Architecture and Evaluation of a User-Centric NFC-Enabled Ticketing System for Small Events*

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Abstract. Small events are events with a limited number of attendees and limited financial means for the organizers. They represent an uncovered niche in the e-ticketing field. Our contribution, which is mainly practical, consists in proposing a solution to address this issue. We introduce an offline approach that uses Near Field Communication-enabled (NFC-enabled) mobile phones in a e-ticketing system dedicated to the management of these small events. In other words, we present an architecture which does not make use of an Internet connection during the ticket validation phase and that requires no infrastructure. Based on this architecture, we evaluate a prototype that we developed in terms of user experience, security, economical aspects and speed of use in order to show its relevance. Starting from a scenario with four use cases, we focus on the *ticket issuance* and the *ticket presentation* phases.

Keywords: Small Events, E-Ticketing, NFC, Mobile Phone, Peer-to-Peer.

1 Introduction

1.1 NFC Presentation

NFC (Near Field Communication) is an emerging technology that takes its roots in Radio Frequency Identification (RFID). It is a wireless communication tool that offers a range of about 10 centimeters. One of the most important driver for NFC is the mobile phone industry, many notable manufacturers integrating it within their devices [3] [4]. NFC offers three modes of operation: reader/writer, peer-to-peer and card emulation. The reader/writer mode makes it possible for NFC devices to interact with passive NFC tags ; the peer-to-peer (P2P) mode supports direct communication between NFC devices ; the card emulation mode allows a NFC device to act as if it were a smart card.

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NFC devices offer support for an embedded smart card chip that is called a secure element [5]. In this mode the data (application, information to transfer, etc.) is stored in the secure element. Most of the time, with NFC-enabled mobile phones, the procedures to store data in the secure element and to update them are delegated to an external infrastructure named the Trusted Service Manager (TSM). The TSM is the entity which manages the loading, deletion and personalization of applications on the secure element of a mobile phone through a mobile operator network. Therefore the management of applications stored in a secure element can be complex to operate (especially for small structures).

The most advanced peer-to-peer communication protocol for NFC is LLCP (Logical Link Control Protocol) which makes asynchronous communication between devices possible. Peer-to-peer communication is always between two peers and multicast is not possible. Communication between devices is not secured by LLCP, but security may be achieved by other layer protocols [6].

NFC has found a domain of application in the transport area as public operators within cities are very keen on deploying NFC-based systems [7]. The deployment of NFC-based systems increases the possible passengers flow and reduces the wear of the smart cards as there is only need to touch the reader to validate a ticket. Therefore, one of the first implementations of NFC based ticketing appeared in public transportation systems being furthermore given that there is an existing infrastructure for smart card based ticketing. For example RMV, the local Frankfurt (Germany) public transportation company, has implemented a NFC transport ticketing pilot [7] using the card emulation mode. The domain of events, especially for e-ticketing management, is also more and more concerned by the NFC technology.

1.2 E-Ticketing

The use of electronic tickets (e-tickets) has become more and more common. In the event management field, ticketing has gone electronic in some stages of the chain. Generally, it reduces the costs for the service provider while accelerating the tickets issuance and validation processes. In some cases, it also improves the overall system security. From the user point of view, e-tickets are more convenient to use than standard paper tickets.

Event ticketing is a big industry [8] [9] concentrated in the hands of just a few players. Consequently, only large events, those that generate the most revenues, can use the service of ticketing companies, which charge significant fees.

The emergence of NFC associated with the use of mobile devices offers new opportunities in the e-ticketing field. As customers begin to use ticketing with NFC in public transportation, the event ticketing must aim at becoming compatible with NFC [10] because of all the advantages it brings in terms of user experience (quick and easy validation of tickets). With the release of new smartphones endowed with NFC, it is evident that big players are ready (if it is not already done) to make necessary investments in terms of infrastructures in this business sector. However, in this rising ecosystem, the small events organizers, with their limited financial means, are a little deprived in front of the costs of such investments.

1.3 Small Events Concepts

We have interviewed representatives of two major Finnish cities about categorization of events. Due to the lack of official categorization within the cultural domain, an internal size based categorization was defined where small events were up to 500 participants, medium sized events 500-3000 participants and big events over 3000. For cities the most natural way to categorize events was by the nature of their organizer. Public-owned and non-profit organizations are treated differently than commercial organizations. One of the cities questioned event organizers. The biggest complaint was that ticketing is too expensive to arrange when the amount of tickets to be sold is small. The fees of nationwide ticketing companies are scaled to be in line with events of high cost tickets, like stadium-size concerts. Consequently, another pragmatic approach in the events categorization was to consider the financial means: if an event does not have the ability to use the service of ticketing companies, then it is considered a small event.

Events organizers mentioned other problems. As they support diversified point of sales, it is difficult to monitor the sells as a whole. Moreover, they wanted to have the capability to contact the ticket buyers. A direct channel for promoting and possibly informing buyers about changes in the event was identified as one of the most desired features. It is then evident that small structures need an adapted lightweight solution to manage an event ticketing system.

1.4 Contributions

The NFC Forum, as a consortium of different stakeholders in the field of NFC technology, believes that the cost of providing event ticketing systems, in terms of card issuance and management, can be driven down by using NFC-based systems [11]. The need of moving the e-ticketing systems for events to the NFC-enabled mobile devices field is evident [12] and we believe that it is relevant to build a lightweight system to manage a NFC-enabled event ticketing system with mobile phones. This system aims at setting up an affordable solution that lowers the costs of e-ticketing particularly for the small events organizers. There is also a need for evaluating such a system to present its pros and cons, and also to show its relevance for small events organizers. Therefore, in this paper, we propose a description of a solution that requires no Internet connection at the ticket validation step (offline approach), present the implemented prototype and evaluate it in terms of security, speed of use, user experience and economical aspect. As a starting point, we lean on a four-phase event ticketing scenario and focus on the ticket issuance and the ticket validation processes which are key points in most e-ticketing architectures.

In this paper we focus on three main points: the presentation of the architecture we designed ; the description of the novel application (a combination of some state-of-the-practice technologies) derived from the architecture ; the analysis of the solution on real mobile devices to validate its efficiency and to point out the field deployment issues.

This study is part of the work on the Event ticketing with NFC-enabled mobile phones that takes place in the framework of the Smart Urban Spaces (SUS) project. It brings a preliminary solution to the problem of building an e-ticketing system dedicated to small events. In this context VTT (the Technical Research Centre of Finland) and the LaBRI (the Computer Science Research Laboratory of Bordeaux, France) are collaborating to achieve a better definition and deployment of this new service.

2 NFC-Enabled Event e-Ticketing

2.1 General Overview

For simplicity concerns, the terms 'ticket' and 'e-ticket' are used interchangeably in the rest of this paper.

A e-ticketing system can be described as a token-based authentication platform that involves 3 main entities : an Issuer, a User, and a Verifier [13]. Figure 1 presents the commonly used architecture. A NFC-enabled e-ticketing system using mobile devices will follow the same approach. The e-ticket represents the token which circulates between the different entities and can be defined as a collection of data items that gathers various information for a particular event. The data contained in the ticket can be divided in three main parts: the ticket ID, the event ID and the ticket details (price, seat number, date, time, type of ticket, etc.). Most of the time the ticket ID and the event ID are mandatory fields. The ticket details are optional and highly depend on the type of event. For instance, the type of ticket can allow to make a distinction between single tickets, serial tickets, season tickets or discount tickets for example. Event e-tickets can also contain a digital signature generated by the ticket issuer so that their authenticity can be verified (figure 2).

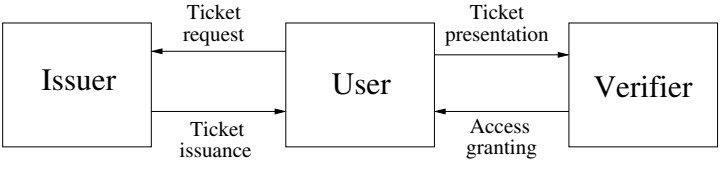

Fig. 1. Common e-ticketing architecture

Ticket ID	Event ID	Ticket info
Signature		

Fig. 2. E-ticket data model

2.2 Existing Solutions

There are many companies that work in the field of e-ticketing but the number of e-ticketing initiatives that rely on the use of NFC is very limited. Furthermore, these initiatives, although demonstrating the added value of NFC in ticketing services, either need significant infrastructure deployment at the event site or are not mobile phone oriented.

An interesting solution is the Tapango system [14] which is an electronic voucher system based on NFC smart cards used as e-Wallets. The system aims at reducing the use of paper tickets and was implemented by the Artesis´ research lab. With Tapango, the users first buy tickets via a web interface, then at the event location they synchronize their e-Wallet (by introducing their card in a reader connected to the Internet) to 'physically' acquire the tickets and finally they present the NFC card at the entrance of the event to get access. The use of NFC-enabled mobile devices is presented as a step to come in the evolution of the system. In the SmartTouch project [15], a pilot related to event ticketing in the theater of the city of Oulu (Finland) was deployed [16]. The users were able to receive tickets on their NFC-enabled phones via a specific equipment in a point of sale at the theater. The control of the tickets was achieved using another NFC-enabled mobile phone. Despite the fact that the ticket validation was relatively slow (using the peer-to-peer NFC mode) because of the phone brand, the users showed a real interest.

2.3 Need of Small Event System and Requirements

From the previous section, we can conclude that the existing solutions require the deployment of specific pieces of equipments or a steady Internet connection at the event entrance what leads to big investments (and thus only make sense for big events). Consequently, there is a lack of suitable proposition that could meet small event organizers needs and requirements. As mentioned in the introduction, the reason for using NFC is to facilitate all the event ticketing processes. It is then a question of defining a system which is flexible enough to be adapted to different types of events while answering the e-ticketing constraints in the specific context of small events. Such an approach has its limitations and benefits we want to identify. The designed system must as much as possible reduce the deployment costs (at the event location and for the tickets issuance) and rely on the assumption (which is a futuristic view for the moment) that the attendees own a NFC-enabled phone. Furthermore, the system must offer the possibility to monitor the level of sales and to send (when necessary) updated information concerning the events to the customers.

3 Presentation of the Solution

3.1 Scenario, Use Cases and Architecture

Assume that Adam wants to go to a private rock concert. He starts the application on his mobile handset which connects to the events portal where he has an

account linked to his email address. From the portal, he receives a list of proposals by querying for available tickets in the rock shows category. He previews a multimedia presentation of the events he could be interested in before deciding rather to buy a ticket or not. Once he has made a decision, he selects the proper concert and enters the payment details and validates the transaction. When the payment is done, he can then download the ticket which is stored in his phone. In the case information related to the show is updated, Adam is informed via email box. The day of the show, he goes to the venue and at the entrance he presents the corresponding ticket by taping his phone on another NFC-enabled mobile handset (operated by the person responsible for the tickets validation). The ticket is transferred to the validator handset where its validity is checked by mean of a mobile application. Finally Adam is granted access to the concert. From the previous scenario four use cases can be identified: selection of an event, event description visualization, event tickets issuance, and ticket validation at the event site. These cases (see figure 3) represent the steps to follow in our solution to attend an event using a mobile phone. It is to be noted that the system follows an offline approach the concept of which was presented in Suikkanen and Reddmann work [17] ; it means that the validation phase is achieved without the use of an Internet connection (thus eliminating the need of an infrastructure at the event site). Moreover, as presented by the scenario, the system only targets single events.

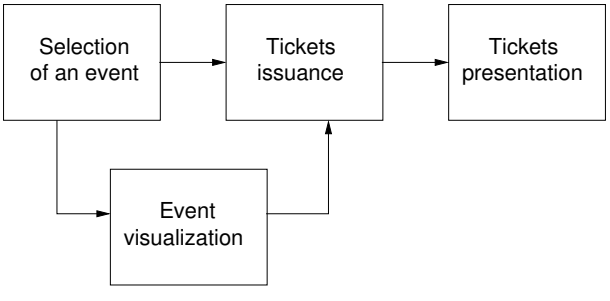

Fig. 3. Small event ticketing scenario with use cases

It is important to mention we assume that the events organizers have at their disposal a web interface where they can enter all the relevant details about their events (show description, payment options, etc.) so that it can be published. This interface also has to allow them to monitor the tickets that have been sold and to send updated information about their events.

The involved entities and their interactions as well as the processes we want to focus on are presented figure 4 and described in more details in subsection 3.2.

3.2 Processes Description

Issuance Process. The interactions during the issuance process (figure 5) involve two entities: the Client Application and the Events Portal.

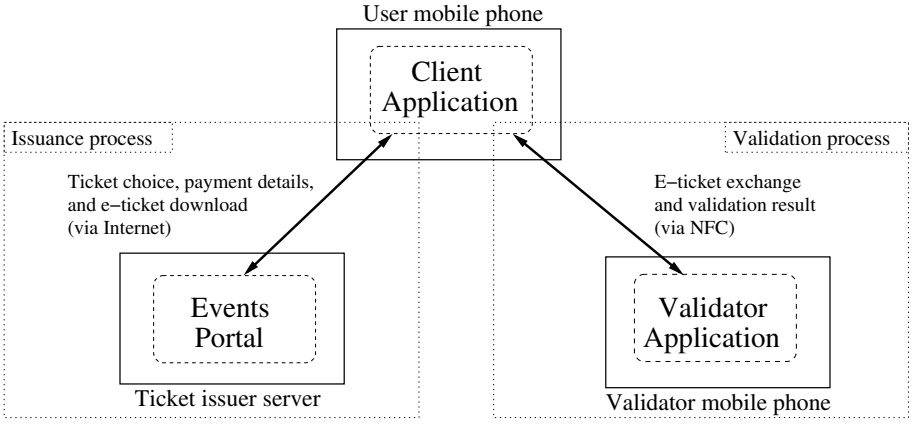

Fig. 4. Small event ticketing system architecture

The Events Portal can take the shape of a website and must present the list of events, allow the selection of the chosen event and support payment. The Events Portal is also responsible for generating the digital ticket, once the payment is done, by gathering the different pieces of information (at least the ticket ID and the event ID) and formatting them properly. Additionally, a signature with a private key must be applied to the ticket, so that its integrity can be checked at the event venue, the corresponding public key being provided to the Validator Application. A specific public/private key pair corresponds to one event. Once the ticket has been built, a link to download it must be provided. The Events Portal must also be linked to an online payment platform to ensure the security of the purchase (if the event is not free).

Concerning the Client Application, it connects to the Events Portal by Internet and displays its interface. Users can then buy a ticket and, when the purchase is validated, the digital ticket is stored by the application in the phone memory. They are other storage locations for the ticket, for instance in a secure element of the mobile phone, but that would require an infrastructure (with the use of a TSM). It would thus not meet some of the small event organizers needs.

Validation Process. The validation process (figure 6) involves two entities: the Client Application and the Validator Application.

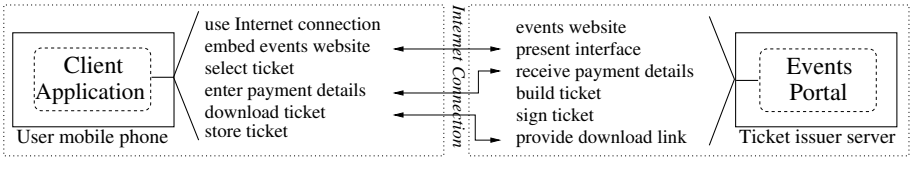

Fig. 5. Issuance process entities

First, the Validator Application must be able to receive data (a signed digital ticket in our case) sent from another mobile phone via an NFC connection. Moreover, it has to contain the mechanisms to check the signature of a ticket (using a public key) to make sure of its integrity and validity. The procedure is made possible by the fact that the Validator Application is provided, beforehand, with the public key (the corresponding private key being used to sign the event tickets). This can be done, prior to the day of the control, by connecting to a secure web interface part of the Events Portal or the Events Portal can simply send the key via SMS to the Validator Application. Finally, to avoid re-use of a ticket, a system to keep track of the presented tickets must be part of the Validator Application.

Concerning the Client Application, it allows the user to list the ticket he bought and to select the ticket he wishes to present at an event gate. The Client Application also manages the direct communication by mean of a NFC connection of the mobile phone with the validator mobile handset. This is made possible because the digital ticket is not stored in a secure element. Beforehand, the digital ticket is properly formatted so it can be easily sent to the validator device.

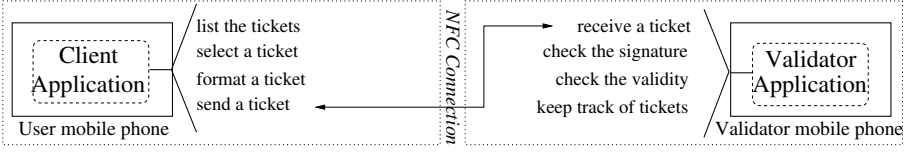

Fig. 6. Validation process entities

3.3 Technological and Equipment Choice

Our system requires, for the client and the validator, the use of NFC-enabled mobile phones that support NFC peer-to-peer mode (for direct communication between the phones). The client mobile phone must also be able to connect to Internet to download the purchased tickets. Android which is one of the major platform at the moment is supported by phones that correspond to the required specifications. We then decided to target Android which offers NFC APIs (in its 2.3.4 version) and provides a support (even though limited) for NFC peer-to-peer mode. A first lightweight prototype has been developed to analyze and to validate some aspects of the proposed architecture for a small event NFC-enabled e-ticketing system.

4 Prototype Description

4.1 Overview

As can be seen figure 7, the prototype we developed is composed of three main application blocks. The client application allows the end-user to download tickets

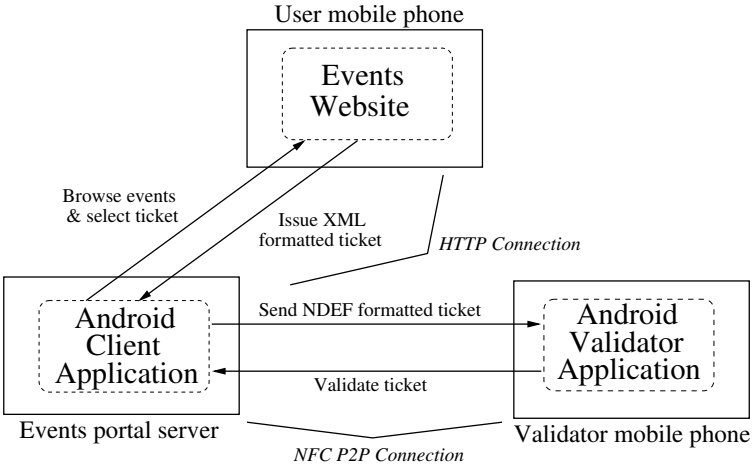

Fig. 7. Prototype Architecture

on his handset and to present them at the event entrance. The issuer application is responsible for presenting future events and issuing valid tickets. Finally, the validator application verifies the presented tickets and grants users access to the event. The mobile used for the development of this prototype is Samsung Nexus S. In this prototype, a ticket consists of a XML file that contains information about the event (ticket ID, event name, event location, etc).

4.2 Client Application

The client application provides a user-friendly interface that allows the user to easily interact with the ticket issuer (figure 8): this means browsing through a list of events as well as downloading tickets to the mobile handset. Additionally, the application offers a ticket management interface with simple actions (i.e view the ticket details, remove it or send it via NFC peer-to-peer mode to another device). Note that for the time being, the Nexus S only supports a limited version of the NFC peer-to-peer mode. It is not possible to establish a connection and have a bidirectional communication channel between two handsets. Instead, one device creates a virtual tag and behaves as a passive target allowing the second device to read it just like any other tag. Consequently, in our prototype, the ticket is embedded in a NDEF formatted message in order to be sent to the validator application. NDEF stands for NFC Data Exchange Format and is the standard format for exchanging data between a NFC handset and a NFC tag [18].

4.3 Issuer Application

In our prototype, the ticket issuer is essentially implemented through a website. It exposes a static list of events and allows client applications to download tickets through a HTTP connection. At the moment, no ticket payment platform, database or secure connection (HTTPS) is integrated.

4.4 Validator Application

The validator application retrieves the ticket from a client application through a NFC peer-to-peer link and verifies its validity. It offers a basic interface as shown in figure 8. Upon successful verification the visitor is granted access to the event. For efficiency purpose and to enhance the user experience it is essential for the validation to be performed as quickly as possible.

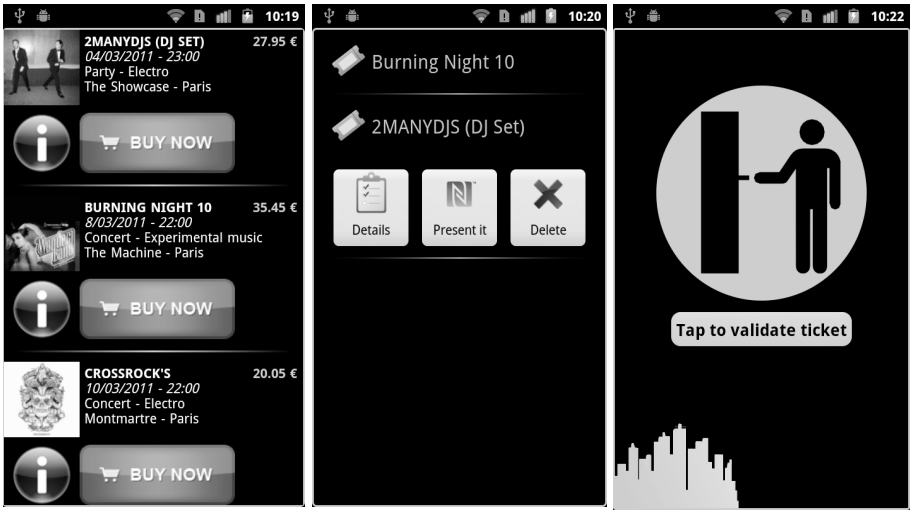

Fig. 8. Prototype Screenshots

5 Tests and Evaluation of the Solution

5.1 Security

In this section, we discuss the security of our approach. It is clear that this will require (see section 6) further investigation including a formal validation.

During the issuance process the security mechanisms deployed to secure the payment procedure (which we will later integrate) and the e-ticket download are the usual ones [19] . The security analysis described thus targets the validation phase. To achieve this verification, the user taps his phone on the validator phone and a direct communication between the two devices is established.

The security of the proposed e-ticketing system mainly relies on the e-ticket signature, the recording of the tickets presented at the entrance and the trust granted to the person responsible for the validation (which must be easily recognizable as a member of the organization team, see the relay attack below). To summarize, these elements make it possible to ensure that only valid tickets can pass the validation (forgery prevention), that two identical tickets cannot be used to get access to the same event and that the validation is performed with an

authorized phone. Since our approach makes use of the NFC peer-to-peer mode, the question of security is directly related to this technology. The NFC threat model contains some attack scenario such as eavesdropping, man-in-the-middle, relay, skimming, data corruption or phishing [20] [21]. All these scenarios are not to be taken into account in our context.

The phishing attack for instance, most of the time, concerns NFC tags reading systems [20] and the man-in-the-middle attack is really difficult to set up in a real NFC-based environment [21]. Concerning the relay threat, it was demonstrated that it is feasible [22]. In this kind of attack, the exchanges between two authorized entities are relayed so each entity believes it communicates with the other one. However, in our context it is the user who initiates the validation and he necessarily stands next to the person (easily recognizable as an authorized person) manipulating the validator handset. This type of attack is thus impossible. For the eavesdropping threat, we can also consider that if a user selects too early the e-ticket to be validated and then makes it ready to be transferred (using the NFC peer-to-peer mode), an attacker with the appropriate equipment could retrieve the ticket information by capturing the data to be transmitted [23]. This threat can be reduced by making sure to be in front of the validator before selecting the ticket to be presented. It will obviously increase the waiting time at the entrance, which can be a system limitation. We can also consider that the attacker can eavesdrop the transmitted data when the user taps his phone on the validator phone. However, it will be useless because an e-ticket can only be validated once since the system keeps the id of the tickets.

Another point is that the ticket is stored in the phone memory (and not in a secure element) which allows for more flexibility since the user can easily manage the tickets (i.e send it to another device, erase it, etc). A drawback is that a ticket can be duplicated. However, a validator will spot duplicate tickets and only grant access the first time the ticket is presented. This requires that one single validator is used which is most often the case for small events.

Globally, the balance between the equipment needed to perform some of the listed attacks (a passive antenna connected to an oscilloscope for instance in the eavesdropping scenario or more specialized equipment [24]) and the cost of a ticket for small events pleads in favor of a reduced number of real threats. Also, according to the properties of the NFC technology (among which very short-range communications), associated with the listing of presented tickets, the fact that the tickets are signed and the collaboration of the users, the confidentiality and the authenticity can be ensured. Some improvements are possible, for instance to perform a mutual authentication between the involved entities during the validation process to make sure of the identity of the person who presents the e-ticket, or even to better preserve confidentiality (as it is possible to eavesdrop the data transmission). Still, compromises have to be done between improvement of the system which could require the deployment of an infrastructure and the small events objective among which simplicity of deployment.

Even if the system can be enhanced, it nevertheless offers reasonable security level for small events in a lightweight system (which is the main requirement).

5.2 Validation Speed

In many e-ticketing systems, speed of validation is a crucial point. For instance Transport for London expects the validation time of an Oyster card not to exceed 500 milliseconds [25], otherwise the user experience would not be smooth and the flow of passengers would be slowed down at busy stations. In a ticketing system for small events the user flow is significantly less important but we still consider fast validation to be an important requirement. In our case, the validation time is measured, for technical feasibility reasons, from the moment the peer-to-peer target (the virtual tag) is discovered until the ticket signature is verified. With the current Android API we have reached a validation time of 400 milliseconds. The size of the ticket which is used is relatively small, it only encloses the ticket ID, the event ID and a 1024 bits digital signature. Larger tickets (i.e. tickets containing more details about the event) are longer to transfer and will thus increase the validation time. In some cases, we noticed that the Android handsets take more time than usual to establish a peer-to-peer connection bringing the validation time to more than 1 second. The reason for that delay is still to be explored.

5.3 User Experience

The use of a completely paperless NFC-enabled e-ticketing system enhances the overall user experience as demonstrated by the work of Ghiron, Sposato, Medaglia and Moroni [26] (even if it was in the transportation domain). The *Virtual Ticketing application* they developed and tested was a prototype where virtual tickets are stored in a secure element embedded within a mobile equipment. In a general way, by purchasing tickets online, the users avoid queuing at specific points of sale. Furthermore, the tickets do not need to be printed and, on top of that, the validation is done by simply taping a phone on a reader.

One of the main drawbacks of our system is that the user must select among his tickets the one he wishes to present, what can slightly reduce user-friendliness. Indeed, the way the NFC peer-to-peer mode works in the Android APIs (a virtual tag must be generated as described in 4.2) leads us to implement a solution where the user chooses in his list of tickets the one to be validated so the right ticket can be verified during the validation phase.

To get more relevant feedback for the user experience analysis (particularly for the client application), we performed basic tests with 15 persons (through a questionnaire to attribute a note on 100) with the 10-items of the system usability scale by John Brooke [27]. This system, which is meant to evaluate the usability of a system from a user point of view, has been proven valuable and robust [28] and is used by some companies member of the Smart Urban Spaces consortium. The testers were also able to make comments at the end of each test which was monitored by a member of our group. The sample of 15 people gathers men and women between 20 and 30 years old with various professional background (computer science oriented or not). We proposed a simple two-points scenario to the testers: we suppose that you need to buy two tickets for two

different concerts, launch the application and try to buy the tickets ; we suppose now that we are the day of one the concerts, try to select one of the tickets you bought and to present it for validation (by taping the phone on the validator phone). By taking into account the questionnaire of each user, we obtained an average of 77 out of 100. This result provides a first idea of the potential of the application, and we received many remarks regarding the user interface. Another considerable point is that most of the people were not used to the way to tap the phone on the validator phone.

Despite the fact that many improvements can be brought to the user interface of the client application, the test results allow us to say that the user experience reaches an acceptable level.

5.4 Economical Aspects

The relevance of the proposed model can be analyzed through its underlying business model. In the SUS project, a model for the management of e-ticketing systems has emerged. The goal of the SUS consortium is to implement service prototypes that could ease the everyday life of citizens. In this context, the cities will most likely be keen to design, develop and maintain, with the help of external resources (like specialized companies), a platform for small events organizers such as the Events Portal described in our solution. The events organizers will be able to subscribe to the platform (to publish the details of their event and launch the sale) and the cities will sign the necessary agreements with them regarding the income generated by the purchase of the tickets. In the case a city has a special culture promotion policy, the platform can also be used to allow free tickets download. Obviously this business model, although viable, is strongly connected to the policy of cities in terms of ICT and to their associated investments.

6 Future Work

We will, within the framework of the Smart Urban Spaces European project, deploy pilots targeting small events (such as private concerts or small art exhibitions) in collaboration with the cities that are members of the consortium. These cities wish to set up a flexible and cheap ticketing system as the organizers of this kind of events cannot afford the deployment of expensive equipments. At the moment, some French and Finnish cities are potential candidate.

Another step in our work will be to study the scalability of the presented system (to manage larger events) and to enhance its security level by improving the countermeasures against possible attacks (for instance for a Denial of Service). Another step in our research is to focus on a e-ticket standard description completely dedicated to events and the associated storage procedures inside mobile phones. As far as we know, there is no event e-ticket standard and it would thus be relevant to make contributions in this area. Another point will be to work on interoperability.

7 Conclusion

In this paper we have presented a NFC-enabled approach to deal with e-ticketing issues in the context of small events. Starting from a definition of the concept of small event, the relevance of such a system has been shown and a business model with the involvement of the authorities of cities has been described. Even if some more points need to be discussed and defined, the prototype that we have developed demonstrates the feasibility of the proposed solution. The evaluation that we have conducted shows that it offers a reasonable level of performance. The pilot phase, which will be developed in cooperation with the interested cities, will allow to obtain more indications to improve the system and prepare a real large scale deployment.

Acknowledgement. The work presented here is carried out within the framework of Smart Urban Spaces, an ITEA2 European project, the goal of which is to define new e-services for cities. The proposed services mainly take advantage of specific technologies, in particular NFC, in order to ease the everyday life of European citizens. Several use cases are concerned for instance daycare organization, transportation or cultural events management. We would like to thank all the partners of the Smart Urban Spaces project with whom we have been working and we have discussed the topics described in this paper.

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