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Semantic-based Middleware Solutions to Support Context-Aware Service Provisioning in Pervasive Environments

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Title

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Abstract

The dynamicity and heterogeneity that characterize pervasive environments raise new challenges in the design of mobile middleware. Pervasive environments are characterized by a significant degree of heterogeneity, variability, and dynamicity that conventional middleware solutions are not able to adequately manage. Originally designed for use in a relatively static context, such middleware systems tend to hide low-level details to provide applications with a transparent view on the underlying execution platform. In mobile environments, however, the context is extremely dynamic and cannot be managed by a priori assumptions. Novel middleware should therefore support mobile computing applications in the task of adapting their behavior to frequent changes in the execution context, that is, it should become context-aware.

In particular, this thesis has identified the following key requirements for novel context-aware middleware that existing solutions do not fulfil yet. (i) Middleware solutions should support interoperability between possibly unknown entities by providing expressive representation models that allow to describe interacting entities, their operating conditions and the surrounding world, i.e., their context, according to an unambiguous semantics. (ii) Middleware solutions should support distributed applications in the task of reconfig-

uring and adapting their behavior/results to ongoing context changes. (iii) Context-aware middleware support should be deployed on heterogeneous devices under variable operating conditions, such as different user needs, application requirements, available connectivity and device computational capabilities, as well as changing environmental conditions.

Our main claim is that the adoption of *semantic metadata* to represent context information and context-dependent adaptation strategies allows to build context-aware middleware suitable for all dynamically available portable devices. Semantic metadata provide powerful knowledge representation means to model even complex context information, and allow to perform automated reasoning to infer additional and/or more complex knowledge from available context data. In addition, we suggest that, by adopting proper configuration and deployment strategies, semantic support features can be provided to differentiated users and devices according to their specific needs and current context.

This thesis has investigated novel design guidelines and implementation options for semantic-based context-aware middleware solutions targeted to pervasive environments. These guidelines have been applied to different application areas within pervasive computing that would particularly benefit from the exploitation of context. Common to all applications is the key role of context in enabling mobile users to personalize applications based on their needs and current situation.

The main contributions of this thesis are (i) the definition of a metadata model to represent and reason about context, (ii) the definition of a model for the design and development of context-aware middleware based on semantic metadata, (iii) the design of three novel middleware architectures and the development of a prototypal implementation for each of these architectures, and (iv) the proposal of a viable approach to portability issues raised by the adoption of semantic support services in pervasive applications.