# Architecture and Comparison of Two Different User-centric NFC-enabled Event Ticketing Approaches

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**Abstract.** This paper describes two different approaches to use Near Field Communication (NFC) enabled mobile phones in a ticketing system dedicated to event management: *(i)* a offline version where some equipments are not connected to the Internet ; *(ii)* a online version where an Internet connection is available on all the equipments composing the infrastructure. These two propositions are compared so as to evaluate their pros and cons in terms of user experience, security, economical aspects, reliability and speed of use. We also identified a scenario with six use cases and decided to focus on ticket issuance and ticket presentation.

**Keywords:** Events, E-ticketing, NFC, Mobile Phone, Secure Element

## 1 Introduction

### 1.1 Overview

The use of electronic tickets (e-tickets) has been significantly growing in the past few years. It still remains that a vast majority of the existing e-ticketing systems are proprietary solutions, primarily designed for the transportation industry and thus cannot be used in other domains.
For instance e-tickets can be helpful in the event ticketing industry which is a multi-billion dollar business. For example in North America gross concert revenue was 4.2 billion USD in 2008 and movie ticketing in 2009 was worth over 29.9 billion USD worldwide[1][2]. Ticketing has gone electronic in some stages of the chain, but the tickets themselves are still physical and these physical tickets have to get somehow to the buyer and also allow easy validation process. One solution is Near Field Communication (NFC)[3].

### 1.2 NFC Technology

NFC is an emerging technology that takes its roots in Radio Frequency Identification (RFID). It is a wireless communication technology that has a range of about 10 centimetres. One of the most important drive for the NFC has been the mobile phone industry where many notable manufacturers are integrating it within their devices (or they at least claimed that the NFC will be part of their future phones[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 mode supports direct communication between NFC devices, and the card emulation mode allows a NFC device to act as if it were a smart card. NFC devices offer support for an embedded smart card chip that is called a secure element. This secure element is connected to the NFC chip by the so called Single Wire Protocol (SWP)[5]. This secure element can be a (U)SIM card[6] or an integrated chip[7]. In card emulation mode, NFC devices do not create their own RF field but are powered by the electromagnetic field of an external device. The supported smart card types are MIFARE ISO/IEC 14443 Type A and Type B, FeliCa and ISO 15693.
The first implementations of NFC based ticketing appeared in public transportation systems as there is an existing infrastructure for smart card based ticketing that NFC-based ticketing can integrate. For example RMV, the local Frankfurt (Germany) public transportation company, has implemented a NFC transport ticketing pilot[8]. Doubtless, the NFC technology can also bring many advantages for e-ticketing in the domain of event management. Nevertheless, in the current mobile phone environment, there is a lack of standard propositions in this domain of event e-ticketing that would rely on the use of NFC-enabled mobile phones. As a starting point, we leaned on Suikkanen and Reddmann work[9] in which they have identified two basic approaches for NFC-ticket validation: offline and online ticketing. In the proposed paradigms, the validation is done either locally (offline) or through and Internet connection (online).

### 1.3 Contributions

The NFC Forum, as a consortium of different stakeholders in the field of NFC technology, believes that the cost of providing event ticketing, in terms of card issuance and management, can be driven down by using NFC-based systems[10]. Consequently, there is a strong need of moving the e-ticketing system for events to the NFC-enabled mobile devices field[11]. There is also a need to compare between the solutions and the context in which they can/cannot be used. Therefore, we propose a description of two solutions derived from the offline and online paradigms, and evaluate them in terms of security, reliability, speed of use, user experience and economical aspect. We present a six-phases event ticketing scenario and focus on the tickets issuance and the tickets validation processes which are key points in most e-ticketing architectures. For simplicity concerns, the terms ’ticket’ and ’e-ticket’ are used interchangeably in the rest of this paper.

## 2 Existing E-ticketing Solutions

### 2.1 Overview

There are numerous initiatives and many companies that work in the field of e-ticketing. Most of the proposed solutions target transportation systems and are not necessarily adapted to events. Moreover, some of the solutions adapted to mobile phones use the 2-D bar code system (and not NFC), which has disadvantages in some situations[9]. One interesting example in e-ticketing is the Cityzi[12] initiative in Nice (France) that uses NFC-enabled mobile phones but that provides no solution for the management of event tickets. Nevertheless, there were some trials to combine e-tickets and NFC but no standard solution for mobile devices appeared. We present here a small sample of some projects that we believe are representative of what is deployed today.

### 2.2 The Domain of Transportation

In the airline industry, electronic tickets have long replaced paper tickets. Some airline companies also issue electronic boarding passes which are sent to the mobile phone of the passenger or printed out by the passenger himself. The Air France online check-in option[13] is an example of this system where the user receives his identifier via SMS, MMS or email as a 2-D bar code.
Public transport operators within cities are also very keen on deploying e-ticketing systems. The Oyster card in London[14] and the Yikatong in Beijing[15] are transportation cards based on the *MIFARE*[16] technology. In Asia, the Octopus Card[17] in Hong Kong is based on the *FeliCa* standard[18] which is a contactless card technology.
Using NFC technology solutions, Ghiron, Sposato, Medaglia and Moroni developed and tested a *Virtual Ticketing application* prototype for transport in Rome where the virtual tickets are stored in a secure element embedded within a mobile equipment[19]. This user-oriented offline implementation showed that NFC could improve usability of e-ticketing systems.
The French transportation company *Ligne d´Azur* in collaboration with Cityzi in Nice also provides a mobile phone based application to buy tickets and validate them using NFC[20].

### 2.3 The Domain of Events Management

Digitick, which is an online event ticketing company, offers as Air France does, a 2-D bar code system. The mobile phone users can buy their tickets through website and then download them as images representing the corresponding 2-D codes[21]. At the event entrance they present the code which must be displayed on the phone screen for validation purpose. In this online oriented solution, no NFC is involved.
Another existing solution is the Tapango system[22] which is an electronic voucher system based on NFC cards as e-Wallets. The system reduces the use of paper tickets and was implemented by the Artesis´ research lab. With Tapango, the users first buy tickets via a webinterface, then at the event location they need to synchronize their e-Wallet (by means of a machine connected to the Internet) to 'physically' acquire the tickets and finally they present the NFC card at the entrance 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[23], a pilot related to event ticketing in the theatre of the city of Oulu (Finland) was deployed[24]. The users were able to receive tickets on their NFC-enabled phones and the control of the tickets was achieved with another NFC-enabled mobile phone. Despite the fact that the ticket validation was relatively slow (using the peer-to-peer NFC mode), the users showed a real interest.

## 3 Event Ticketing Concepts

### 3.1 Scenario and Use Cases

Thereafter is reminded that for simplicity concerns, the terms 'ticket' and 'e-ticket' are used interchangeably throughout this paper. Event ticketing follows a well-known scenario. If we want to attend an event, we first need to choose a type of event and a

specific venue. After the choice is done, we gather all the available information on the selected show before deciding rather to buy tickets or not. In some special cases we can directly receive advertisements about events related to our hobbies. Once we have made a decision, we find a date and a time that suit us the best and we then go to the shop (which can either be virtual or physical) where we can buy the approriate number of tickets (most of the time the possibility is given to buy tickets for friends). The day of the show, we go to the venue and at the entrance we present the ticket which corresponds to the event. Six use cases can be identified from the scenario: selection of event, event description visualization, reception of alerts, event tickets issuance, event tickets exchange and ticket presentation at the event site.
In the 'selection of events' use case, the user browses through different categories (for example theater, cinema, concert, etc.) to find the shows he could be interested in. He queries to look for available tickets in the selected categories. Finally, he receives the propositions which correspond best to his choices. For the 'visualization of event' description use case, the user simply visualizes a multimedia presentation of a specific event on his mobile phone before deciding rather to buy tickets or not. Concerning the 'reception of alerts', the user registers to receive alerts as soon as information is available for the kind of events he is interested in. In the 'tickets issuance' use case, the user selects one or several tickets for an event, chooses a payment option, enters the necessary information and validates the transaction. The tickets are then issued and pushed to his mobile phone. The 'exchange of tickets' gives the user the possibility to transfer tickets for instance to a friend by sending them to his mobile phone. Finally, for the 'ticket presentation' at the event site, the user shows his mobile phone to be granted access. These six cases (figure 1) represent the scenario or the steps to follow to attend an event using a mobile phone. This paper focuses on the description of *event tickets issuance* and *ticket presentation at event entrance* steps.

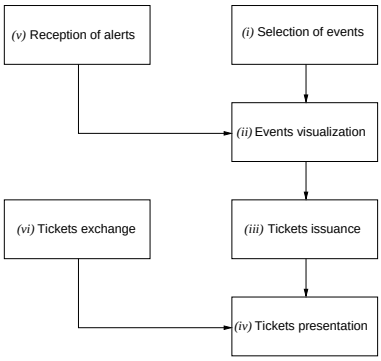


**Fig. 1.** Event ticketing scenario with use cases.

### 3.2 E-tickets for Events

To properly define the e-tickets in the event ticketing context, we must consider the architecture which is commonly used in e-ticketing systems. To be precise, a e-ticketing

system can be seen as a token-based authentication platform that involves 3 main entities : an Issuer, a User and a Verifier[25]. The e-ticket represents the token which circulates between the different entities. Figure 2 briefly explains the role of each entity of the system. An event e-ticket gathers various pieces of information (ticket ID, event ID, price, seat number, etc.) for a particular event[26]. It contains at least the information that can be found on regular paper tickets. Event e-tickets can also contain cryptographic data such as checksums or digital signatures from ticket issuers so that the integrity and authenticity of the tickets can be verified/guaranteed (figure 3).

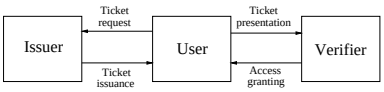


**Fig. 2.** Common e-ticketing architecture.

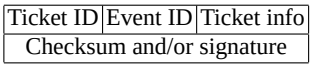


**Fig. 3.** E-ticket data model.

## 4 Two Different Approaches: Offline vs Online

### 4.1 Offline System

**Use Case.** Adam wants to go to see a concert downtown. He connects to the concert website using a computer or his mobile handset and finds a link to the ticket issuer's website. He enters all the necessary details such as his mobile phone number or his payment option and finalizes the purchase. He receives the ticket in a digital format which is sent over the mobile operator network to his mobile phone. When Adam arrives at the concert location, he taps his phone on the reader at the entrance. The ticket is transferred to the ticket verifier which authorizes (or not) the access. The light turns green and Adam can enter to find his seat.

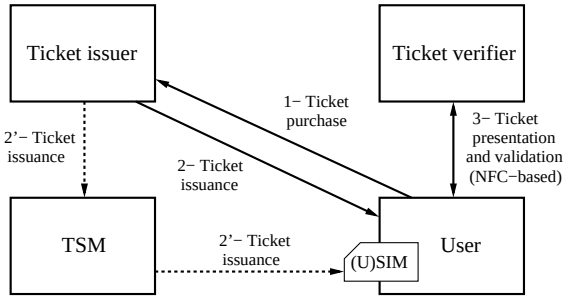


**Fig. 4.** Offline System Architecture.

**Architecture and Interactions.** Four main entities (figure 4) are involved in the offline ticketing approach: the ticket issuer, the ticket verifier, the user with its NFC-enabled mobile phone and the Trusted Service Manager (TSM). In our context the TSM is the entity which manages the loading, the deletion and the personalization of data on the secure element of a mobile phone through a mobile operator network[27].
The entities interact as follows. The user takes the decision to attend an event, selects the event and sends the payment information to the ticket issuer. Then, the ticketing system issues the ticket and sends it to the secure element of the mobile phone of the user using the proper mean of communication (via a TSM or a secure channel). At the event gate, the user presents his NFC phone to provide the NFC-enabled ticket verifier with his e-ticket in order to be granted access. In this offline approach, the ticket verifier has the ability to control the tickets without the use of any external infrastructure, i.e. without any network connection.

**Requirements.** The user must own a NFC-enabled mobile phone with the ability to receive a e-ticket, to store it (in a secure element) and to transfer it to a NFC reader. All these actions can be managed by a mobile application deployed on the phone and its secure element. The Trusted Service Manager has its usual role since its main functionality is to load, when necessary, the digital ticket to the secure element embedded in the mobile phone by using the mobile operator network. The ticket issuer offers a web server and is responsible for the generation and issuance of the tickets. The web server shows the information concerning the available tickets to the user and receives the payment details. The digital tickets are then built by gathering different pieces of information and formatting them properly. Additionally, a digital signature can be applied if required for the verification. In this case, the signature is achieved by the ticket issuer with a private key, the corresponding public key[28] being provided to the ticket verifier. The ticket issuer transfers the ticket either over the mobile network or through any other kind of secure connection to the mobile phone secure element. Before the control, the ticket verifier must be provided with the relevant information regarding the corresponding event. In most cases, the event identifier and the ticket's period of validity are necessary elements for the verification. During the validation phase, the ticket verifier makes sure of the authenticity and integrity of the received ticket. In order to avoid a re-use, the verifier must either keep track of the tickets that are presented or modify their validity (date, status, etc.). A ticket verifier can be composed of a NFC reader embedded in a mobile phone or connected to a computer and linked to an application for the cryptographic and ticket management operations.

### 4.2 Online System

**Use Case.** Adam wants to go and see a university theatre show. He goes to the event organiser's website, where there is a link to the ticket issuer's website. He already has an account at this website so, he logs in, adds the proper ticket to his shopping cart and pays for it. When Adam goes to the show, he taps his phone on the reader and once the permission to enter has been checked by connecting to the ticket issuer, the light turns green and Adam can enter.

**Architecture and Interactions.** The online event ticketing paradigm is based on the premise that no dynamic information (here a ticket) is installed on the user's device.

The assumption is that there is just a static identifier stored in the secure element of the user's mobile device, that same static identifier being stored in the ticket issuer's backend system where all dynamic information are processed. This means that a user does not have any ticket with him (in his mobile phone) when he goes to an event; he only has an identifier that will be used by the verifier to check by the ticket issuer that he is authorized to attend the event.

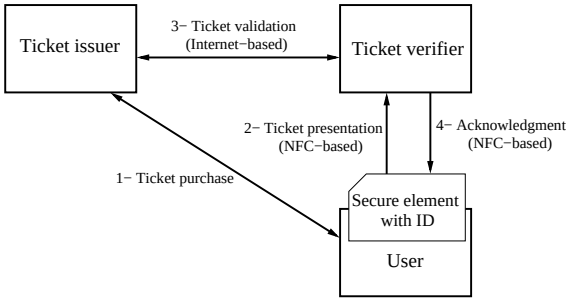


**Fig. 5.** Online System Architecture.

**Requirements.** Online event ticketing requires a secure element to be available in the user's mobile device, where to store static identifiers. This secure element may be a (U)SIM or another secure element that is embedded in the device. Obviously for convenience reasons, an application loaded on the secure element ensures a proper setting and provides the static identifier when required.
The online event ticketing system is described in figure 5. The relationship between the event organiser and the ticket issuer is similar to what they are today: the ticket issuer sells the tickets and the event organiser validates them. In the online events ticketing scheme, event organisers need a working Internet connection at the event gate. At the gate the right to enter is verified by reading the identifier from the secure element of the user's mobile device and then sending it to the ticket issuer's system. It returns the authorization (or not) to enter.
When the user buys a ticket for a specific event from a ticket issuer, the ticket is stored in the ticket issuer's back end system and it is connected to the static identifier stored in the user's mobile device secure element. Because the user does not carry the ticket information with him, the ticket issuer's back end system needs to be able to provide this ticket information when requested. This may be done by using the ticket issuer's Internet site.

## 5 Paradigms Comparison

### 5.1 Overview

To compare the two paradigms that we have described, we will focus on five criteria: user experience, security, economical aspects, reliability and speed of use. Some prototypes illustrating the online and offline systems were developed to run reliability and

validation speed tests. The Nokia 6212 classic[29] has been used for this purpose. This NFC-enabled mobile phone can run J2ME[30] midlets and embeds an internal secure element which can run Java Card[31][32][33] applets. With two of these phones we have implemented a basic prototype for each paradigm we consider, online and offline. The first handset acts as the client device and has a ticket or a static identifier stored in its internal secure element. The second handset is the validator device and reads the ticket from the client device in order to check its validity (either offline or online). The secure element of the client phone is loaded with a Java Card applet containing the ticket information (either the whole digital ticket or the static identifier). The validator phone runs a J2ME midlet in charge of retrieving the ticket information and checking the validity of the ticket (either locally or by accessing a remote database via a HTTP request).

### 5.2 Security

In our study, the security analysis targets the validation phase. In this phase, online and offline approaches both make use of a secure element and rely on the NFC card emulation mode. Consequently, they achieve the same level of security. To proceed to the ticket validation, the user taps his phone on the reader what leads to a direct communication between the secure element and the reader. The use of a secure element prevents the static identifier or the whole ticket (depending on the approach) from being forged or spoofed as a secure element is assumed to be a tamper resistant device[34].
In both cases, to improve communication security, a mutual authentication is performed. This authentication, which uses the GlobalPlatform standard[35], ensures that the information exchanged (between the phone's secure element and the validator) only involves authorized entities (a real user and a real validator).

### 5.3 Reliability

Regarding the ticket issuance phase, both models have a strong need for a steady Internet connection. However, for the validation phase, only the online approach requires a connection in order to query the ticket issuer's database. Any disconnection at that time would prevent tickets from being validated. Another issue arises, for both paradigms, if the mobile handset runs out of battery during the validation process. In this situation, there can be no communication between the reader and the mobile device, thus preventing the validation process from taking place. However, some NFC phones have a 'battery off' feature which allows the secure element to interact with the reader regardless of the battery state[36]. We believe that this feature will be common in future NFC-enabled phones and will thus improve the reliability of both approaches.

### 5.4 Speed of Use

Fast ticket validation is an important requirement. In the mass transit sector the transaction time should not exceed a few hundreds milliseconds[37]. In our tests validation is achieved in three steps: mutual authentication, data retrieval and network use (for the online approach). For the offline approach, the data retrieval targets the transfer of a 1 kilobyte ticket from the secure element to the validator and there is no network needed

(as the ticket validity check is performed locally). For the online approach, the data retrieved from the secure element is the static identifier (a 10 bytes String) and the network is used to access the ticket issuer database (3G connection). The results presented in figure 6 show that the offline solution is much faster. It is nevertheless necessary to observe that the Nokia 6212, which is used as a validator, has no broadband Internet connection capability (no WIFI for instance) and that the validation time of the offline option increases with the size of the ticket.

### 5.5 User Experience

Our e-ticketing applications offer three main features: ticket purchase on a website; ticket presentation for validation purpose at the event entrance; listing of tickets that have been bought. As the online and the offine versions allow to perform the same actions and since the underlying processes (for the website and the tickets listing) are transparent to the user, we can assume that there is no major difference in the user experience. Nevertheless, for the ticket validation phase, we can find a small difference. In the online approach, there is no need to select the ticket to validate (no ticket is stored in the mobile phone and unique identifier is used), but in the offline approach the user must select the ticket he wishes to present what can slightly reduces the user-friendliness aspect.

### 5.6 Economical Aspect

NFC-based event ticketing brings new players to the industry as Mobile Network Operators (MNO) and TSMs providers can offer new channels for events ticketing; but it remains to be seen if they can offer these channels cheap enough or offer cost savings. Anyway, as customers learn to use ticketing with NFC in public transportation, the event ticketing domain becomes also under pressure to go compatible with NFC.
Generally, the economical aspect always depends on the business model which is used. For now, online and offline event ticketing are open fields where a lean business model might be created and a market niche be found. With the opportunities offered by NFC, the experience gained in transportation system and the release of new smartphones endowed with NFC, we believe that the big players can afford investments in this business sector. For these companies, there is no significant difference in the investments that have to be made in terms of infrastructure (TSM, adapted NFC readers, backend systems, website) between the two approaches. Both systems could thus coexist.

### 5.7 Summary

The two paradigms, offline and online ticketing that we have presented, mainly differ in the need or not of online connection. Speed of validation and user experience were identified as parameters that can help decide which paradigm should be used in which context. However, the online and offline approaches are more or less equivalent in terms of performance. The comparison of the two approaches is summarized in figure 7. For each category, the symbol + represents an advantage and the - is a disadvantage; the = symbolizes a similar level of performance.

| | Offline | Online |
|---|---|---|
| Authentication | 161 | 161 |
| Data retrieval | 605 | 52 |
| Network Use | 0 | 4091 |
| Total (in ms) | 766 | 4304 |

**Fig. 6.** Validation speed tests results

| | Offline | Online |
|---|---|---|
| Security | = | = |
| Reliability | = | = |
| Speed of use | + | - |
| User experience | - | + |
| Economical aspects | = | = |

**Fig. 7.** Comparison of both approaches

# 6 Future Work

## 6.1 Pilots

Within the framework of the Smart Urban Spaces[38] (SUS) European project in which this research around NFC-based event ticketing is conducted, the deployment of pilots using some aspects of the proposed models description are planned. These pilots target small events such as private concerts or theater plays. For this kind of events, there is a strong need for a flexible and cheap ticketing system as the organisers cannot afford big investments. Some French and Finnish cities (working with LaBRI and VTT) like Helsinki or Caen are potential candidate to deploy these pilots.

## 6.2 Perspectives

The next step in our research is to focus on e-ticketing system based on NFC-enabled devices dedicated to small events. Small events, which are events with a limited number of attendees, represent an uncovered niche. This research will take into account the ease of deployment, a lightweight architecture (with no need of big external infrastructure such as a TSM for instance) and the reduction of the costs still targeting offline and online options.
Another point, regarding event ticketing management, is to work on a e-ticket standard description and the associated storage procedures inside mobile phones. As far as we know, there is no real event e-ticket standard and it would be thus relevant to make contributions in this area.
Finally, by leaning on the previous points, we will work on the concept of interoperability from the perspective of users running mobile NFC-based applications (such as the event e-ticketing system) in different European cities in the framework of the SUS project.

# 7 Conclusion

Two different approaches to deal with ticketing issues and their respective architecture, described as *offline* and *online* solutions, were presented in this paper. In the former solution, the platform responsible for validating the tickets at the entrance has no need to communicate with the ticket issuer, and thus does not use an Internet connection. Conversely, in the latter solution, a direct link exists between the ticket issuer and the ticket verifier platform. The prototypes that we have developped and that make use of

NFC-enabled phones, demonstrate the feasibility of the proposed solutions. Although both of these approaches have advantages and drawbacks, the comparison shows that globally they can achieve the same level of performance. As big companies will most likely deploy online and offline applications for big events, it is certainly relevant to target small events in the next research topics in the context of a NFC-enabled mobile phone ticketing system.

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