

The Semantic Middleware for Networked Embedded Systems Applied in the Internet of Things and Services Domain

Peter Kostelník¹, Martin Sarnovský¹, Karol Furdík^{1,2}

¹ Technical University of Košice, Faculty of Electrical Engineering and Informatics,
Letná 9, 042 00 Košice, Slovakia

{Peter.Kostelnik, Martin.Sarnovsky, Karol.Furdik} @tuke.sk

² InterSoft, a.s.,

Floriánska 19, 040 01 Košice, Slovakia

Karol.Furdik@intersoft.sk

Abstract. The paper presents the LinkSmart middleware system that addresses the Internet of Things and Services approach. The system supports an integration of various external devices and services into the mainstream enterprise systems. The development of LinkSmart goes across two integrated European R&D projects. In FP6 IST project Hydra, the LinkSmart prototype was developed by combining the service-oriented architecture, peer-to-peer networking, and semantic web services. The FP7 ICT project EBBITS is aiming at enhancing the LinkSmart middleware on service orchestration, event handling and workflow processing capabilities.

Keywords: Semantic web services, Internet of Things and Services, ontology for services, devices and events, networked embedded systems.

1 Introduction

The innovative and rapidly evolving research area of Internet of Things and Services (IoTS) [7], [8] addresses an investigation of ways and means for seamless functional interconnection and effective, so-called intelligent, communication of various devices, services, information systems and resources towards operational scenarios. The aim of efforts in this area is focused on a development of platforms and solutions providing pervasive computing environment for networked embedded systems [2], which may be employed in real-world applications in industrial domains such as manufacturing, e-Business, e-Health, etc. In the European context, the IoTS research is supported, for example, by the CERP-IoT cluster [8], which helps to coordinate the research efforts in tens of involved FP6/FP7 projects. The projects such as ASPIRE, BRIDGE, CoBIs, CuteLoop, Hydra, and EBBITS can be explicitly mentioned as mostly related to the topic of this paper, i.e. the IoTS-enabling middleware.

A wide scale of technologies is employed in IoTS frameworks or applications, ranking from Radio Frequency Identification (RFID) and sensor signals processing to computer network technologies, web services, or service-oriented architectures of

information systems. However, in this paper we will focus on the middleware layer that enables, by means of semantic web services and related knowledge representation structures, a networking of physical devices, sensors, or components in order to provide higher value-added (i.e., more advanced, sophisticated, or intelligent) solutions to the end users. This was the objective of the FP6 integrated project Hydra (Networked Embedded System Middleware for Heterogeneous Physical Devices in a Distributed Architecture, <http://www.hydramiddleware.eu>), which started in July 2007 and finished in December 2010. Hydra aimed at the development of a middleware for intelligent networked embedded system, which is based on service-oriented architecture and is deployable on both new and existing networks of distributed wireless and wired devices [1]. The resulting system, which was named as the LinkSmart middleware, is described in section 2.

Furthermore, the development continued by adapting the middleware for a broader exploitation. Directions of extensions and enhancements were identified namely in the underlying semantic structures, where several significant improvements were proposed – for example, a new ontological model of generated events, more advanced reasoning, inclusion of more types of devices, etc. To test these extensions, two application cases were specified in the areas of automotive manufacturing and food traceability. A new FP7 integrated project EBBITS (Enabling Business-Based Internet of Things and Services, <http://www.ebbits-project.eu>) [9] was launched in September 2010, where the major part of the Hydra consortium decided to participate. Some of the LinkSmart enhancements that will be accomplished in EBBITS are briefly presented in section 3.

2 Architecture and Functionality of the LinkSmart Middleware

The LinkSmart middleware, produced as the main outcome of the Hydra project, combines semantic web services technology with SOA-based principles applied on the solution. It provides a mechanism for wrapping standard API interfaces of sensors and various physical devices with a defined web service extension, which is enhanced by a semantic description of provided or generated WSDL files [2]. This way, the devices and their local networks are connected to the outside world through broadband and/or wireless networks. For example, the binding of a thermometer device to the respective semantic description in LinkSmart ontology is as follows:

```
<linksmart:binding device="http://linksmart.eu.com/ontology/Device.owl#thermometer" />
```

The LinkSmart can generate a stub of the related client and/or server code, based on e.g. available ontology instance for the device's state machine. The proxy stub is created according to the device's capabilities as either directly embedded on the device or using the OSGi framework [6]. The device can then be accessed and controlled in the application code of a networked embedded system using the following Java statements:

```
AppDeviceManager myMgr = new AppDeviceManager();
```

```

ThermoMeter.LSDeviceWS myThermometer = new
ThermoMeter.LSDeviceWS();
myThermoMeter.SetHID(myMgr.GetHID("Off1Thermometer"));
Light.LSDeviceWS myLight = new Light.LSDeviceWS();
myLight.SetHID(myMgr.GetHID("Off1Light"));
...
if (myThermometer.GetTemperatureC() > 25)
{
    myLight.Flash(2);
    myPhone.SendsMS("Too hot in the office 1,
temperature:" + myThermometer.GetTemperatureC()+
"+421329264552");
}

```

LinkSmart is installed as a node in the peer-to-peer network, which encapsulates interfaces of internally referenced devices and provides them as semantic web services to other network nodes – LinkSmart instances. The architecture of the main functional modules of LinkSmart is depicted in Fig. 1.

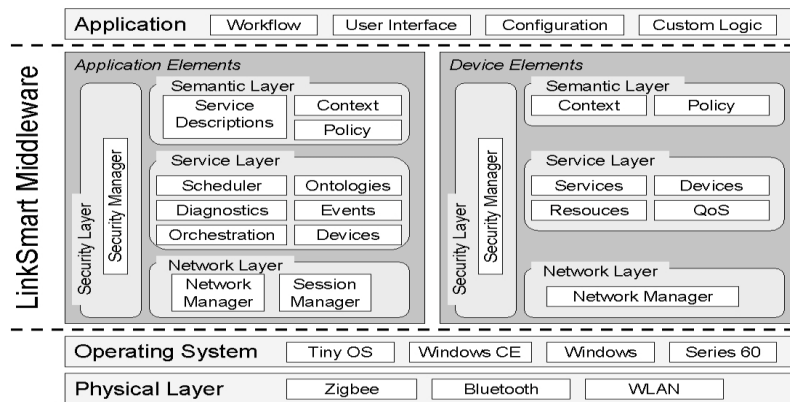


Fig. 1. Structural overview of the LinkSmart middleware layers.

The inner middleware elements are enclosed by the physical, operating system and the application layers shown at the bottom and at the top of the diagram, respectively. The physical layer provides several network connections like ZigBee, Bluetooth or WLAN. The operating system layer enables managing the physical layer objects and provides methods for accessing the resources of network connections. The operating system layer provides means to access and manage the physical layer objects. The application layer contains customizable user applications that may include modules for workflow management, user interface, custom logic and configuration details. These three layers are not a part of the LinkSmart middleware.

The middleware itself is divided into the Application Elements and Device Elements parts, representing the “close” (i.e. running in a performance-wise mode, e.g. on the same machine as the resources used) and “distant” (i.e. remote, with a slow

access or performance) components, respectively. Each of the parts consists of the network, service, semantic, and security layers, which contain the LinkSmart business logic, i.e. the functions for context sensing, service requests handling, network management and synchronization of peer nodes, access control, etc.

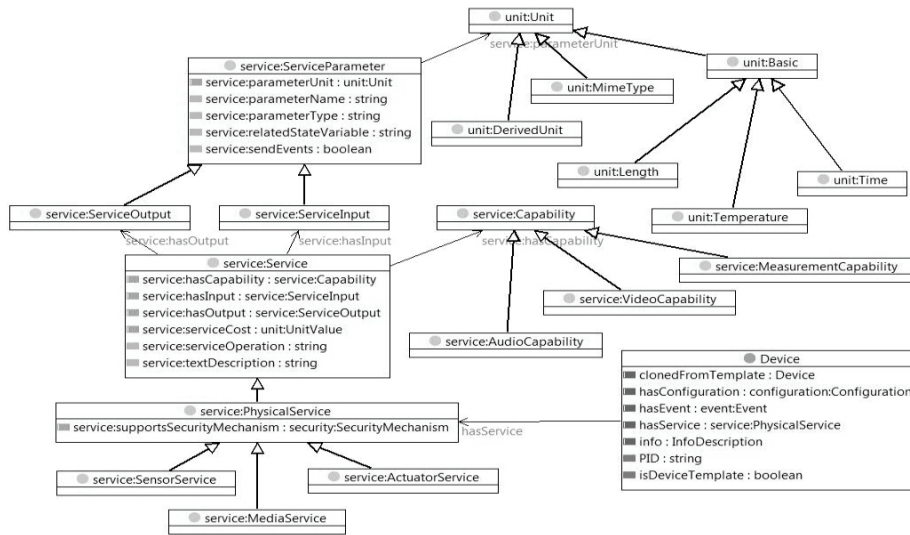


Fig. 2. Conceptual model of services in the LinkSmart ontology.

The middleware functionality is supported by a structure of OWL ontologies, which provide a semantic basis for particular business logic elements. For example, the ontology structure of the LinkSmart service model is presented in Fig. 2. Services, which are tied to devices, are described by capabilities and I/O parameters such as name, data type and unit. Similar ontologies were produced for modeling devices, network connections, and security issues [4].

3 EBBITS Extensions towards the IoTS Domain

The EBBITS project is aiming to shift the IoTS paradigm of Hydra more towards the services that are orchestrated in complex workflow sequences corresponding to the real-world scenarios in industry or other application domain [9]. This way, the EBBITS platform should provide a bridge between enterprise and public information systems, as well as between human users and “things” in the physical world.

Obviously, EBBITS builds on the outcomes of the Hydra project. The LinkSmart middleware system middleware is taken as the implementation basis, which will be extended on the functions and capabilities of semantic business process modeling, workflow management, service choreography and orchestration, event handling and processing of complex events generated by devices. The development will also

what a particular application would like to have. The basic idea of this approach is to hide all the underlying complexity of the mapping to, discovery of, and access to physical devices. The programmer just uses it as a normal object in his application focusing on solving the application's problems rather than the intrinsic of the physical devices.

The foundations of this concept were investigated in the Hydra project and resulted in the LinkSmart middleware system, currently available under the LGPL 3.0 open source licence. The EBBITS project builds on the Hydra outcomes and tries to extend the LinkSmart software on a fully featured support of business processes, event handling and workflow processing. This approach will be tested in two pilot applications: (1) automotive manufacturing, where LinkSmart should help to manage the production optimisation with special focus on reducing energy consumption, and (2) food producing industry, supporting the service and resource traceability through the whole process cycle, from the production to consumption stage. Currently (April 2010), the design and analysis work is ongoing; the first prototype of the enhanced LinkSmart system should be available in autumn 2011.

Acknowledgments. The project Hydra was co-founded by the EC within the FP6 IST-2005-034891. The presented work is partially funded by the European research project EBBITS (FP7 ICT-2009-5-257852), and by the Slovak Grant Agency of the Ministry of Education and Academy of Science of the Slovak Republic within the 1/0042/10 Project "Methods for identification, annotation, search, access and composition of services using semantic metadata in support of selected process types". We like to thank all partners in the EBBITS project for their support.

References

1. Eisenhauer, M., Rosengren, P., Antolin, P.: HYDRA: A Development Platform for Integrating Wireless Devices and Sensors into Ambient Intelligence Systems. In: *The Internet of Things*, pp. 367--373. Springer, New York (2010)
2. Hansen, K. M., Zhang, W., Soares, G.: Ontology-Enabled Generation of Embedded Web Services. In: *Proc. of the 20th International Conference on Software Engineering and Knowledge Engineering*, pp. 345--350. Redwood City, San Francisco Bay, USA (2008)
3. Kostelnik, P. et al: Semantic Devices for Ambient Environment Middleware. In: *EURO TrustAmi 2008, Internet of Things and Services*. Sophia-Antipolis, France (2008)
4. Kostelnik, P., Sarnovsky, M., Hreno, J.: Ontologies in HYDRA - middleware for ambient intelligent devices. In: *Ambient Intelligence Perspectives II*, Vol. 5, pp. 43--46 (2009)
5. Lefort, L., Henson, C. (eds.): *Incubator Report*. W3C Semantic Sensor Network Incubator Group (2010). Available at: http://www.w3.org/2005/Incubator/ssn/wiki/Incubator_Report
6. The OSGi Service Platform, OSGi Alliance, <http://www.osgi.org>
7. Santucci, G.: *From Internet of Data to Internet of Things*. European Commission, Directorate General, Information Society and Media, Brussels (2009)
8. Sundmaeker, H., Guillemin, P., Friess, P., Woelfflé, S. (eds.): *Vision and Challenges for Realising the Internet of Things*. CERP-IoT cluster, European Commission, Information Society and Media DG, Brussels (2010)
9. Vajda, V., Furdik, K., Glova, J., Sabol, T.: The EBBITS Project: An Interoperability platform for a Real-world populated Internet of Things domain. In: *Proc. of Znalosti (Knowledge) 2011*, pp. 317--320. Ostrava, Czech Republic (2011)