Mobile Interaction with the Internet of Things

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Abstract. The interaction between mobile devices and physical objects in the real world is gaining more and more attention as it provides a natural and intuitive way to request services associated with real world objects. We currently see several approaches for the provision of such services. Most of them are proprietary, designed for a special application area or interaction technique and provide no generic concept for the description of real world services. On the other hand the *Internet of Things* provides a set of standards and methods to tag objects in the real world. We think that the combination of these two technologies can support the development and dissemination of mobile interactions with the real world. Therefore, in this paper we present a concept, an architecture and an early prototype currently under development for mobile interactions with the Internet of Things. Hereby we use Semantic Web services for the description of services provided by the physical objects. This service description is then used for the automatic generation of user interfaces rendered by the mobile device.

1 Introduction and Motivation

Today users are more and more immersed into a complex sphere of ubiquitous information. Mobile clients offer increasingly sophisticated methods to capture information, to make use of context information and to interact directly with objects in the real world. On the other hand physical objects are increasingly associated with digital information through the augmentation with visual [1] and wireless markers such as RFID tags. In this context physical mobile interactions [2] allow users to select virtual information and invoke services through the interaction with objects in the real world [3, 4]. Currently there are several approaches for the provision of applications that take such interactions into account. Most of them are proprietary, designed for a special application area or interaction technique and provide no generic concept for the description of real world services. One example is the Nokia Local Interactions Server which is a real-time web service that acts as a back end for RFID-based mobile interactions [5].

In addition we currently see a big interest in industry and academia in the *Internet of Things* in which real world objects have an individual digital presence [6]. Here physical objects are uniquely identified and described in a standardised way which facilitates access to and interaction with them. We think that the combination of physical mobile interactions and the Internet of Things can support the development and deployment of mobile interactions with the real world. Therefore, in this paper we present a concept, an architecture and an early prototype currently under development for mobile interactions with the Internet of Things, its objects and their associated services. Hereby we use Semantic Web services for the description of services associated to physical objects. This service description is then used for the automatic generation of a user interface on the mobile device.

Web service technology provides a new way of making information and services available while reducing interoperability issues and enhancing extensibility, platform independence and standardized exchange of messages. Furthermore we want to improve their flexibility and expressiveness by adding semantic descriptions and thus enhance the modelling and dynamic composition of web services. As shown in [7] modelling services as Semantic Web services is powerful enough to acquire implicit context information by composing web services and therefore relieves the user of providing information explicitly. Thus, we exploit in our architecture the expressiveness of Semantic Web services for the automated generation of user interfaces rendered by the mobile device.

We want to explore how such user interfaces can be optimized to provide easier and more familiar interaction with physical objects in the internet of things and the services associated with them. Since there is still no consistent way to integrate web services and means for physical interaction, our architecture has to meet several technical requirements. Among them are:

- Modelling, composition and provision of Semantic Web services;
- Description, automatic generation and integration of mobile user interfaces to abstract the complexity of web service functionalities and support the user interaction with physical objects;
- Connection between mobile devices and marker technologies as well as modelling and exchange of messages among components.

Several efforts are underway dealing with automatic generation of mobile user interfaces. The Pebbles project focuses on the interaction of mobile devices with physical appliances such as TV or VCR [8]. Although web service semantics provide only limited support for the description and creation of user interfaces, [9] explains how a service description extended by semantic user interface annotations is capable of automatically generating a user interface that is both highly flexible and expressive. We consider this approach as an interesting starting point for our own automatic user interface generation.

2 Architecture and Prototype

As mentioned, there are two separate domains which we want to combine in our approach: the Internet of Things and physical mobile interactions where mobile devices are used to interact with physical objects. The main goal of our approach is to connect these two domains whereas the mobile device acts as a mediator between them. Fig. 1 depicts a high level view of our architecture. The mobile device acts as a

Universal Client which is independent from the physical objects it interacts with and also from services it invokes. To interact with both domains it uses different components denoted as *Interaction Client* and *Service Client*. The Interaction Client detects unique identifiers and additional data stored on the *Physical Object* while the Service Client communicates with the service domain. The Universal Client stores user context information and device capabilities which could enrich the automatic user interface generation. As device context we consider several mobile platforms which vary in their physical interaction capabilities (e.g. camera or RFID/NFC reader) and user interface capabilities (e.g. XHTML browser or J2ME runtime environment). Therefore, the Universal Client has to be able to support an arbitrary combination of device capabilities involved in the interaction process.

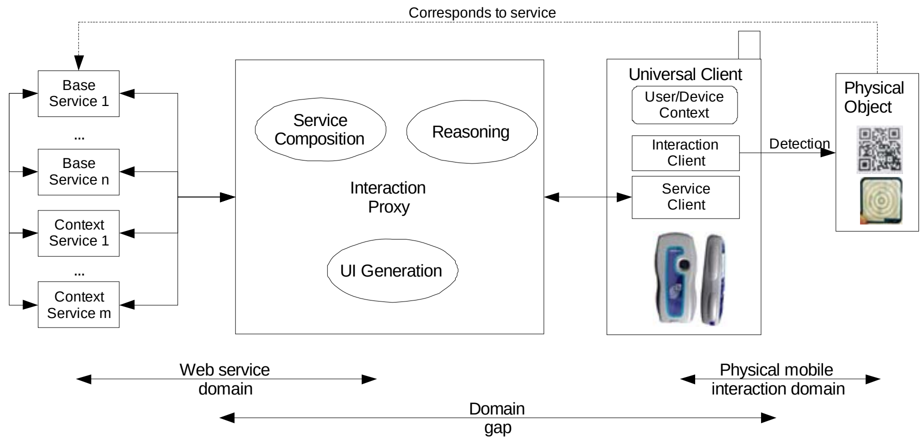

Fig. 1. High level architecture for physical mobile interactions with the Internet of Things

Services in the web service domain are described as Semantic Web services to facilitate interoperability, automatic service invocation/composition and automatic user interface generation. Services are grouped into *Base Services* and *Context Services*. Base Services execute the main functional tasks related to the interaction with physical objects. There may be a fixed relationship between a Physical Object and an initial Base Service. Context Services provide context information such as location and time. All services can interact with each other. For example a Base Service can request other Base Services or Context Services. However the Universal Client should also be capable of accessing Context Services directly.

For connecting the service domain and the physical interaction domain we propose a concept called *Interaction Proxy* which provides three main functions: service composition, reasoning and user interface generation. Service composition describes the interaction with several web services that can be involved in the physical interaction process. Reasoning is required to resolve the lack of semantic interoperability between different services.

Another focus of our work lies in the automatic generation of a user interface for different services which should be provided to the user in a consistent and transparent way. By providing a definition of required inputs and outputs for the service invocation, the semantic service description already defines a raw structure of the device user interface. In our approach the semantic service description is enhanced by an additional user interface extension which describes a parameter type-based mapping to a concrete user interface.

From the architectural point of view we identified different approaches to which domain the Interaction Proxy can belong. The user's privacy could be ensured by assigning the Interaction Proxy to the Universal Client. On the other hand the process of reasoning is presumably too computationally demanding for mobile phones. Therefore we decided to have a hybrid approach in which the Interaction Proxy concept is split into a device and a server component.

To illustrate our concept we are currently implementing an early prototype. We have defined a mobile commerce scenario in which a poster from a movie distribution provider offers a ticketing service for different cinemas. We assume different movies being advertised on a poster which have to be explicitly selected by the user. As shown in Fig. 2 a Near Field Communication (NFC) [10] enabled mobile phone is used for the interaction with the movie poster. The NFC/RFID tags are fixed on the back of the poster as depicted in Fig. 3. The service can use implicit context information such as location to determine the nearest cinema or time to restrict the starting time slot of the movie. In this simple scenario there is a main movie distribution service composed of several different cinema services and context services.

Fig. 2. Physical mobile interaction between NFC equipped device and poster.

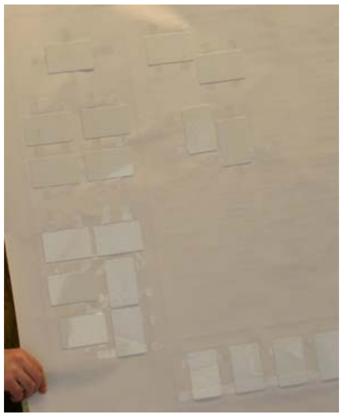

Fig 3. NFC tags fixed on the back of the poster.

The implementation of the framework and the interacting service components is currently under development. For describing Semantic Web Services we intend to use OWL and OWL-S [11] descriptions which can be developed with the ontology modelling tool Protégé [12] in combination with the Protégé OWL-S plug-in. Furthermore we plan to deploy Web Services with the Apache Axis framework. For invoking and composing multiple services we use the Mindswap OWL-S API [13] on top of Axis.

3 Conclusion

So far the vision of an Internet of Things is restricted to the standardized description of physical objects. Enhancing physical objects with service interaction support is still only accomplished by proprietary solutions. In this work we discussed the idea of combining physical mobile interactions and the Internet of Things in a generic way. We presented a system enabling the mediation between physical objects and multiple services through a *Universal Client*. Our work focuses on the composition of independent services which should be provided to the user in a consistent and seamless way. By using Semantic Web service technologies we see a great chance to overcome the semantic incompatibility between different services. Moreover we can benefit from describing services semantically to automatically generate a uniform user interface utilizing the proposed semantic user interface annotations. A prototype based on an entertainment scenario is currently under development. The next steps will consist in the evaluation of our concept and the improvement of our implementation following an iterative design process.

4 Acknowledgement

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