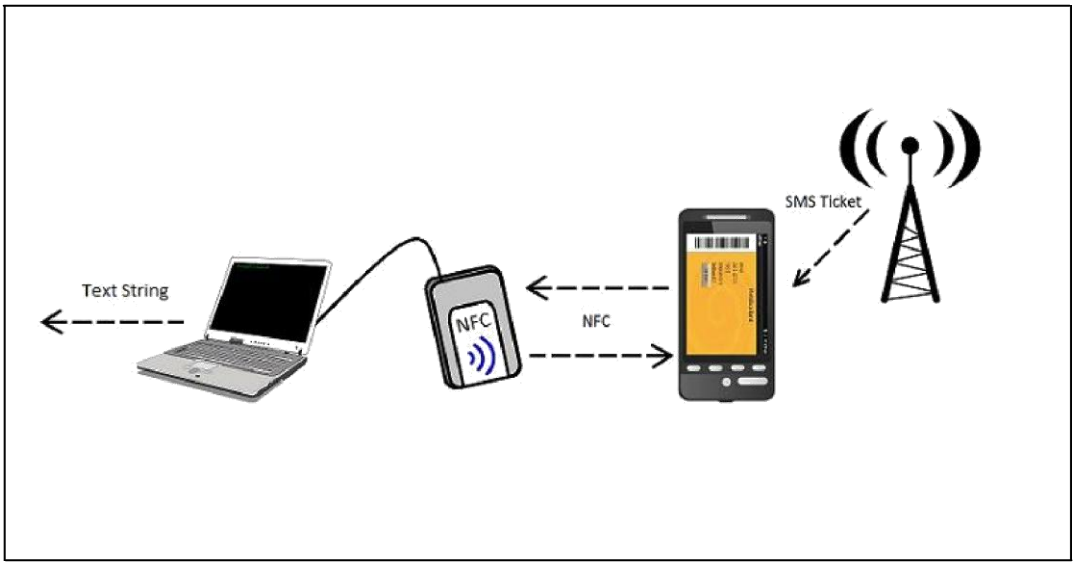

A design research exploration of Near Field Communication technology

Building and evaluating an NFC-ticket prototype extending an existing system

BACHELOR OF SCIENCE THESIS IN THE PROGRAMME SOFTWARE ENGINEERING AND MANAGEMENT

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Cover:
The picture describes the distribution of a ticket via SMS and the NFC communication between the cell phone and the NFC reader connected to the computer. The text string output from the computer represents a ticket ID (See page 5).

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***Abstract*—There are several indicators suggesting that Near Field Communication (NFC) is about to have a major breakthrough in the market. In this paper we explore the feasibility of implementing an NFC event ticketing system and investigate potential future functionality while answering our research question: How could NFC be used to better apply to the field of event ticketing, as compared to existing NFC ticketing solutions? We answered this question by using a design research approach in order to implement and evaluate an event ticketing prototype which transfers information through NFC using peer-to-peer mode. Our findings imply that implementing a system in this way makes NFC more applicable for event ticketing purposes as compared to existing solutions.**

I. Introduction

A. Background

Near Field Communication (NFC) is a short-range wireless technology for connecting two electronic devices. With an operating frequency of 13.56 MHz NFC supports data transfer up to 424 Kbits/second using three different modes of operation: card emulation, reader/writer, and peer-to-peer (Steffen, Preißinger, Schöllermann, Müller and Schnabel, 2010). The short connection range decreases security issues that would have been present with a longer range, (Fressancourt, Héraultet and Ptak, 2009) it would for instance be very difficult for another device to monitor the data stream without getting noticed.

In 2007 Nokia launched the first cell phone with NFC technology. Their vision was to facilitate data sharing, and to use the cell phone for payment and ticket solutions (Nokia, 2007). Since then there has not been any major breakthrough in NFC-services and only a small amount of NFC enabled cell phones has been released. There are however several indicators suggesting that the technology is about to increase in popularity. For instance Tuikka, Siira and Saukko (2011) states that all major cell phone manufacturers have proclaimed that they will implement NFC technology in their future devices. Furthermore Vodafone and Visa has recently announced their upcoming service collaboration (Vodafone Mobile Wallet) which will make it possible for customers to manage their everyday payments through the use of NCF enabled smart phones (Vodafone, 2012). Additionally this service will be open to all relevant industries (Vodafone, 2012).

B. Problem

There are evident indications that NFC will soon have a major breakthrough in the market, but the limited amount of research about its application shows that this novel technology still has a long way to go. In which direction it will go is still uncertain but our work will continue the exploration of the subject in a new direction: application of NFC within the field of event ticketing. To acquire a deeper understanding of the ticketing industry we chose to collaborate with Tickster AB (Tickster), a ticketing company located in Sweden that provided us with the information and feedback we needed throughout the project. This paper responds to the practice problem experienced by organizations such as Tickster, hoping to leverage benefits of NFC technology, as well as extends the limited published research on the topic of NFC applications within the field of ticketing. This leads to our research question: How could NFC be used to better apply to the field of event ticketing, as compared to existing NFC ticketing solutions?

We set out to answer this question by using a design research approach (Hevner, March, Park and Ram, 2004) in order to design an NFC ticket prototype. The intention behind our choice to use this approach was to allow us to explore and discuss both practice and research implications from the design process. Our strivings to answer our research question has resulted in research contributions in the form of a working prototype as well as this design research report which we based on both the practical and theoretical findings in order to provide a proposition for future work within the area.

Related literature is described in section 2. In section 3 we describe our design story which consists of method and results. In section 4 we discuss our findings and present our proposition. Our conclusions are described in section 5.

II. Related Literature

The first research paper on NFC was published in 2005 (Özdenizci, Aydin, Coskun and Ok, 2010). The research spans over several areas, for instance the automotive industry (Steffen et al., 2010) the public transportation industry (Tuikka et al. 2011; Widmann, Grünberger, Stadlmann and Langer, 2012; Finžgar and Trebar, 2011) and social networks

(Siira and Törmänen, 2010; Fressancourt et al., 2009). Özdenizci et al. (2010) published an extensive review of the NFC literature published between 2006 and 2010. The authors divide the reviewed literature into four broad categories: NFC Ecosystem, NFC Infrastructure, NFC Theory and Development, and NFC Applications and Services. These categories constitute a framework which provides a base for understanding the NFC research.

As mentioned earlier, NFC supports three different modes (Steffen et al., 2010). The first is card emulation mode where the device is passive. An example of card emulation is opening car doors with an NFC device simulating a key (Steffen et al., 2010). In the second mode, i.e. reader/writer mode, the device is able to read from and write to a passive tag. An example of this mode is from Siira and Törmänen's (2012) paper where they describe an NFC-based application called Hot in the City. This application enables the users to read from or write information about a certain location onto a passive NFC tag using a cell phone The third mode is peer-to-peer where both devices are active, establishing a two way communication. The concept of adding friends in Siira and Törmänen's (2012) application is an example of when this mode is used. This is done when two users bring their cell phones together and thereby exchange contact information.

Within the research field of NFC ticketing, the card emulation and reader/writer modes are described but not peer-to-peer mode. For instance Tuikka et al. (2011) as well as Widmann et al. (2012) explains how an NFC-device could emulate a public transportation pass. Another example Mulliner's (2009) description on how the public transportation system Wiener Linien uses readable tags. By scanning a tag the customer receives a pre-written short message (SMS), when this SMS is sent to the supplied phone number a ticket is received in the form of a new SMS. After discussions with Tickster we decided to implement our prototype using the peer-to-peer mode. This was done in order to explore the feasibility of implementing such a system and to open for future functionality, for instance enabling distribution of bonus materials such as event schedules to customers when checking in at an event.

Considering Özdenizci et al.'s (2010) categorization, we classify our paper into the NFC Applications and Services category in which papers concerning the application of NFC using any of the three modes are found.

III. Design Story

A. *Research setting and problem identification*

Our research was initiated after a dialogue with Tickster where it became obvious that the limited body of research and practice reports from NFC-based services constituted a problem. Since the technology is still not widespread, and thereby not the knowledge about its potential applications, Tickster could not provide clear requirements regarding the desired outcome of our project. The choice of method and tools was entirely up to us. In other words the project scope was vague. It was obvious that more research had to be put into the area of NFC ticketing.

In order to extract the requirements from Tickster's business needs, and to acquire a deeper understanding of the NFC-technology and its current applications we used two data collection techniques, literature review and interviews (see Fig. 1). Hence, we took both the business needs and the knowledge about the technology into account. Similarly, Hevner et al. (2004) emphasize the importance of taking both the business needs as well as applicable knowledge into consideration when building theories and artifacts. The literature review was conducted in order to develop an understanding of the NFC applications in various fields with emphasis on the ticketing field and to identify relevant gaps in the body of knowledge. The understanding gained through the literature review was used to formulate relevant questions for the interviews where we engaged in direct contact with the managers at Tickster. The questions posed during the interviews were open-ended, i.e. conversational, hence allowed a two-way communication to be established (Runeson and Höst, 2009). This enabled us to acquire rich data, and facilitated the process of extracting requirements from their business needs. Similarly Lethbridge, Sim and Singer (2005) argue that open-ended questions should be included in interviews in order to gain information that is not possible to obtain when posing more specific questions. Moreover, the interviews were semi-structured which means that the questions were not posed in a predetermined order. Such structure provides room for improvisation and exploration (Runeson and Höst, 2009).

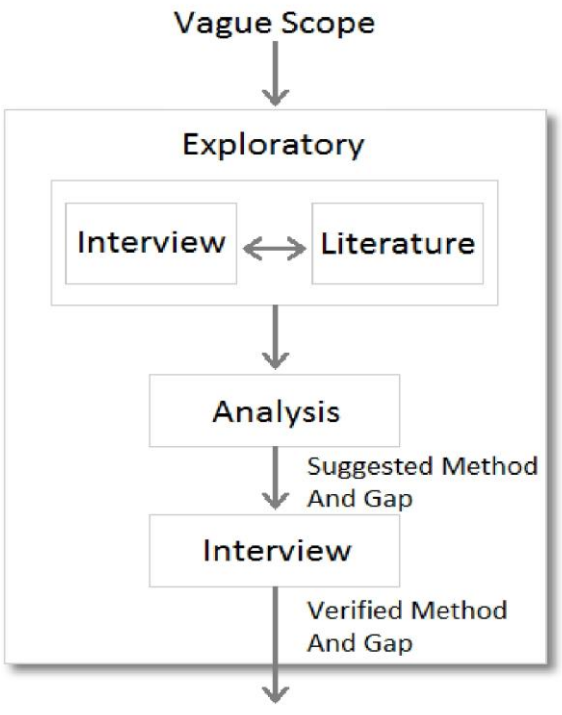

Figure 1. Our process of clarifying the scope and selecting a method to address it.

When the data was collected, we initiated the analysis phase where parts of the data gathered from the literature review and the interviews were coded according to certain themes that we could recognize in the material (Runeson and Höst, 2009). One of the more obvious themes was the potential application of NFC ticketing which occurred mainly in papers about public transportation e.g. Finžgar and Trebar (2011) and Tuikka et al. (2009). A sub-theme was the distribution of NFC tickets which was an aspect that stood out from the interviews with Tickster. By analyzing the coded information we found that a gap existed in the literature regarding the use of NFC within the area of event ticketing.

B. Motivation for the design research approach

We chose to follow the design research methodology as described by Hevner et al. (2004). This method has received much attention in recent years and has been successfully applied in several research projects (Hevner et al., 2004). For instance, Gavish and Gerdes (1998) used this method to design and implement anonymity in group decision support systems (GDSS). The requirements for such a system were unclear since there was a lack of research related to the implementation techniques in GDSS environments. Moreover Aalst and Kumar (2003) used design research to create a Workflow Language for Inter-organizational Processes. This was a difficult task since the standards for exchanging workflow models were not clear. The common denominator between these projects is what Hevner et al. (2004) refer to as wicked problems which among other things are characterized by unstable requirements. To address these problems the authors implemented their artifacts by using design research methodology. Similarly the requirements for our project were unclear due to ill-defined environmental contexts and the lack of previous research related to the implementation of NFC systems. Due to the fact that design research has previously been successfully applied to address wicked problems (Hevner et al., 2004), we decided to work according to this methodology. The result of the analysis phase was a suggestion to Tickster about using design research in order to fill the gap in the body of knowledge concerning the use of NFC within the field of event ticketing.

An additional interview was conducted in order to minimize the risk of misunderstanding and to ensure that Tickster agreed with our suggestions formulated during the analysis phase. Our endeavour was to construct a convincing argument for the utility of our prototype which was yet to be implemented, with regards to the gap in the body of knowledge and to the nature of the project. In other words, we strived to construct an informed argument (Hevner et al., 2004) by using the knowledge obtained during the analysis phase and support it with the input provided by Tickster. When this was done we entered the design phase.

C. Design iterations

During the build phase of the first design iteration (see Fig. 2) we gathered information by conducting a search for NFC hardware available on the market, i.e. NFC enabled readers and cell phones. This was done by calling several hardware suppliers and browsing the internet. Moreover, we searched for NFC libraries which could provide a high-level interface to low-level functionalities that are required on the computer side of our prototype, in order to receive data from an NFC enabled cell phone. Thus it is evident that the aim of this phase was to build a foundation for the practical work regarding the implementation of our prototype. The next step was to evaluate the collected information. Beginning with the hardware, the devices were compared by considering their functionality and price. As a result, we decided on a set of hardware that provided sufficient functionality for our purposes and at a reasonable price. The NFC libraries on the other hand were evaluated by how well they were documented. We were not limited by which programming language the libraries were written in. The evaluation phase resulted in a descriptive informed argument (Hevner et al., 2004) that motivated our selection of hardware and library. We based this argument upon available documentation, existing code examples, as well as our findings from hands on experience. Table I describes the tools of our choice.

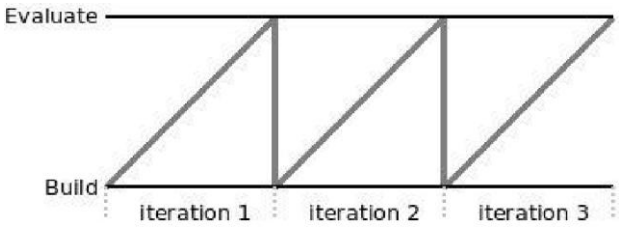

Figure 2. Build and Evaluate phases within our design iterations.

TABLE I. TOOLS

Tool	**Description**
Advanced Card Systems ACR122U (referred to as NFC reader)	Usb-connected smart card reader/writer. Compliant with the ISO/IEC18092 standard for Near Field Communication.
Sony Experia S (referred to as cell phone)	An NFC-enabled Android phone.
Nfcip-java (referred to as Nfcip)	Open source Java library that facilitates communication between NFC smart card readers and NFC-enabled cell phones.
SimpleNDEFPusher	A simple open source Android application that pushes a String via NFC

The second iteration was the first of two implementation iterations in which we used methods and concepts that we have learned during our education at the Software Engineering and Management programme. The pedagogic approach of this education is problem based learning where the students get a scope for a project but are provided limited help and information. This approach has given us a good experience with the kind of situations we faced during this project.

As mentioned earlier, the NFC technology is in its infant stage which implies that there is a gap in the existing body of knowledge regarding this technology. This further implies that requirements are unclear and that these are likely to change throughout the development. We chose to work according to the Extreme programming (XP) methodology because of it being particularly applicable for projects where the requirements are unstable (Kokkoniemi, 2008). One of the elements in XP is the concept of pair programming in which all programming tasks are performed in pairs (Padberg and Müller, 2003). As opposed to programming individually pair programming was more suitable for our purposes because it addressed the time constraint imposed on our project by increasing the development speed and reducing the number of defects in the code (Padberg and Müller, 2003).

The problem ahead was that we had to develop software for both the cell phone and the NFC reader in order to establish an NFC connection. However, we did not have any knowledge regarding the NFC communication protocol, i.e. which format the transferred data should follow. To get around this problem we used an open source Android application called

SimpleNDEFPusher that pushes a text string from the cell phone via NFC. On the computer side we implemented a program based on the Nfcip library and used the library's built in debug functionality to get printouts of received data. With this setup we could receive a number of bytestrings at the computer side whenever the cell phone touched the NFC reader. But we still did not know if the data we received were erroneous or not, the only thing that stood out at a first glance was that every message received ended with the same pair of bytes (0x90, 0x00). To solve this we referred to the NFC specifications regarding the NFC Data Exchange Format (NDEF) and saw that this specific pair of bytes denoted a successfully accomplished transfer of information. The specifications also provided us with the knowledge that it was the last bytestring from the communication that contained our transfered text string. Once we knew this we created a function which sorted out only the text string data by removing the descriptive information, e.g. the successful transfer message, and decoded the remainings of the bytestring in to a proper human readable string. By setting the text string as the only output from the computer-side of our prototype, we had complied with the current design of

Tickster's system where text strings are retrieved from bar code scanners at the entrance of events. This meant that the output from our prototype should represent a ticked ID registered as sold in Tickster's system.

We evaluated our prototype by using an experimental method which consisted of simulating our prototype as a whole (Hevner et al., 2004), i.e. both the the cell phone and the computer side. The outcome of this evaluation proved that we had successfully established an NFC connection.

For the third and final iteration we set out to implement the remaining parts of our system that were needed to make it into a complete working prototype. This implied figuring out how Tickster could potentially distribute the tickets as well as implementing functionality and a user interface. This iteration initiated with the build phase in which we conducted further literature review in order to acquire an understanding of how tickets are distributed and handled by ticket issuers in the fields of ticketing where NFC is used. For instance, Widmann et al. (2012) suggests distribution of a unique ticket ID by touching an NFC terminal belonging to the ticket issuer or Over The Air (OTA) which is over an http-connection where the distribution relies upon the availability of an internet connection. The unique ID makes it possible for the back end of the ticket system to keep track of the user's travel history when the user checks in and out from different public transportations (Widmann et al., 2012). Widmann et al. (2012) also mentions systems in both Germany and Austria that uses similar solutions. Tuikka et al. (2011) suggests the same functionality with exception for the OTA distribution. Finžgar et al. (2012) suggests another solution where an NFC tag is read using a cell phone which triggers an application which enables the user to order a ticket using a login username and password. Another example is the previously mentioned solution used by Wiener Linien in Vienna, Austria. Mulliner (2009) describes this solution where an NFC tag is scanned with a cell phone which brings up a pre-fabricated SMS which the user simply sends to order a ticket. The ticket is then received in the form of an SMS that upon verification for validity has to be checked manually. Our approach to the NFC ticket distribution is somewhat different. It is almost a reversed set of actions compared to the Wiener Linien solution. Our requirements stated that NFC should be used at the entrance of an event.

Today a customer can log in to Tickster's website and order a ticket which is then received as a pdf-document via email. We advocate that the ticket should be distributed without requiring the customer to have internet access available on the cell phone or require the customer to visit a physical location to retrieve it. Our idea was to extend the functionality of Tickster's existing system and give the user an option to get the ticket as an SMS containing all necessary information. Our inspiration to this solution came among other things from the Swedish Railways' (SJ) system where customers order tickets online and receives them as SMSes. Our proposed solution differs from SJ's in the sense that we will use NFC to validate a customer's ticket. Consequently, we implemented an SMS handling function to our application that reads all SMSes from a prespecified phone number (in this case Tickster's) and stores them as separate ticket objects. The next step was to make use of this functionality by implementing a user interface (UI) which enables the user to interact with the application.

We commenced the implementation of the UI by developing what we refer to as the Ticket View which is shown to the customer when the application is launched (see Fig.3). This view is designed to resemble the appearance of an ordinary paper ticket. In other words we created a metaphor that resembles a real-world object which is familiar to the user (Heim, 2007). This was done in order to facilitate the application of our prototype which implies increased usability (Heim, 2007). The Ticket View has two requirements to fulfill. Firstly, it should graphically present essential ticket information, as retrieved from the SMS handling function, for a selected ticket such as: event name, time of event, section and seat (if applicable), etc. Secondly, the logic of the ticket view should activate the NFC module of the cell phone to transmit the ID of a selected ticket to the NFC reader. The selection of a ticket is done via what we call the List View (see Fig.4) which is accessible from the Ticket View by the push of a button.

To increase the performance as perceived by the customer (Wikipedia, 2012) the SMS handling function runs in the background while the Ticket View is displayed. The result of this is that when the customer pushes the button to select a ticket, the processing of the ticket data has already been done. Pushing the button makes the application switch to the List View (see Fig. 4).

In the List View all received tickets are presented by their event name. When the customer selects a ticket (in this example Metallica Band) the application switches back to Ticket View (see Fig. 5) which presents the ticket information. At this point the customer can check in at an event using NFC.

The final evaluation phase considered the prototype as a whole and consisted of a simplified usability test (Hevner et al., 2004; Heim, 2007). The outcome of this test assisted us in building an informed argument for the utility of our prototype (Hevner et al., 2004). The purpose of the usability test was to inquire whether potential users are comfortable using our NFC ticket application instead of a regular paper ticket when entering an event. We initiated this test by presenting a brief scenario to 10 participants, describing the goal of the test session (Heim, 2007). The results showed that 8 out of 10 participants were positive about replacing paper tickets with our ticket application. For instance, one of the participants said -"This system seems so fast compared to using paper tickets at the entrance of an event where someone must receive your ticket, scan it, and then hand it back. This solution could save a lot of time and personnel at the entrances." Another participant said -"I find this application very handy since I always carry my phone with me, and don't have to keep track of paper tickets." One of the less optimistic comments we received was -"Your solution requires that all customers have Android phones, I don't even have a smart phone."

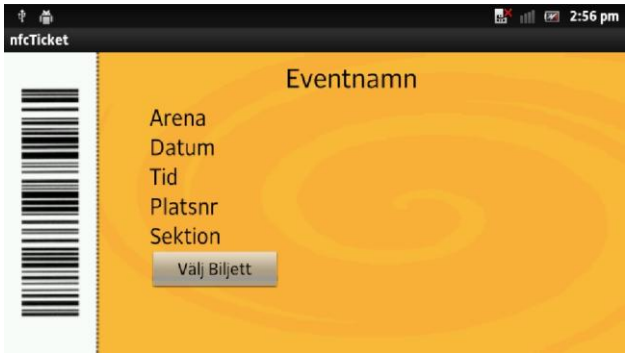

Figure 3. Ticket View.

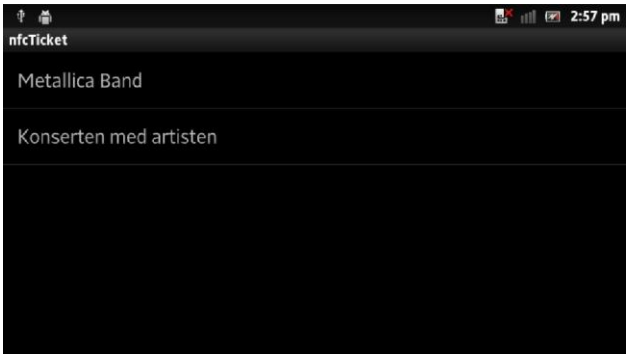

Figure 4. Ticket View.

Figure 5. Ticket View after selection of a ticket.

IV. DISCUSSION

A. Method reflection

We followed the design research methodology proposed by Hevner et al. (2004) and discovered some of its pros and cons. On the positive side we have the iterative build and evaluate phases which make it easy to adapt to changing requirements as well as gives a chance to explore unknown tools and information throughout the project. Design research also emphasizes the importance of taking current business needs into consideration throughout the project, e.g. technologies used today, and organizational strategies (Hevner et al., 2004). This is something we benefited from since we in the end could produce a functional prototype that could be integrated with Tickster's existing ticketing system.

From our point of view the design research demand regarding taking business needs into consideration, in our case by engaging in close collaboration with a company, became a drawback. Companies do not always have the time to prioritize a research project. Since we held meetings and interviews via video conference, due to long geographical distances between us and Tickster, it was not as easy as just dropping by occasionally. Sometimes meetings had to be postponed or even canceled due to changes in Tickster's schedule. This resulted in great delays for us when we had inquiries to make about critical decisions regarding the design of our prototype. So if working towards a deadline, one should bear in mind that things might take more time than expected.

B. Proposition and implication

After presenting our prototype and evaluation results to Tickster we engaged in a brainstorming session together where we discussed what could be the next step in the evaluation of the NFC technique for event ticketing purposes. Tickster emphasized the importance of addressing potential security issues in order to attain and maintain customer confidence. Similarly, Hutter and Toegl (2010) states that integrity and confidentiality must be considered when two NFC devices establish a connection. Within the field of NFC ticketing several security aspects has been described regarding card emulation mode as well as reader/writer mode. Tuikka et al. (2011) states that secure applications using card emulation mode relies upon what is called secure element technology, i.e. a unique ID is stored within the cell phone for identification against a back end system where it is registered. The ID is read by a terminal connected to the back end system where all information about purchased tickets is stored. This solution requires security solutions that spans over both the front end (cell phone) as well as the back end of the system since an authentication procedure similar to the one used for normal payment cards, is required to make sure that the ID presented by the cell phone is genuine (Tuikka et al., 2011).

A security threat regarding the reader/writer NFC mode was identified by Mulliner (2009) where an NFC tag is replaced with another containing malicious data. A possible solution to this threat could be the Trusted Platform Module described by Hutter and Toegl (2010). Their solution aims at the back end of the NFC system, i.e. the terminal side, and uses a protocol referred to as Remote Attestation which allows the user to verify the integrity of a terminal based on the authentication details it provides (Hutter and Toegl, 2010). This reduces the risk of being exposed to scams. Hutter and Toegl (2010) also provide an example of how their solution could be extended by strengthening the authentication process by checking it against a database via the cell phones potential internet connection. They did however not implement this extension.

Our paper is the first to explore the use of peer-to-peer mode for ticketing purposes (see Fig. 6) and it is thereby evident that its potential security issues has not been explored. This offers an opportunity for future research regarding the security issues and solutions. Such research would be classified into Özdenizci et al.'s (2010) category NFC Infrastructure.

As mentioned earlier our application should not require the users to have internet access on their cell phones. Thus Hutter and Toegl's (2010) example where the security is located in both the front and the back end of the system is not applicable since the former requires internet access for authentication. Moreover, relying on a mobile internet connection is not suitable at large events since the mobile network might get overloaded and hence affect its performance negatively. This might cause delays at the entrances when the customers checks in. Thus we posit the following:

> *Proposition:* We propose that the security component should be located in the back end of the system (see Fig. 6) in order to provide a reliable system without requiring internet access on the cell phone. This could assist in both attaining and maintaining customer confidence in the ticketing system as well as preventing distribution of malicious data when bonus material functionality is introduced in the system.

Our results show that it is possible to design a functioning NFC system which can handle distribution and validation of event tickets and requires minor modifications to the existing back end system. This implies that ticketing companies can adopt the NFC technology without having to concern about costly reconstructions of their current systems. Moreover the usability test that we conducted showed that the majority of the test participants were positive about replacing paper tickets with our ticket application due to factors such as ease of use, and an anticipated shortening of ticket validation time at entrances.

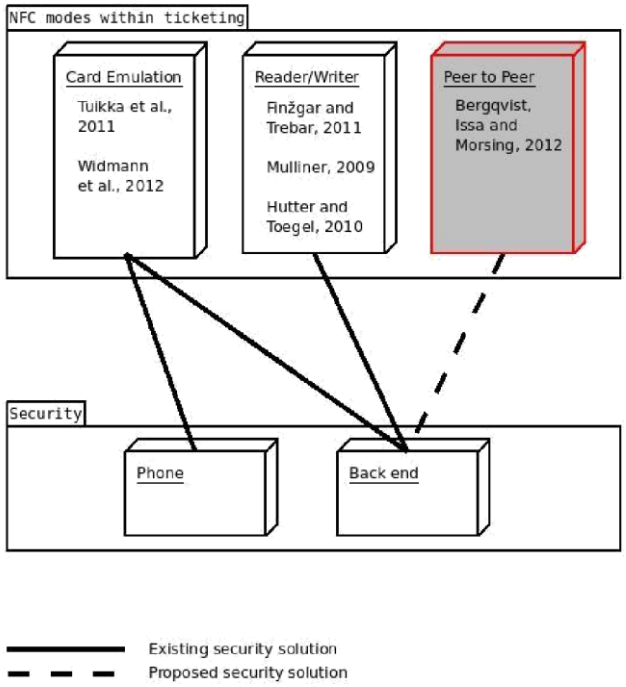

Figure 6. This figure shows how our paper fills a gap in the body of knowledge and how our proposition relates to previous work.

V. Conclusion

In this paper we set out to answer the research question: How could NFC be used to better apply to the field of event ticketing, as compared to existing NFC ticketing solutions? We have answered this question by using a design research approach (Hevner et al., 2004) in order to implement and evaluate an event ticketing prototype which transfers information through NFC using peer-to-peer mode. As mentioned earlier peer-to-peer mode has not been used within the field of NFC ticketing up until now (see Fig. 6). Our choice of mode opens up for future functionality such as sending bonus material to the customer's cell phone when entering an event. In other words, the use of peer-to-peer mode makes NFC more applicable for event ticketing purposes.

Our contributions are based on both practical and theoretical findings and consist of two parts. First our prototype, and second this paper which includes our proposition regarding the implementation of security in such a system. Our work is focused on, but not limited to, Tickster's business needs. In other words, other ticketing companies can benefit from our findings.

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