Towards an Interoperability Evaluation Process for Mobile Contactless City Service

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***Abstract*— Interoperability of mobile contactless city services has been emerging as a topic of discussion in many of the recent events by the representatives of industry and city organizations. Evidently, the interoperability has a connotation of a world where systems and devices interoperate or work together seamlessly. In the real world, such interoperability is a myth, and must always be built by considering the specificities of the existing artefacts. This paper studies and defines interoperability in the context of mobile contactless city services. We present three piloted mobile contactless city services to identify which kind of interoperability issues can be raised. Based on this analysis, an interoperability framework is proposed first by delineating the set of relevant entities and then by presenting four dimensions of the interoperability issues between the entities. We believe that this framework helps finding other related elements to make a coherent picture of interoperability in this context. It also leads to the definition of a relevant evaluation process. The goal of the paper is: (1) to properly define interoperability in our context; (2) to propose a set of evaluation criteria; (3) to propose an overview of an evaluation process**

Keywords-interoperability; seamless; cities; contactless; NFC; mobile services; user

I. INTRODUCTION

Mobile phones have become a commodity and are increasingly in use by urban dwellers. One of the emerging technologies for the mobile services is contactless technology, already known in city or smart cards. This can be considered to be the next paradigm change in the smart city end-user services. When the mobile contactless technology becomes more common, also other smart city services will appear, combining payment, loyalty, and city services.

Mobile contactless services in smart cities are and will be based on Near Field Communication (NFC). NFC means, simply put, an upgrade to usability of a mobile device; the user can touch a reader with the mobile in a similar manner as with a contactless card [13].

The work presented in this paper is carried within the Smart Urban Spaces Project abbreviated as SUS (www.smarturbanspaces.org). One of the objectives of the SUS project was to reach a certain level of interoperability regarding mobile contactless city services deployments and interactions. Then, it was necessary to define a framework. The role of the framework is to help understand the environment of mobile contactless city services, to analyze the relations between the different stakeholders (in legacy systems and services to be deployed) and also to provide relevant information concerning the level of interoperability that can be reached. For an end-user, interoperability simply means that the services and systems work together so that a service can be accomplished. Looking simply at technological interoperability does not help sufficiently when mapping the service opportunities or analyzing the smart city services. Technological level, which consists of hardware and software, will not guarantee service level usability or the service success. Taking into account all these factors deserve a more general approach and a clear view of the environment where the services exist. Then, in our attempt to unfold the term interoperability through a framework dedicated to mobile contactless city services, it was essential to enlarge the focus on aspects such as usability, business cases, regulations, etc.

The questions that have guided our work and that lie at the core of this paper are as follows: what are the elements to consider when building such a framework to analyze the interoperability in the context of contactless city services? What should be the form of the evaluation process, related to the interoperability framework, which needs to be implemented? The work presented in this paper details the main basis and the first practical elements regarding the development of a complete evaluation process.

In the following section, we give elements related to the mobile services context. We more precisely expose the mobile contactless city services concept and we shortly explain how the NFC technology that enables it operates. Section 2 also provides a definition of interoperability, presents in more details the interoperability issues raised by the specificities of the SUS project and propose an approach to address these problems. Section 3 mainly deals with the interoperability framework proposal and section 4 describes the resulting evaluation process. Eventually, section 5 presents the next steps to follow in the complete achievement of the evaluation process.

II. CONTEXT

A. Mobile Contactless City Services

City services around the world are different and they are dependent of the local culture, laws, etc. Transform a city service into a mobile city service requires a certain amount of technological advancement and maturity that is not the

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same for each city service. For example, SMS-based information and ticketing services have been around over 10 years already. As technology has gone forward, the NFC technology has become a promising enabling technology for various city services. From the user perspective it is a new mean of interaction with the environment that is based on the touching paradigm [14]. Mobile phone is essential in a sense that it is the central mean for the user to connect to the content information or make an action such as payment [6]. NFC, which is a wireless communication technology derived from Radio Frequency Identification (RFID), has three kinds of modes: the reading and writing tags mode, the peer-to-peer mode which enables connections between two mobile phones, and the card emulation mode. These modes are all enablers for new city services, e.g., for tagging the city [8], access control [7], home care with sensors [12] or city tourism [2].

Initiatives, which are mainly research demonstrations and pilots, have shown the interest in contactless services for the benefit of citizens in cities. The SmartTouch project, that brought together European industrial and academic partners, has particularly proved the added value of NFC in ticketing and transportation by contributing to the deployment of real services on the field [11]. Another notable example is the Cityzi project [3] allowing users to access in French cities of Nice and Strasbourg, a bunch of contactless services (in the field of transport, event management, car parking and banking) by using their NFC-enabled mobile phone.

B. Interoperability Overview

Interoperability is usually defined as Wegner does in [15] as "the ability of two or more software components to cooperate despite the differences in language, interface, and execution platform". Consequently, the most usual approach to interoperability is to consider it simply as a technological issue. For instance, securely managing smartcard applications in NFC devices [9], considerations on how to develop applications on top of an operating system [4], the ecosystem perspective [10], or multi-application approach as done by [1] are some examples. This approach generally leads to propose a service assessment model [5] based on 5 levels: the signature level, the protocol level, the semantic level, the quality level, and the context level.

Aforementioned view seems too restrictive in our context because it only takes into consideration the technical aspects. Of course, interoperability of mobile contactless city services is an issue that comes up in discussions especially on tourist scenarios when a tourist would need to use a local bus or to buy a train ticket. However, the interoperability concept is a larger issue in the mobile contactless city service context, though. In addition to interoperability of technology, such as software architecture, protocol level or looking at how devices and services communicate between each other, a ubiquitous and contextual contactless mobile service deserves a deeper consideration on the emerging services themselves. As far as we know, there is a lack of appropriate models to study the role of the essential players interacting in the context of the deployment and the use of contactless services for smart cities. Our conception of interoperability goes beyond the traditional approach, in that it is necessary to provide background information and analysis taking into consideration the whole ecosystem (at the legal and business level for example) that represents a city or even a network of cities.

C. Examples of Issues in Interoperability in the Context of SUS Project

There were 49 piloted and planned services in the SUS project. From there we can see the challenges in the interoperability of a mobile contactless city service concept. The difficulty lies in the fact that it is necessary to take into account all aspects of interoperability that could affect the deployment of such services and analyze the interactions between the different players involved in the development and the exploitation. To highlight some of the interoperability issues that may arise, we give examples of SUS city services: Daycare, Small Event Ticketing and Open Europeans 2011. The Daycare service provides a solution for registering children to the day-care by using passive NFC tags and mobile phones. The Small Event Ticketing service proposes a system to manage ticketing operations (issuance and validation) for small events with NFC-enabled mobile phones. Regarding the Open Europeans 2011, it provided a control access system (with smart cards and mobile phones) for the sailing competition held in Helsinki.

Technical interoperability issues were not uniform. One service was encountering standardization failures within NFC ecosystem (the Small Event Ticketing service that uses the NFC peer-to-peer mode) while the other was encountering the difficultness to integrate legacy backend systems refitted to be mobile and contactless (Daycare). Usability and social interoperability issues were also raised and demonstrated the need to motivate and educate the users. For example, the Daycare case needed 1200 employees to be trained and the motivation to use the system was in the reduction of routine paperwork that allows the employees to spend more time in the real work with the children. A learning curve for users has been observed in all of the services. From the business side of interoperability, the presented services had different kind of parties involved. For the sailing competition case, the local transportation authority smart cards were used during the piloting phase. Thus, the sailing competition access control case was dependent of the business decisions of another company.

D. An Approach to Analyze the Interoperability

We have been involved with close to ten workshops on how to delineate the smart city services in European cities

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together with services providers, city representatives, application developers, and infrastructure developers. During the effort we delineated and presented a set of entities in the use case ecosystem: Mobile, User, Service, Infrastructure, City, and Country. These are high level entities to find out and understand the intersections of interoperability of smart city services. Each of the entities can be mapped with another and analysis can be made in the crossroads of this mapping. A set of dimensions have been chosen to give structure for analysis and design of smart city services. These dimensions are business, legal, usability, social and technical aspect.

In addition to the possible interoperability levels (service to service or mobile to user for instance) that need to be reached, other aspects (the eventual hierarchical relationship between entities for instance) must be taken into account. We believe that we need a more general framework that could identify these particular levels and deal with them. An evaluation system, so that already existing entities interactions can be analyzed in an efficient way or the conception of future services can be assessed, could be useful in this process.

III. INTEROPERABILITY FRAMEWORK

The goal of this section is to give a good intuition of what we intend by interoperability and how it fits in the SUS context. We will define the entities that are involved and their relationships. These relationships are those for which we would like to be able to talk about interoperability.

A. Criteria

Before defining the possible levels of interoperability, we must choose relevant evaluation criteria. Intuitively, the example of two possible actors, namely the service and the country, and the study of what the term suitability represents in their context is a first approach. The suitability of a service for a country means:

- the legal compatibility which includes the nature of the service and the type of data stored by the service (Example: the regulations regarding privacy differ from one country to the next).
- the social acceptability which takes into account the nature of the application that provides the service and the impact on persons (Example: using mobile phones in a kindergarten would probably not be well accepted in all countries)
- the localization capability with the language and the cultural references.

This first analysis suggests that the eligible elements, to 'measure' the interoperability, are the technical, the legal and the social details. A second analysis, regarding the services proposed in the SUS project and the interoperability issues that they raise, confirms that the previously presented criteria are to be taken into account. In addition, the nature of the SUS project, that connects academic and industrial partners, and its goals also lead us to highlight both the technological and commercial aspects of the interoperability evaluation. Then, because of the relevant elements (in our context) that our preliminary studies have identified, we choose to focus, as presented Fig. 1, on 4 specific points to analyze the relationship between two entities:

- the **technical issues** which correspond to the evaluation of available technologies (and their use) and to the communication standards both at hardware and software level
- the **legal issues** which are the consideration of laws and regulations that may impact on the entities
- the **usability/social acceptability issues** which target the cultural aspects as well as those related to the customization and the seamless use of a service regardless the environment
- the **business issues** which include, among other things, the business model that can be built and that could be convenient for the stakeholders

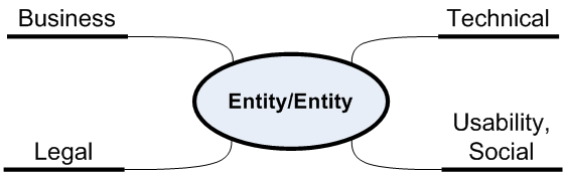

Figure 1: Dimensions of interoperability analysis

B. Entities and Interoperability Matrix

The concept of interoperability encompasses the relations that can exist between two or more entities. Then, the understanding of this concept requires prior knowledge of the behavior of entities in each specific case. Consequently, the study of interoperability within a well-defined ecosystem starts by the identification and the description of the involved entities. In the framework of the city services proposed in the context of the Smart Urban Spaces project, we have identified six main entities:

- the **mobile phone** which is the personal electronic device by means of which a person interacts with the (real or virtual) external environment. Note that this interaction can also be at the initiative of some external entity or the mobile phone itself and not necessarily its owner, who, in some cases, is perhaps not even aware an interaction took/is taking place.
- the **user** who corresponds to the person that will use a mobile phone to access the different proposed services
- the **infrastructure** which consists of either NFC readers, either contactless smart cards or tag systems that correspond to the 3 operating mode of NFC. In particular, a tag system is a system which manages the interface between a NFC-enabled device and a set of operations it is

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willing to launch by means of reading a tag while a tag is a small piece of hardware (usually a plastic component with electrical circuits) that stores data accessible through the reader/writer NFC mode.

- the **service** which includes, in a particular field, a set of elementary operations to improve the daily lives of citizens (for instance a mobile ticketing service). The service takes generally the shape of an application running on a mobile phone
- the **city** represents the geographical area for which a range of services is offered to the citizens
- the **country** is the country where the city is located

Depending on the environment, several players of the same type can coexist and interact. Obviously, in a defined ecosystem, many mobile phones (belonging to many users) are activated as many services are offered to the citizens. Precisely, the possible interactions between these different actors allow defining the different levels of interoperability that can be achieved. For example, if we consider the case of two mobile phones that need to exchange some data, we will deal with potential hardware compatibility issues and communication standard problems.

	User	Mobile	Infras.	Service	City	Country
User						
Mobile						
Infras.						
Service						
City						
Country						

Figure 2: Interoperability matrix

Consequently, the study of relationships between each presented entity allows us to introduce the concept of 'Interoperability Matrix' (Fig. 2) to model the different possible levels of interoperability. Each cell represents the links that exist or can/should be tied. For example, the cell entity #1-entity #2 should be read as follows: what are the requirements for entity #1 to be 'interoperable' with entity #2? It should be noted that not all the cells play the same role regarding the notion of interoperability. This is explained in the following section.

IV. RESULTING EVALUATION PROCESS

A. *Description*

The evaluation process can be used to describe/define requirements/interoperability for an entity over the other components of the ecosystem, for example a given service that must interact with the other actors (Mobile, User, etc.). The process, regarding two entities, is derived from a questionnaire that makes it possible to analyze the possible interactions in a cell of the interoperability matrix. The structure of the form can be decomposed into different blocks: a first part with general questions, a second part related to technical issues, a third block concerning legal aspects, a fourth part for the business related questions and finally a fifth part dealing with the usability/social acceptability elements. Thus, the stakeholders involved in the evaluation process correspond to the relations to analyze (cf. the general questions part of the forms).

The general part presents information (question to answer - who should fill this form - prerequisites) that help to explain and understand the context in which the analysis is performed. As for the other four parts, which correspond to the four dimensions of analysis, they each contain a set of questions to answer. These questions enable a detailed study of the elements that we find essential. It should be noted that these issues have only three possible answers, i.e., yes, no or maybe, to keep the process as simple as possible. 'Maybe' corresponds to a situation where the stakeholders are not sure about the answer to provide (for example because details are missing regarding a given entity or because the answer lies between yes and no).

From a practical point of view, the assessment is done by assigning a value to each answer. An answer 'maybe' is equivalent to 1 point, while the answers 'yes' or 'no' can both correspond to 0 or 2 points depending on their negative or positive nature concerning interoperability. For example, an answer 'yes' to the question 'Can the Service be localized if required' gives 2 points while a 'yes' to the question 'Does the service make any country specific cultural reference' gives 0 point. Then, for each category (technical, legal, business, usability/social acceptability), we define a percentage that is calculated as the ratio of the sum of the responses on the maximum (2 times the number of questions). This percentage represents in some way the degree of 'interoperability' achieved in the chosen dimension. In the previous example, assume that the answers to three questions in the Usability/Social category are respectively 'yes', 'yes' and maybe. The resulting percentage is therefore (0+2+1) / 6 or 50%.

Then, to graphically illustrate the set of results for an analysis of interactions between two entities, we use a Kiviat diagram. The diagram has four axes for each analysis dimension scaled from 0 to 100 (to represent the percentages). Depending on the references values which are used for the diagram (50 for each axis in our case, cf. Fig. 3), the results lead to a conclusion regarding the level of interoperability reached by the relation between two entities. This graphical representation also enables comparisons between different levels of interoperability (different types of relations in the interoperability matrix) or between different entities of the same nature.

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B. *Application on a case*

We apply the Service to Country form to a real case to show its practical use. It represents the complete form for the Service to Country relation among the set of forms that must be built for each cell of the interoperability matrix. We first answer to the questions according to the four dimensions, then we calculate the percentages and finally, we draw the Kiviat diagram. In this example, the Service is the Daycare system and the Country is Finland. The form is presented Table I.

TABLE I. Service to Country form for Daycare and Finland

Daycare → Finland	
Question to answer: What are the necessary conditions so that a given service can be used in my Country? **Who should fill this form:** This form must be filled by a representative of a Country who is considering using a pre-existing Service, with the help of the Service provider. **Prerequisite(s):** the country has rules and legislations for open data, privacy and security, and open interfaces of public information systems	
Questions	**Answers**
Technical issues Can the Service be localized if required? Can the Service fit with the available hardware/software infrastructure available in my Country? Is the Service technology standard based?	 Yes (2) Yes (2) Yes (2)
Legal issues Does the Service obey the specific regulations of my Country? Does the Service use and provide open public data as required by the regulations and contracts?	 Yes (2) Maybe (1)
Business issues Will the benefit(s) gained by deploying the service be concrete? Is the cost/benefit ratio positive? Is it possible to use the same solution in many cities to save costs of public investment?	 Yes (2) Yes (2) Yes (2)
Usability/Social questions Might the Service be subject to acceptation arguments in my Country? Can the Service be localized if required (note that this is also a technical issue)? Does the Service make any country specific cultural reference?	 Yes (2) Maybe (1) Yes (0)

The results are presented in the Kiviat diagram Fig. 3. Globally, we can conclude that the Daycare reach a good level of interoperability at the Service to Country level in Finland.

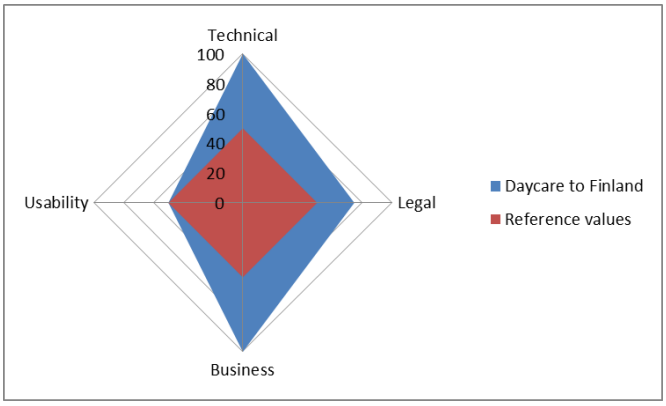

Figure 3: Daycare to Finland interoperability level analysis results

C. *First Contributions*

The first analysis and the initial feedback enable us to raise positive elements concerning the proposed interoperability evaluation process:

- Some partners of the SUS project started to use the first forms we have built as an evaluation tool for the services they have deployed, thus demonstrating it is a practical tool. The forms include quite simple questions (with yes/no/maybe answers) and the process (computation of the percentages for each category) that leads to the evaluation results is easy to achieve. By clearly identifying the forms to be filled on the basis of the interoperability aspects that are targeted, it is relatively easy to obtain a concrete result.
- The awareness of the possible problems is another positive element of the evaluation process. Indeed, the Kiviat diagram resulting from a form filling presents a clear view of the level of interoperability with respect to the reference values (namely the average values). In other words, the diagram allows pointing out the eventual strengths and weaknesses (of the evaluated interoperability relationship) according to the different criteria presented in the subsection 3.A. These eventual strengths and weaknesses are the points, with reference to the corresponding parts of the considered form, to take into account in the improvement of a given service.

V. FUTURE WORK

Obviously, to achieve the definition of the evaluation process, it is necessary to build a complete set of form mapping the cells of the matrix. Then, each cell of the matrix will be associated to a form whose structure will be the same as previously defined. This set of forms will not only provide guidance on services to be developed (before a concrete implementation), but also on improvements to existing services (to be deployed in other contexts).

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Depending on the situation, it can be used by each player, by selecting the relevant elements to evaluate, to assess its level of interaction with external partners. These forms will provide a simple tool (questions with yes or no answers), flexible and including means for measuring (assessment model, Kiviat diagram) to focus on the dimensions of interoperability to enhance. The objective is to make it possible for the SUS project partners to use the complete tool and also to test it on more mobile contactless city services to obtain other valuable feedbacks. This set of forms has a dynamic aspect as it is built from exchanges between SUS partners and the experience gained during this project. It has an evolutionary shape and it also intended to be enriched by the experience feedbacks associated with its use.

VI. CONCLUSION

It is extremely difficult to take into consideration the entire elements which are essential to provide seamless services. Nevertheless, the experience of the SUS project has allowed us to understand and properly define the environment in which mobile contactless city services are expected to evolve. It helped us to identify the actors (User, Mobile, Infrastructure, Service, City and Country) which play a major role in this ecosystem. Based on this experience, our study on interoperability allowed us to specify the dimensions (technical, legal, business, usability/social) to consider while showing the possible interactions between entities in the interoperability matrix. We were able to present achievable levels of interoperability (represented by the cells of the matrix).

The consideration of these criteria and the interoperability framework that we have defined led us to initiate the implementation of an evaluation process based on a set of forms. This set, with elements structured according to the criteria defined above, contains forms that refer to the cells (levels) of the interoperability matrix. To deploy a seamless service, we must ensure to analyze its environment and the levels of compatibility (depending of the objectives) to reach. The set of forms provides tools to give a clearer view of the operating environment with a simple assessment model and to help achieve this goal. We were able to use the framework and a part of the forms on specific cases (the Daycare for instance) to show its relevance. Of course, we still need to complete this set of form and test it on another bunch of mobile contactless services.

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