# Mobile Service Interaction with the Web of Things

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*Abstract*— **In this paper we present a vision and a system framework for supporting mobile interaction with the Internet of Things. Hereby a mobile device can click on physical links to services that are represented by electronic or visual tags attached to objects in the real world. Our framework seamlessly crosses the boundary between the Internet of nets and the Internet of Things providing access to information independently of where it resides. It provides a natural and intuitive interface to objects and services and delivers services and information on any terminal independently of its features.**

*Index Terms*—**mobile service interaction, Internet of things, NFC, RFID, system architecture, mobile user interface.**

## I. Introduction

UNTIL now the distribution of information has been associated with the Internet and the different applications that have been built on it, such as the Web or e-mail. This vision is going to be challenged with the advent of the different forms of electronic tagging that are emerging on the marked. Technologies such as NFC (Near Field Communication) [1], RFID (Radio Frequency Identification) and Sony FeliCa succeeded in associating a new electronic presence to objects in the real world. Exploiting these technologies, anybody with an enabled phone can gather, or leave, electronic information directly from the pages of a newspaper, or from a poster in the subway station. This ability to access electronic information from virtually any objects has sparked the vision of an *Internet of Things* [2], as a parallel to the real Internet.

While the vision of the Internet of Things is very appealing, not surprisingly it is also full of technical challenges. Many of the challenges are associated with the technology itself, but, we believe that there are also very important challenges that have to do with the use of the technology. Most notably the connection between the Internet of Things and the Internet itself still requires profound investigation. For example, one of the most recent developments in Internet and Web technology has been the advent of the Web Services stack. Yet, the invocation of a Web service from the Internet of Things is still a challenge, and to our knowledge no general solution has been proposed yet. Furthermore, there is a problem of synchronization where any change in the content of an Internet site should be associated with a change in the content of the corresponding tags on objects that may no longer be under the control of their creator.

The second, and deeper, challenge is to enable a user to access the Internet of Things. While it is very easy to swipe a phone in front of a tag, it is also very difficult to guide the user in an interaction that requires multiple access of the same object. One such case is highlighted in the example shown in the section 2 in which a user can use a poster in a Subway station to buy tickets to a movie, or any other product.

The human prospective of the Internet of Things is especially important since we have a very close and sometime intimate relation with the many objects in our life. The immediate problem is to understand how to construct the new user interfaces of familiar objects, but more deeply there is a need to address issues such as the reassurance that a service will be invoked somehow by swiping the phone at a given location, or that the user has some control on what happens an no private information will be leaked out of the phone.

In our research we are working on the understanding of *physical mobile interactions,* i.e. the ability of interacting with physical objects through the mobile phones under the believe that the technological and human aspects are intimately related. The goal of our work is the provision of a generic infrastructure connecting mobile devices with real world objects and associated services. With respect to the user interaction issue, we aim to shift the interaction focus from the mobile phone to physical objects and explore how we can derive generic user interfaces from the object and the service description. In our approach, we represent services using the Semantic Web services paradigm; semantics helps us in two ways: first, it lowers the interoperation barriers between the mobile phone and the service by providing a common meaning to all the terms exchanged; second, it facilitates the automatic generation of concrete user interfaces, from abstract interfaces. Combining semantic and context information would then be used for the generation of a concrete user interface rendered on the mobile device.

This paper is organized as follow. The next section presents a user scenario describing the usage of a movie ticket service through physical mobile interaction with a poster. In section 3 the generic architecture of our infrastructure is presented. Afterwards we discuss relevant physical mobile interaction techniques and their integration in our framework. In section 5 we relate our work to other approaches.

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## II. Scenario

Before providing technical details on the system we are building, we would like to provide a scenario highlighting the usage of physical mobile interaction techniques and their advantages.

Karl is coming back home on Friday evening by public transportation. He starts wondering what he could do this evening with his girlfriend Ina, when he sees a movie poster at the train station and gets closer to it. The poster, shown in Figure 1, displays four movies as well as several options such as different cinemas, movie timeslots, the number of required movie tickets and the available transportation means.

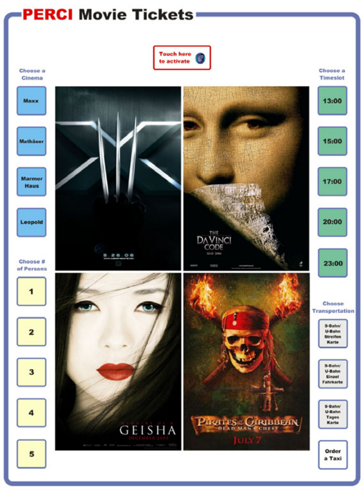


Fig. 1. An example of movie poster, behind each box there is an NFC tag.

Karl calls his girlfriend and they rapidly agree to go watching the Geisha movie this evening at 20:00. Karl puts his NFC - enabled mobile phone on the poster (see Figure 2) selecting the movie *Geisha* and gets a sound and visual feedback on his phone confirming his selection. In a similar manner he consecutively selects the *Tivoli* cinema next to his flat and the 20:00 timeslot. Then he points the 2 persons item and finally chooses a daily transportation ticket.


Fig. 2. An example of physical interaction with a poster.

Once all the necessary information has been selected, Karl's mobile phone displays the choices that Karl made, and presents Karl with a payment form. Karl enters his credit card details on his phone to further proceed and receives an electronic confirmation. Some hours later, Karl and Ina take the train on the way to the cinema, as a ticket Karl simply shows the electronic confirmation on his mobile phone to the transport controller as he will do later on to the Cinema officer.

While the scenario presented is of course artificial, yet it is not far from reality. The underlying technology is of already available. Indeed, similar services are already available. Payments based on FeliCa contact-less technology are very common in Japan, and NFC trials for public transport and entertainment are already in progress in places such as Frankfurt[1] and Atlanta[2].

However, the main goal of our work is the provision of an infrastructure allowing the easy development and deployment of such services.

## III. The Architecture

To support the type of interactions required in the scenario described in the previous section, we developed a general architecture that supports the whole interaction between the user, the physical object and the services. The architecture of our system is shown in Figure 3. The physical object, displayed on the top right of the architecture diagram, corresponds to any tagged physical object, as for example the movie poster of our scenario. On the other side of the spectrum, the interaction with a physical object may require multiple services. For example, in our scenario Karl may have to interact with a service run by the movie theater to book the ticket, with a transportation service run by the local public transport company, and with one or more payment services. These services are shown on the left side of our architecture diagram.

The easy solution to manage the interaction would be to download a client that reads the content of the tags and automatically transmits them to the services. Unfortunately, this solution is not going to work in practice since phones have very different capabilities: some have very high processing power, others good graphic, others yet are more limited. Furthermore, downloading code every time the user interacts with a physical object makes her vulnerable to security attacks that are avoided with our solution.

Rather than downloading a service client, we opted for a more general solution in which services are described abstractly using the OWL-S [3] Web service description language. Such a description specifies the interaction protocol of the service: the messages that the service expects in input and the messages it will provide as output. The use of semantics is essential at this point since the phone will have to decide which information to send during each interaction, and how to interpret the answers that it receives from the services.

The interaction protocol of the services may also affect the user interaction with the poster. For example, given the poster in Figure 1, the movie theater may have to be selected before specifying the number of tickets. To maintain synchronization between the user and the services, we adopted a solution,

[1] http://press.nokia.com/PR/200411/966921_5.html
[2] http://press.nokia.com/PR/200512/1025543_5.html

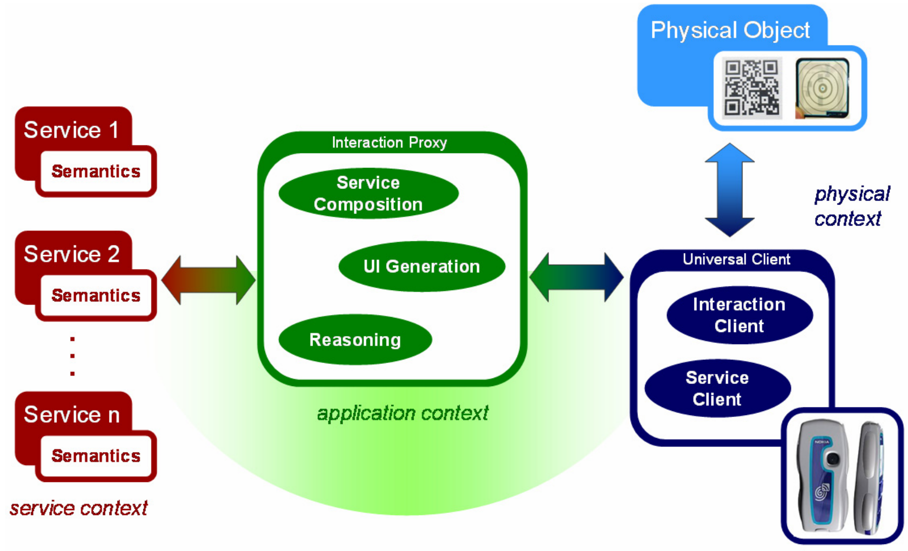


Fig. 3. The PERCI Architecture

suggested originally in [4], to derive the user interface directly from the service description.

In our implementation, we use the service description to derive also generic user interface description, that describes the type of choices that the user has to make during the interaction, but it does not specify which graphical widgets are to be used. These widgets are to be decided at run time depending on the features of the phone and the preferences of the user. On some phones, HTML may be the best way to present the interface, on other phones, some native graphic widgets may be used instead.

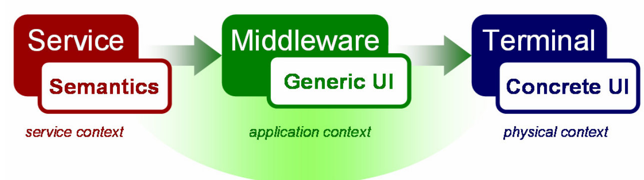


Figure 4: The steps to compile the User Interface

Upon receiving the service description from the tag, the phone instantiates an *interaction proxy* that is responsible to manage the interaction between the services and the phone. Such a proxy may reside on the phone, if the phone has enough resources, or on a server outside the phone. The actual location of the proxy is just an implementation detail.

The proxy is responsible for three tasks: the first one is *service composition* to decide which service should receive the information provided by the user. The second one is the *UI generation* module that is responsible to decide how to display the information to the user. The third one is the *reasoning* module that is responsible to select the information that is to be sent to the services, and to interpret the information received from the services.

The complete system has been completely implemented using Nokia 3220 phones that provide an NFC Shell [5] which is able to read NFC and RFID tags.

## IV. Toward Physical Mobile Interactions

In our discussion so far, we implicitly assumed that contactless technologies, such as NFC, RFID and FeliCa, are the only technologies that supports the Internet of Things. Indeed, most of the existing solutions only support one of them as a mean for augmenting objects in the real world. For instance, Semacode [6] just supports the usage of visual markers and Nokia's Field Force solution [7] only focuses on the usage of NFC and RFID.

But contactless technologies implement only one of the many possible interaction techniques, namely *touching*. Yet, the Internet of Things provides a wider range of technologies that we can use to interact with physical objects. For example, objects can be augmented by associating them with visual markers such as the 2d bar code shown in Figure 5. By taking a picture of the 2d visual marker, the phone can automatically decode the bar code and extract the information coded in it. For example the visual marker in Figure 5 encodes the URL of an airline site. Visual codes require a new interaction technique, which we name as *pointing* since the user needs to point the camera to the visual marker. Pointing is not restricted to visual markers; it is also used to control many appliances in our homes through remote controllers emitting infrared beams. Indeed some phones already double up as remote controllers.

Furthermore, objects can be associated with other technologies such as Bluetooth or Wi-Fi. It is not unusual to see wireless keyboards or mice or even mobile phones controlling computers via Bluetooth. These technologies implement additional interaction techniques such as *scanning* that permit to find nearby augmented objects in the environment.

When we consider these additional technologies and interaction techniques, the Internet of Things becomes a much richer environment than described so far. In our framework, we are investigating the use of an *InteractionController,* which provides a plug-and-play mechanism for the integration

Fig. 5. A visual marker in a Tokyo street

of new interaction techniques. So far our framework supports touching (NFC / RFID), pointing (visual markers, infrared beam) and scanning (Bluetooth). Furthermore it supports interaction techniques such as *location based object selection* and *user mediated object selection*. Concerning the first one, if the distance between the user and real world object is below a defined threshold the object is selected. In the second interaction technique the object is for instance augmented with a number which is typed in by the user through which she indicates that she wants to interact with this object.

## V. Related Work

Kindberg et al. [8] were the first ones who presented in the context of the Cooltown project a generic concept and architecture for mobile interactions with augmented objects. However they just focused on one interaction technique and used URLs for addressing web pages associated to physical objects. Want et al. [9] presented an approach for augmenting everyday objects like books, documents or business cards with RFID-Tags. The system uses the contactless identification of these objects to reference associated information and invoke simple associated actions on a tablet computer, such as opening the electronic file of a document when touching the tagged printout.

There exists a hug set of papers discussing contactless communication technologies for supporting physical mobile interaction. For example users can take pictures of visual markers [10] in magazines or on posters and use this information for the automatic invocation of associated services. NTT DoCoMo's i-mode FeliCa service combines for instance NFC-enabled mobile phones and a service framework based on i-mode [11].

Since we wish to automatically and seamlessly link physical objects and information through the Internet, we also took into consideration the infrastructure for weaving the Internet of Things [2]. Similar to our NFC-based approach this infrastructure relies on RFID-tags to attach a unique Electronic Product Code (EPC) to objects. The Object Naming Service (ONS) is used to match the EPC of an object with the URL of its associated information stored on a server. The Physical Markup Language (PML) was developed to describe and store information about an object on the network.

## VI. Conclusion

The ability to associate electronic tags to any object essentially transforms any object in a source of information enabling the Internet of Things. Yet, the success of the Internet of Things hinges on a number of issues including the ability seamlessly cross the boundary between the Internet of nets and the Internet of Things providing access to information independently of where it resides; the ability to provide a natural and intuitive interface to objects and services; and finally the ability to deliver services and information on any terminal independently of the features of this terminal.

In this paper, we propose a general architecture that meets these requirements by allowing the free flow of information from physical tags to services residing somewhere on the Internet and back to the user platform independently in a seamless uninterrupted flow. Furthermore, we show how constraints produced either by the interaction protocol of the services, or by the interaction procedure of the user can be naturally accommodated by our architecture.

But the scope of the paper is not just restricted to providing an architecture. More importantly, we provide a vision in which the interaction with objects is not restricted to a single read or send data, as it happens in the current applications. Rather we foresee users interact with objects such as posters, magazines and other objects in a way that bridges the divide between the electronic world of the Web and the real world of physical objects. Crucially, this vision is supported by the architecture that we have proposed in this paper, and that we have implemented in our systems.

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