Chapter 6.11
Ontologies for Scalable Services–Based Ubiquitous Computing

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ABSTRACT

This chapter discusses scalability problems and solutions to services-based ubiquitous computing applications in real time enterprises. The scalability problems are (1) identifying relevant services for deployment, (2) verifying a composition by a logical rule framework, and (3) enabling the mapping of required services to the "best" available device. We argue that ontologies can help to counter these challenges. Subsequently, we provide a detailed introduction to ontologies. We focus on the ontology languages emerging from the corresponding W3C Semantic Web activity. The W3C recommendations have a high impact on future tools and the interoperability of ontology-based applications. We contrast the pros and cons of ontologies at a general level and demonstrate the benefits and challenges in our concrete smart items middleware.

INTRODUCTION

Ubiquitous computing for real time enterprises calls for novel approaches to distributed applications since both the *economic* and *technical* scale of these applications will increase dramatically. Regarding the *economic* scale, applications grow beyond enterprise boundaries and potentially involve frequently changing, partly unknown participating entities. Therefore, much more open

approaches are desired. In the world of enterprise computing, service-oriented architectures and Web services are considered important steps on the road to economic scalability as discussed in the chapter "Ubiquitous Services and Business Processes."

The concepts and technologies of service-oriented architectures can be fruitfully applied to ubiquitous computing for real time enterprises to counter the economic scale. However, the *technical scale* of services-based ubiquitous computing, which concerns the number of nodes and processes involved, still remains a challenge. We discuss the use of ontologies as a possible means of countering the scalability problem, and evaluate their promises and limitations for services-based ubiquitous computing applications.

Services-based ubiquitous computing applications are highly distributed applications that run in the form of cooperating services on a variety of possibly heterogeneous devices. The devices run services that can be combined, that is, "composed," into more complex services or applications. Such a services-based approach to the development of ubiquitous computing supports the distribution of functionality across the set of available devices, enables better reusability of components in new or different applications, and the division of the overall functionality into independent services with clearly defined interfaces that can be developed and tested separately.

However, the capability to decompose business processes into individual services and to deploy them on different smart devices poses new technical challenges. In particular, the services to be executed on the devices need to be modeled and described for identification and selection, mapped to appropriate smart devices, remotely deployed, configured, and monitored. The reason for such additional tasks is the heterogeneity of the underlying hardware platforms in terms of different communication protocols and technologies.

To facilitate such tasks, a service composition model tailored to smart device interaction

is required. The service composition model has to enable the explicit modeling of the heterogeneities of different device platforms and has to support the identification, deployment, and composition of services for smart devices. While the identification, deployment, and composition are fairly simple with a small number of services and devices, the challenge of coping with such tasks increases with the number of devices and services.

In the remainder of this chapter, we show how ontologies may counter the fundamental scalability challenges of: (*1*) identifying relevant services for deployment, (*2*) verifying a composition by a logical rule framework, and (*3*) enabling the mapping of required services to the "best" available devices.

We begin by detailing the scalability challenges in a service-oriented smart items middleware. The chapter continues by introducing the reader to ontologies. We focus on the recent W3C recommendations RDF(S) and OWL that, for the first time, provide standard languages for ontology specification. These recommendations have a high impact on future tools and the interoperability of ontology-based applications. We proceed by contrasting the pros and cons of ontologies on a general level. Finally, we sketch how ontologies are used to counter challenges (*1*)-(*3*) in a service-oriented smart items middleware.

CHALLENGES IN SERVICE-ORIENTED SMART ITEMS MIDDLEWARE

As mentioned in the introduction, the technical scale of services-based ubiquitous computing applications struggles with the heterogeneity of the underlying smart devices, and the inherent complexity of a system that requires automatic or semi-automatic monitoring and deployment of services. In this section, we refer to the service-oriented smart items middleware presented in the

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