Modeling NFC-triggered User Interactions with Simple Services in a Smart Environment

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Keywords: NFC, NFC Interaction, Context Awareness Service, Mobiquitous Services, HCI, Smart Environment.

Abstract: NFC is an emerging wireless technology that can enable users to interact with smart objects in a smart environment. NFC applications have been developed to provide services like ticketing, access control, tourism information extension, voucher redemption and contactless payment. The interaction technique is a sort of "tap-and-go" as it is currently employed in smartcard usage for travel operations and workspace access/logging. Employing a recently introduced framework for human interaction with mobiquitous services, we present a model of NFC-triggered user interactions with simple context-awareness services in a smart environment. The rationale is to provide a conceptual tool for both an appropriate communication among NFC ecosystem stakeholders and the interface design of NFC apps with a generic applicability. Lastly, we discuss the application of the model in a project which required the design of NFC-based interactions with services for car parking management in a city area.

1 INTRODUCTION AND BACKGROUNDS

Near Field Communication (NFC), a two-way communication technology based on RFID, is a relevant enabler for smart environment applications, where people can invoke associated services by bringing together two NFC compatible devices close to each other. Nowadays, NFC technology has been employed in a large range of business/consumer applications and services in various industry sectors. Nevertheless, many researchers continue to propose application scenarios or use cases in order to explore new opportunities of NFC apps that can generate significant business value through the provision of more accurate and timely information, (Dodson and Lam, 2012; Haselsteiner and Breitfuß, 2006). However, a characterization of NFC interaction with services is still needed in order to provide both a common understanding of capabilities and features of NFC apps and a support to the design, development and deployment of novel services.

NFC-based interaction uses two NFC enabled devices to facilitate human interaction with information and services. Such interaction is performed by means of a very elementary touching technique consisting in a simple tap gesture, i.e. the user brings a NFC device into close proximity to another. More precisely, two compatible NFC devices (e.g. a contactless card and a mobile phone) communicate with each other when they are less than few centimeters nearby; the communication may occur either between two active devices, powered and equipped with data processing capability, where two NFC peers actively exchange messages, or between an active device and a passive device that only serves as a passive tag.

This communication provides simple and fast data transfer including calendar synchronization or electronic business cards, as well as access to online digital content. Therefore, NFC technology permits creating a bridge between digital and physical worlds and it allows some applications in a smart environment to be made more personalized, dynamic, and intelligent (Chang et al., 2011).

Actually, NFC smart phones that embed the NFC device are employed in a growing number of applications and services (Volpentesta et al., 2013; Beny'o, 2007). An NFC phone can switch operation modes. Therefore, it can not only serve as the basic key for authenticating entry to a smart environment (e.g., a household environment), but also it can provide personalized control of a variety of smart objects (e.g. smart home appliances) that are driven by the request from NFC mobile phone using

P. Volpentesta A. and Frega N..
Modeling NFC-triggered User Interactions with Simple Services in a Smart Environment.
DOI: 10.5220/0005377500960104
In *Proceedings of the 17th International Conference on Enterprise Information Systems* (ICEIS-2015), pages 96-104
ISBN: 978-989-758-098-7

predefined ontology and rule based reasoning (Chang et al., 2013).

Unlike other human-computer interaction technologies and styles that require specialized controllers and instructions, NFC interaction is a sort of easy touch-driven interaction between physical and digital space without requiring any particular training process: a tap gesture action is translated into information flow in digital space, which is in turn reflected by media activity in physical space through an associated output device resource. For instance, a NFC enabled smartphone can be used as an active scanner in order to detect a tag in its range, and trigger an interaction with a service that is provided through some output device (phone, TV, stereo,etc.) (Chen et al., 2011). Apart from simple interactions with single tags, NFC have been used for more elaborate interactions with physical user interfaces (UI) that comprise multiple tags, i.e. multi-tag interactions, where different features of NFC applications are mapped to multiple tags and spread on physical UIs, in order to allow a user to select them directly (Broll and Hausen, 2010). Application examples are given by smart posters for mobile ticketing (Broll et al., 2009), home care services (Häikiö et al., 2007), sharing multimedia content (Sánchez et al., 2008), and dynamic NFC-displays (Broll et al., 2011).

In this paper, we focalize our attention on NFC-based smart environments where simple context-awareness services are provided by networked computing devices that include NFC enabled devices and application servers running in a separate computer room, or remotely on a "grid". A simple service is intended as a service that just returns a simple result when it is invoked by the user; its execution delivers an expected result that fulfills user's needs without requiring any other information to the user.

In (Volpentesta, 2014), framework for human interaction with mobiquitous services has been introduced. Such framework is independent of the particular technology employed in the smart environment. In this paper, we focus on NFC-based smart environments, and we use that framework in order to provide a model of NFC-triggered user interactions with simple NFC services. This model could be regarded as a conceptual tool for supporting either an appropriate communication among NFC ecosystem stakeholders and the interface design of NFC apps with a generic applicability. Lastly, we discuss the application of the model in a project which required the design of NFC-based interactions with services for car parking management in a city area.

2 NFC-BASED SMART ENVIRONMENT

In this paper we define a NFC-based smart environment as a small world populated by users, simple context-awareness NFC services, and interaction resources (NFC enabled devices and output devices) interconnected to some application servers that may run in a remote place. A context-awareness NFC service may provide a user with access to information about the environment surrounding him (weather conditions, up-to-date traffic, …), organizational systems (current product prices, local events, flight status, …) and other people (phone numbers, birthdays, meetings, …) whom he is interested to have relations, as well as it may allow a user to control physical devices (printer, home appliance, …), or to pass information assets (buying preferences, medical data, …) to an organizational system.

In what follows we discuss the main elements of an NFC-based smart environment and their inter-relationships.

2.1 Interaction Resource

In the NFC-based smart environment, we distinguish between input and output resources, and we assume that any input resource is associated to a simple service and an output resource.

An ***input resource*** is constituted by two compatible NFC enabled devices one of which may act as a NFC reader and the other one may act as a NFC target, i.e. a source of data. The NFC reader (e.g. an NFC smart phone) reads data contained by the NFC target that is a physical device with attached/embedded an NFC tag. Moreover, the NFC reader may have built-in pre-processing options (e.g. filtering and reorganizing the data) and sends processed data to the simple service application by using other protocols (e.g., wi-fi, 3G/4G). These two devices may trigger the simple service only when they are brought together into close proximity, and they are compatible with respect to the NFC reader logic or the service application requirements (the tag content should be in a format ready to be processed by either the NFC reader or the simple service application).

An ***output resource*** is either a device controlled by a NFC reader to provide a basic feedback as acknowledgement that the tapping action has been successful/unsuccessful, or a device controlled by the simple service to provide the needed response. The service response may be provided via a video/audio/

haptic communication channel (e.g., graphic/textual message on a screen, a sound from a speaker, a vibration on a smart phone).

2.2 Simple NFC Service

It is a software function, together with the policies that control its usage. It just returns (depending on the current context situation) a simple result as it is invoked by an input resource, i.e. a pair of compatible NFC reader and NFC target that are tapped together; the tapping action is performed by the user and it triggers the service execution; the data contained in the NFC tag, and possibly preprocessed by the NFC reader, are used as input to the service; the execution of the simple service delivers the expected result on the associated output device, and we assume that it fulfills user's needs without requiring any other information or choice from the user.

2.3 User

A *user* is a person that enters the spatial environment and is capable of:

- being aware of interaction resources, their location inside the spatial layout, and the associated simple NFC services. Previous studies have tackled the usability problem of identifying the interaction resources in a NFC-based smart environment. Such a problem arises when a user is unfamiliar with NFC technology and adopts “false” mental interaction models previously developed (Mäkelä et al., 2007). In order to overcome it, researchers in user interface visual design have proposed user centered approaches that make use of special symbols and a graphic language to visualize NFC resources and the tap-based interactions with them (Hang et al., 2010; Arnall, 2011);
- approaching interaction resources and knowing how to initiate the interaction with them. The user should have normal physical abilities and sufficient experience to overcome their initial difficulties and inhibition threshold (Hang et al., 2010);
- triggering the interaction with a simple service. The user should be able to grasp a mobile NFC device (e.g. a NFC smart phone or a NFC-tagged card/wristband) and bring it to a complimentary NFC device (NFC reader, NFC-tagged physical object) within a short range. However, we take into account possible problems concerning the incorrect alignment of NFC target and NFC reader devices as they are tapped together (Geven et al., 2007).

Fig. 1 illustrates how interactive resources, simple service, and user interact in a NFC-based environment, bridging the gap between virtual and physical spaces.

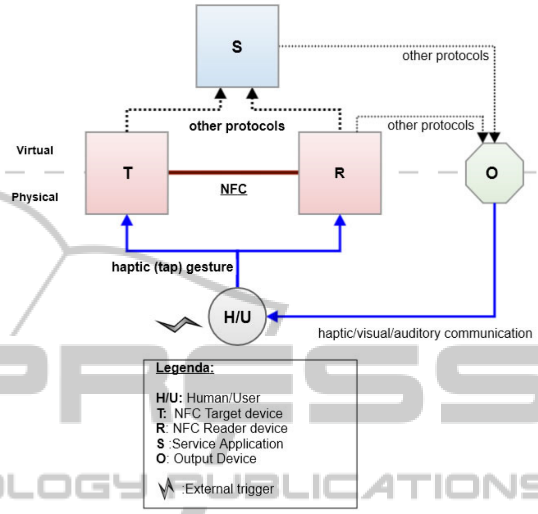

Figure 1: The NFC-based environment.

3 NFC-TRIGGERED USER INTERACTIONS WITH SIMPLE SERVICES

As part of the interaction model, some authors identified the stages of a NFC-triggered user interaction with simple services in a NFC-based smart environment (Sanchez et al., 2011; Hang et al., 2010). These stages may be summarized in: *discovery* (exploring the environment, locating and approaching the input resource to interact with the simple service associated to it), *match* (bringing together the pair of NFC devices of the input resource) and *usage* (providing other inputs and commands required by the service application at any step of the interaction).

We focalize our attention on the match stage, i.e. when the user brings together two NFC devices in order to invoke the associated simple service. We presume that the previous discovery stage has already been properly performed by the user (this is the case when an appropriate physical user interface design approach has been configured around user requirements, or when the user has already got accustomed to the environment). We also neglect the subsequent usage stage, because it is not meaningful in the interaction with simple service, as only one service function is executed after tapping together two compatible NFC devices.

Beyond user, simple NFC services and interaction resources, other basic elements of this framework are represented by interface context, actions performed by a user or a simple NFC service, as well as interaction information flow associated to any pair of user and simple NFC service. Let us specify these elements and their inter-relationships in the case of NFC-triggered user interaction with simple NFC services in a NFC-based smart environment.

3.1 Interface Context

The interface context is a model for a structured representations of entities (called items) whose instances (called items states) describe a single situation that may occur in any interaction between a person (i.e., a user) and a simple NFC service. The model consists of only those items whose current states are needed to be known by a user and a simple NFC service in a contextualized interaction. Interface context items are of the following five types:

- **Identity.** It concerns the identification of the current user, and the input resource (a compatible pair of NFC reader and NFC target) involved in the interaction (a simple service is univocally determined by an input resource);
- **Distance.** It is a discrete measure of the relative distance between the two NFC devices of an input resource. Usually, it is a binary measure that indicates whether these two devices are *in range* or *out of range*;
- **Location.** This refers to the location where the paring of the two NFC devices of an input resource occurs. It may be an absolute geo-location (i.e. determined by GPS position of one of the two NFC devices) or a relative to a fixed point in the physical environment (e.g. a position in a grid, like in mobile interaction with dynamic NFC-displays (Broll et al., 2011)). We assume that one of the two NFC devices has a fixed position;
- **Time.** It refers to time-related properties (current date and time, elapsed time from previous interactions, etc.) of the interaction between a user and an input resource. The item state is determined by an internal clock of one of the two devices and it is expressed in an appropriate date/time format;
- **Environment.** It refers to physical conditions of the output resource associated to an input resource in the spatial environment surrounding the user. An output resource is used as both a RF feedback-notifier of the user tapping action and a container of the simple service response.

Moreover, it is important to distinguish between interface context items that are changeless or changeful. A *changeless* item is an item whose state cannot be changed by the execution of a user or service action during an interaction, whatever its current state and user or service action may be. Of course, a changeless item state can be changed by an action performed by an external entity different from a user and a service. An interface context item is *changeful* when one (or some) of its states can be altered by a user or a service action. In an interaction, a changeful item state can affect and be affected by the user or service behaviour, while a changeless item state can only affect the user or service behaviour (for instance, its change can trigger an action). In NFC interaction, the distance and environment items are the only changeful items, while the others are changeless items.

3.2 Actions

According to (Volpentesta, 2014), it is an act, performed by the user or the service, which changes states of some items and lets the performer counterpart to get information about the current interface context. Therefore, any act, performed by the user or the simple NFC service, that does not change the state of any item of the interface context (and thus not communicating any information to the counterpart) is not considered an action.

In NFC interaction, a user action is a physical act that changes relative distance between the two NFC devices of an input resource, thus changing the *distance* item state (let us denote its values as 1 for *in range*, and 0 for *out of range*). A simple service action is the execution of a software function that changes the state of a *RF feedback notifier* item and , possibly, the state of the *service response notifier* item. Notifications may occur through an audio/visual/haptic a sign in the user surrounding environment and notifier item state may be represented by a binary variable (0 for "unnotified" and 1 for "notified")

Distance, RF feedback notifier, and service response notifier are the changeful interface context items whose states can be changed by actions performed by a user or a NFC simple service it's described in what follows.

- **User actions:**
    - u1: bringing together two NFC devices of an input resource. This action switches the distance state from 0 to1, and it is externally triggered by the user intent to consume the

simple NFC service associated to the input resource;
- u2: detaching two paired NFC devices of an input resource. This action switch the distance status from 1 to 0, and it is triggered by user awareness of the notifier item state change from 1 to 0.

- **NFC simple service actions:**
  - s11: sending both a confirmation that the NFC target has been correctly read, and the service function results to the output resource. This action changes from 0 to 1 both the *RF feedback notifier* item state and the *service response notifier* item state of the output resource. The action is triggered by the execution of u1 when the two NFC devices are compatible and correctly aligned;
  - s12: releasing the output resource. This action changes from 1 to 0 both *RF feedback notifier* item state and the *service response notifier* item state of the output resource. The action is triggered by the end of the execution of s11;
  - s21: sending an error message to the output resource that the NFC target has not been correctly read. This action changes the *RF feedback notifier* item state from 0 to 1. The action is triggered by the execution of u1 when the two NFC devices are not compatible or not correctly aligned;
  - s22: releasing the output resource. This action changes the *RF feedback notifier* item state of the output resource from 1 to 0. The action is triggered by the end of the execution of s21.

The *interaction graph* is the oriented graph where the nodes are associated with the states set of the changeful interface context items and the arcs are associated with the actions transforming one states set into another (Volpentesta, 2014).

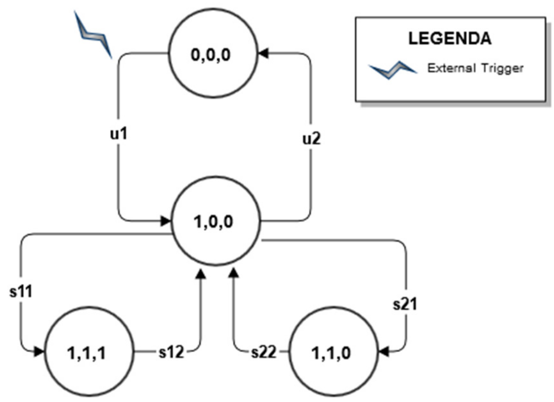

Figure 2: The NFC interaction graph.

Figure 2 illustrates the interaction graph for NFC-triggered user interactions with simple services.

In (Volpentesta, 2014), the concept of interaction pattern has been introduced as the basic structure of chained actions that is common to all interactions occurring in similar situations. In NFC-triggered user interactions with simple services, it turns out that interaction patterns are determined by two circuits in the NFC interaction graph:
- (u1,s11,s12,u2), associated to a *proper interaction*;
- (u1,s21,s22,u2), associated to *an improper interaction*.

3.3 Interaction Information Flow

When an interaction pattern has been performed, some information is exchanged between a user and a simple NFC service. Given an interaction pattern, the interaction information flow is a model of information exchanged between a user and a simple NFC service, during the execution of that interaction pattern. Of course, it includes elementary data pieces needed by the simple NFC service to be aware of the current context situation.

As matter of fact, once the two NFC devices are brought together, elementary data on states of interface context items are exchanged between them (in case of a proper interaction), and then transmitted to the simple NFC service through a protocol other than NFC.

The simple service receives such data and can be aware (or recognizes) the current situation context which is a snapshot of the states of interface context items (relevant properties of the smart environment, the system, and users). In order to do that, the simple service generally makes use of context data coming from other sources, a domain model (taxonomy or ontology) of the interface context, and an inferring capability (e.g. defining attributes and classes or fusing current data into meaningful context situations). Besides data on states of changeful items of the interface context, user and service exchange data of the following types:
- **Identity.** It regards:
  - *User*: personal data (name, age, birthdate, etc.), activity-related data (personal schedules, tasks, etc.), social-related data (community membership, friends, organizational role);
  - *NFC target*: NFC tag identifier and content metadata, as well as other business and physical data useful for a semantic description of the physical object with the attached NFC

tag (e.g. price, warehouse location, expiration date, weight of a product);
  - *NFC reader*: identifier and other device metadata (device type, manufacture, obsolescence, …), trust & security data (access control, usage rights, …), functional data (settings, network address, state and capabilities, etc.);
  - *Simple service function*: function control data and metadata (function type, application server, service provider, policy, …) including a command to perform the function;
  - *Relationships*: elementary data necessary to derive relationships between user, interaction resources and simple service (user access level, user preferences, history patterns, etc.);
- **Location.** It regards "where" the NFC interaction occurs. The location data can be expressed as a qualitative description (e.g. room or floor reference) or as a quantitative information (geo-location, distance from a known point, relative position to known point);
- **Time.** It regards time-related properties of "when" interaction takes place. Temporal data can be also used for a semantic interpretation of the interaction moment (e.g. season, calendar events, day time periods). Generally such data are derived from the NFC reader internal date-time functions;
- **Environment.** It regards environmental data (e.g. temperature, brightness) coming from other smart objects controlled by the NFC reader that send them to the simple service.

4 A REAL CASE STUDY

As a partial validation of the model, we describe its application in an ongoing project addressed to the employment of NFC technology in regulating the use of municipal parking areas in the city of Cosenza (Calabria, Italy). Cosenza is a little town in southern Italy; according to ISTAT statistics dataset (http://www.istat.it) for 2012, Cosenza has a population of 68,000 inhabitants; the number of circulating cars is over 50,000, and there are 138 toll parking slots per 1,000 circulating cars (7th place in national ranking). A municipal agency is in charge of management of the toll parking service in outdoors parking areas (five areas with different payment policy); it manages 140 working parking-meters, equally distributed over the available parking areas. Following the proposed model, we discuss the NFC-based smart environment and the NFC-triggered user interaction with two simple services that we have conceived and developed in the project.

4.1 The NFC-based Smart Environment in the Case Study

The NFC-based smart environment may be described in terms of users, interactive resources and NFC simple services.

Users. We have considered two different type of users: the driver, who desires to use a parking area for his/her car, and the parking officer, who's in charge to check if a vehicle is allowed to stay in a particular parking area or not.

Interactive Resources. We have considered two input resource types:

a) A couple of driver's NFC-enabled smart phone (acting as NFC reader) and NFC tag attached on a parking-meter (acting as NFC target);
b) A couple of officer's NFC-enabled smart phone and NFC tag attached on the windshield of the driver's car.

Both NFC smart phones brought by the two class of users are equipped with a peripheral device, working as output resource.

NFC Simple Services. We have considered a driver-oriented simple service and an officer-oriented simple service that are fully described in the next subsection. Each one of this two simple services is based on a pair of a set of scripts running on the smartphone memory (bundled as an app) and a remote REST API functions that collects, filters and verifies the changeless states of the current interface context items.

4.2 NFC-triggered User Interactions in the Case Study

As we have discussed in section 3, the NFC-triggered user interactions can be described in terms of interface context, actions, and interaction information flow. The interface context is formed by changeful items (namely, distance, RF feedback notifier, and service response notifier) and changeless items in the interaction information flows associated to either the driver-oriented simple service or officer-oriented simple service. Therefore, in what follows we describe actions and interaction information flow for each of the two considered NFC simple services.

4.3 Driver-oriented NFC Simple Service

4.3.1 Actions and Service Functions

The first user/driver action is to bring a couple of NFC compatible devices together, see point a*)* in 4.1, this action is triggered by his/her willingness to get authorization for a parking space occupancy with a car. This action changes distance item state from 0 to 1. In response to it, a service action may change the state of RF feedback notifier, and service response notifier. In case of proper interaction, an information flow (states of changeless interface context items and other data) is enabled between one of the two NFC devices and the simple service.

The simple service checks user's permission rights and payment account, and then, it sends the operation result to the user's smartphone, via a protocol other than NFC. Successively, the user/driver separates the two NFC devices, and this ends the match stage of the NFC triggered user interaction. However, in order to complete the case studio scenario, let us briefly describe the successive usage stage. An authorized user/driver may interact with the app on its smartphone in order to acknowledge the simple service he/she wants to park. At this moment, the simple service starts counting the time the user's vehicle remains stationary. The user/driver can later interact with the app on the smartphone in order to stop the timer at the moment he/she wants to leave the parking lot. At this moment, the simple service is capable to compute the amount of parking cost depending on the elapsed time, the parking zone cost-per-minute (related to the parking-meter-id), and possible special user's permissions (resident permission, disabled person's permission, etc.). Lastly, the simple service deducts the parking cost from user's payment account, and it sends back to the user's smartphone a receipt of the payment (via a protocol other than NFC).

4.3.2 Interaction Information Flow

The interaction information flow consists of the following changeless items data:

- driver/user's identity and an associated vehicle registration plate number. These data come from a local storage of the user's NFC smartphone;
- parking-meter identity and location. These data are retrieved from one of the NDEF records inside the NFC tag attached to the parking-meter;
- parking starting time (the moment when the user acknowledges the simple service he/she wants to park). These data are derived from the internal clock of the user's smart phone.

4.4 Officer-oriented NFC Simple Service

4.4.1 Actions and Service Functions

The first user/officer action is to bring a couple of NFC compatible devices together, see point *b)* in 4.1, this action is triggered by his/her willingness to check the authorization for a car occupying a parking space.

This action is the same of the one described in 4.3.1, but it enables a different information flow (states of changeless interface context items and other data) between one of the two NFC devices and the simple service. This information allows the simple service to check permission rights for the car, and then it sends the operation result to the user's smartphone, via a protocol other than NFC. Successively, the user/officer separates the two NFC devices, and this ends the match stage of the NFC triggered user interaction. Lately, in case on unauthorized parking, the user/officer may issue a parking infringement notice.

4.4.2 Interaction Information Flow

The interaction information flow consists of the following changeless items data:

- user's identity (i.e. officer's identity). These data come from a local storage of the user's NFC smartphone;
- vehicle identity (registration plate number). These data are retrieved from one of the NDEF records inside the NFC tag attached to the vehicle windshield;
- vehicle location. These data are derived from the internal GPS sensor of the user's smart phone;
- time of check (the moment when the user/officer acknowledges the simple service he/she wants to check the authorization for the vehicle). These data are derived from the internal clock of the user's smart phone.

4.5 Case Study Validation

In order to complete early stages (conceiving and developing) of our life cycle project, we have conducted a basic empirical validation of the adopted conceptual model and of the two simple services. To this purpose, we have selected two traffic officers, ten drivers (employers of the municipal bureau) owning a personal Android NFC-equipped smartphone, and three parking-meters near the city hall, where usually the ten drivers get a parking when they go to work.

The two officers were endowed with a specific model of Android NFC-enabled smartphone with pre-installed officer-oriented app, and we have instructed them on how to use the app and how to use a smartphone as NFC reader. Each of the ten driver was given a car's NFC sticker with general guidelines on both how to attach the NFC sticker to the internal part of his/her car's windshield and how to download and install the driver-oriented app on his/her own smartphone. Each car's NFC tag was encoded with only one NDEF record for the car identity. For each parking-meter, we have written two NDFEF records (1 for the identity and 1 for the geo position) into a NFC tag with a typical NFC "tap here" icon. Then, we have asked a municipal operator to stick each NFC tag on the associated parking meter. We provided both officer-oriented app and driver oriented app with an extra notification function in order to record officer and driver actions in the match stage of the NFC triggered interaction. Validation participants were primarily required to interact with simple service via NFC, but we also offered a fall-back solution that allowed them to get service response (checking-in for drivers, checking car permissions for officers) by manually entering input data into a form. Moreover, in case of manual input fall back use, we proposed them a dedicated modal form on each app in order to let them indicate the reasons why they were not interacting via NFC.

In the app modal dialog, the user can choose among these options:

A. Tag not found/not reachable: the user was not able to find or reach the NFC target tag;
B. Tag unreadable: the user did not get any feedback on the output resource after bringing together the NFC reader and the NFC target tag;
C. Tag read error: the user did get an error feedback on the output resource after bringing together the NFC reader and the NFC target tag;
D. Other, specify later: the user will be contacted after the validation period in order to know why he/she chose the fall back solution.

We have been tracking app users actions and collecting data over a period of four successive days of December 2014.

Result analytics, shown in table 1, gives a first insight on the usability/accessibility of the two NFC simple services interfaces in novice users' perspective.

Our validation has made it possible to simulate and visualize requirements and high-level designs very early in the project life cycle; this has pointed out some decisions that should be taken about the responsibilities and behaviour of model components, and their interaction. In particular, the results yielded by our early validation work have suggested:

- more effort must be dedicated to teach users on using a smartphone as NFC reader, in order to overcome their initial difficulties and inhibition threshold;
- how the NFC tags are located onto parking-meters is an important design issue to be considered to facilitate driver NFC triggered interaction (parking meter's NFC tag should be clearly visible and easily tapped);
- the app user should be aware where the NFC reader antenna position is on the back of his/her smartphone, otherwise he/she could have problem in aligning NFC reader antenna with correspondent NFC target one;
- before sticking the NFC tag on a parking meter, the municipal operator should be aware that in some positions the NFC tag antenna could interfere with metallic parts of the parking meter shell;
- additional instructions should be provided to assist drivers in positioning the NFC sticker onto the internal part of their car's windshield in order to facilitate officer NFC triggered interaction (car's NFC tag should be clearly visible and easily tapped).

Table 1: Validation analytics.

	officer interactions	driver interactions
TOTAL	82	87
NFC	74	75
Txt	8	12
% NFC	90,24%	86,21%
Opt A	1	4
Opt B	3	2
Opt C	3	1
Opt D	1	5

5 CONCLUSIONS

NFC-based smart environments establish an easy way to embed the computation in everyday life environments, as they facilitate the human interaction with information and services. Such interaction is not centralized in a single device, but any pair of compatible NFC devices can potentially give an input to a service. In particular, NFC-triggered interaction with simple services does not require the user to manually input values. The concept is that the event, triggered by bringing together two NFC device in close proximity, is translated into information making aware the simple service of the current context situation, and the service execution, depending on the context and service characteristics, is reflected on a corresponding activity in physical space.

In this paper, we have proposed a model of NFC-triggered user interactions with simple NFC services. The model is a conceptual tool readily applicable in designing, analyzing and operationalizing human interaction with real simple service applications in a NFC-based smart environment. Although it has not been completely validated yet, its usefulness has been confirmed within the development of a project which required the design of NFC-based interactions with simple services for car parking management in a city area. The model elements could be regarded as the building blocks of interaction structures with complex NFC services, where the service execution could not deliver the expected result that fulfills user's needs, requiring some more information than the one exchanged during the NFC interaction with simple services. The idea is that any interaction with complex services can be regarded as a combination of elementary structures identified by our model. This lets us hope that our effort serves to open new research avenues that could be taken in the future in order to define a general model of NFC-triggered user interactions with complex NFC services.

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