

A Context-Aware Approach for Integrating Semantic Web Technologies onto Mobile Devices

Stefan Zander

University of Vienna
Department of Distributed and Multimedia Systems
Liebiggasse 4/3-4, A-1010 Vienna
`stefan.zander@univie.ac.at`

Abstract. Semantic Web technologies such as RDF are usually incorporated in the infrastructure of desktop and web applications and can currently not be entirely deployed on mobile devices. Therefore, the unique opportunities and novel features the Semantic Web offers are not amenable in mobile application scenarios, in which context and context-awareness is essential. In this thesis, we propose a context-sensitive Semantic Web framework for mobile devices by which contextual data can be processed semantically and integrated with data sets and services from other communities. Mobile devices augmented with those capabilities can operate autonomously and independent in different environments.

Key words: mobile computing, Semantic Web, context, context-awareness

1 Introduction and Problem Description

Mobile phones and mobile computing in general became central parts in our everyday life. Additionally, new research areas such as Ambient Intelligence or pervasive and ubiquitous computing gain increasing interest. Their idea is to create smart, intelligent, and adaptive environments in which mobile devices can request and consume proliferated services and resources autonomously, where decision making processes are not only based on the user's presence or preferences, but also on the surrounding environment [1]. Central to this idea is the notion of context and context-awareness [2, 3]. Ambient Intelligence environments must elaborate on the semantics and meaningfulness of user-related tasks and activities in order to provide appropriate services and valuable information.

Currently, Semantic Web based applications and services can hardly be deployed on mobile devices because of the lack of suitable implementations for RDF storage and management, although the necessity of Semantic Web technology and ontologies in particular for realizing a context-aware mobile computing infrastructure is broadly acknowledged [1, 4]. In this thesis, we elaborate on the technical and conceptual background needed for integrating Semantic Web technology onto mobile devices and employ technologies such as RDF for the realization of a powerful, adaptable, and scalable context-aware infrastructure for harnessing contextual data that can be used for requesting ambient services and data sets from linked data repositories.

2 Related Work and State of the Art

2.1 Mobile Semantic Web Frameworks

We have analyzed two XML parsers for mobile environments, *NanoXML for J2ME*¹ and *kXML*², as well as two mobile RDF frameworks, *Mobile RDF*³ and *μJena*⁴. Our survey reveals that *μJena* is the most advanced framework providing ontology and inferencing support, although its API is currently in prototypical status and only allows for processing RDF data serialized in N-Triples format. None of the evaluated frameworks support queries on RDF data via SPARQL or other query languages. A serialization mechanism between RDF data and the internal storage mechanisms used by mobile devices could also not be found. Such mechanisms are needed since many mobile platforms do not use a file system for permanent data storage but provide platform-specific storage systems such as the Record Management System (RMS).

2.2 Context and Context-Awareness

The notion of context is characterized by "considerable confusion" according its nature, usage, and its role in interactive systems [5]. Technical disciplines primarily concentrate on sensorial factors such as location, time, activity etc., whereas social disciplines consider context as a dynamic, emergent phenomenon evolving in the course of interaction that cannot be represented by specific properties. Context needs an interdisciplinary and holistic research approach for understanding the interdependence between context and technology [6, 5]. A context model should be developed according to its application domain since the generality of a context model in terms of expressiveness and powerfulness is inversely proportional to its practical applicability and usability [7]. Replacing the prevailing system-centric view of context-awareness by a user-centric view is suggested by [6], since context-awareness is an activity-driven process, centered around user activities. The advantages context provides to the Semantic Web are elaborated in [8] and [4], introducing an architecture for a context modeling and processing framework for pervasive applications ([4]) as well as a context mechanism for the Semantic Web to support data aggregation ([8]).

2.3 Related Projects

*DBpedia Mobile*⁵, a location-aware mobile application, allows users to access information from the DBpedia project [9] about the physical environment surrounding them. Users are able to receive additional information by exploring links to other resources located in the Semantic Web. A similar approach is

¹ <http://sourceforge.net/projects/nanoxml-j2me/>

² <http://kxml.sourceforge.net/>

³ <http://www.hedenus.de/rdf/index.html>

⁴ http://poseidon.elet.polimi.it/ca/?page_id=59

⁵ <http://wiki.dbpedia.org/DBpediaMobile>

taken by the *mSpace Mobile*⁶ project in which access to location-based information according to the user's current situation is provided via a spatial browser. Considered contexts are time, space, and subject. The *IYOUIT*⁷ project collects contextual information about certain aspects of the user's lifestyle such as visited places or people met and reflects this information on the Web. People are able to share their personal contexts within a community portal.

Although these projects make use of Semantic Web technologies such as RDF, the processing of contextual data is done on external servers/applications rather than on the device itself. Certainly, this dependency is useful for a variety of scenarios but embodies risks in case of connectivity problems, server breakdowns etc. If devices were able to process semantic data directly, they could operate autonomously and independent from external services and specific environments.

3 Proposed Approach

Our overall objective is to make Semantic Web technologies attractive to mobile computing by showing the unique opportunities and novel features these technologies can provide. Therefore, we have composed an application scenario demonstrating how a mobile device supports the user by understanding the situations and different contexts in which she operates:

The invitation to a project meeting John received via email mentions the topic, place, and participants. His mobile device semantically interprets this information and adds a calendar entry, the location's GPS coordinates, and information about the other meeting participants (e.g., by retrieving their FOAF profiles⁸) to John's personal dataspace. By combining this information the device could infer on the situation in which John might be at that time ("in meeting") and take appropriate actions when necessary. At the meeting, John's address book already contains the contact data of the other participants together with additional information about them (e.g., personal homepage, department or company website, recently published articles, etc.) and corresponding events, retrieved from exposed LOD⁹ repositories.

The realization of this scenario requires mobile devices to be augmented with capabilities to process semantic data (RDF) directly using a scalable, lightweight context model based on ontological semantics expressed by means of OWL. This model serves as the basis for collecting and interpreting sensed data, which must be done on different levels [4]. Machine learning techniques guarantee that the context model continually adapts according to the user's intentions and tasks. This process is supported by feedback mechanisms implicitly and explicitly to minimize the misinterpretation of contextual data. Time and history have significant influence on the user's behavior and allow for inferencing on what the user

⁶ <http://mspace.fm/projects/mobile>

⁷ <http://www.iyouit.eu/portal/>

⁸ <http://www.foaf-project.org/>

⁹ <http://esw.w3.org/topic/SweoIG/TaskForces/CommunityProjects/LinkingOpenData>

has done in comparable situations to get a better understanding on current and future actions. Since the device is aware of John's current situation, it is able to operate accordingly and suggest appropriate actions (e.g., detect the importance of an incoming call; detect whether John will arrive at the meeting belatedly and notify the other participants before; record all the places one visited within a certain time frame and automatically interlinks them with related data from LOD repositories etc.). We believe that the computational model of the semantic desktop [10] also applies to mobile devices and their personal dataspace.

4 Methodology and Evaluation

The application scenario introduced earlier serves as a basis for deducing requirements of the underlying Semantic Web framework. Since none of the evaluated frameworks provide the required functionalities a priori, we decided to build on the μ Jena framework and extend it as needed. To get an impression about the interdependence between context, context-awareness, and mobile technology we surveyed how context and context-awareness is defined and understood across different communities. Questions on how to align and synthesize them with semantic technologies under the restrictions mobile devices impose will be addressed and redefined in the course of the thesis.

Our Semantic Web framework aims to facilitate the deployment of context-sensitive mobile Semantic Web applications and will be iteratively enhanced and extended. We propose a multi-layer architecture where each layer is responsible for a certain group of context-related tasks (e.g., sensing, acquisition, aggregation, interpretation, inferencing, representation etc.). Questions on how to efficiently process and store triple-based data on devices with limited processing power, memory and power capacity are of concern too.

As proof of concept, the proposed application scenario will be developed as a Google Android¹⁰ application, where the requirements deduced serve as the basis for a qualitative evaluation. Additionally, feedback questionnaires will be developed and answered by industrial partners involved in the related project MobiSem¹¹ to evaluate user satisfactoriness according to the functionalities proposed. We also perform measurements with respect to efficiency in processing, storing, and inferencing semantic data as well as memory consumption on the basis of a quantitative evaluation.

5 Current Status and Results Achieved

Our conducted survey on existing mobile Semantic Web frameworks reveals that almost all evaluated frameworks are in very early stages, the μ Jena framework being the most advanced one. Reviewing the literature on context and context-awareness indicates that these terms are used very ambiguously across communities. Recent research into this topic claims for dynamic, user-centric context

¹⁰ <http://code.google.com/android>

¹¹ <http://www.mobisem.org>

models to better reflect the characteristics and emergent nature. A prototypical Android application based on the μ Jena packages has been implemented allowing for retrieving N-Triple serialized RDF data that can be stored and processed directly on a mobile device. We are currently implementing a simple form of inferencing to reason about the RDF data stored and take specific contextual parameters for requesting RDF data from the *Linked Geo Data* project¹².

6 Conclusion

Semantic technologies are on the doorstep to become central parts of the applications operating on desktop computers as well as on the Web. We want to take this a step further by building a context-sensitive Semantic Web framework for integrating Semantic Web technologies into the applications operating on mobile devices. Our framework will enable the collection and interpretation of contextual data that can be used for requesting ambient services and allocating resources that have a specific relationship to the user's current situation.

References

1. Davy Preuveneers, Jan Van den Bergh, and et.Al. Towards an extensible context ontology for ambient intelligence. *Lecture Notes in Computer Science*, Volume 3295/2004:148–159, 2004.
2. P. Remagnino and G.L. Foresti. Ambient intelligence: A new multidisciplinary paradigm. *Systems, Man and Cybernetics, Part A, IEEE Transactions on*, 35(1):1–6, Jan. 2005.
3. Joëlle Coutaz, James L. Crowley, Simon Dobson, and David Garlan. Context is key. *Commun. ACM*, 48(3):49–53, 2005.
4. Jérôme Euzenat, Jérôme Pierson, and Fano Ramparany. Dynamic context management for pervasive applications. *Knowl. Eng. Rev.*, 23(1):21–49, 2008.
5. Paul Dourish. What we talk about when we talk about context. *Personal Ubiquitous Comput.*, 8(1):19–30, 2004.
6. Hong-Siang Teo. An activity-driven model for context-awareness in mobile computing. In *MobileHCI '08: Proceedings of the 10th international conference on Human computer interaction with mobile devices and services*, pages 545–546, New York, NY, USA, 2008. ACM.
7. Cristiana Bolchini, Carlo Curino, Elisa Quintarelli, Fabio Schreiber, and L. Tanca. A data-oriented survey of context models. *SIGMOD Rec.*, 36(4):19–26, 2007.
8. R. Guha, R. Mccool, and R. Fikes. Contexts for the semantic web. In *International Semantic Web Conference, volume 3298 of Lecture Notes in Computer Science*, pages 32–46. Springer, 2004.
9. Sören Auer, Christian Bizer, Georgi Kobilarov, Jens Lehmann, and Zachary Ives. Dbpedia: A nucleus for a web of open data. In *In 6th Int'l Semantic Web Conference, Busan, Korea*, pages 11–15. Springer, 2007.
10. Tom Heath, Enrico Motta, and Martin Dzbor. Context as a foundation for a semantic desktop. In *Proc. of Semantic Desktop Workshop at the ISWC, Galway, Ireland, November 6*, volume 175, November 2005.

¹² <http://aksw.org/Projects/LinkedGeoData>