Summary

Title: Semantic Interoperability for Smart Spaces: Architecture, Management and Applications

The vision of ubiquitous computing is to facilitate tasks of people via applications that run on embedded devices of various sizes, features and capabilities. One of the areas of ubiquitous computing is the concept of smart spaces. A smart space is a physical environment, which contains cooperating smart objects that continuously and autonomously monitor the environment, interact with users, and adapt their behavior (services) for enhancing user experience according to some contextual reasoning. Such reasoning is based on information gathered either from the physical environment (e.g. via sensors) or from the internet (e.g. via user profiles). Smart spaces can offer smart services, which are beyond those that can be offered by a single device and are widely investigated nowadays with the motivation of enhancing the living standards of people. However, communicating meaningful information (semantics) across smart embedded devices and providing a common understanding of such information among different heterogeneous networks and devices, i.e. *semantic interoperability*, remain as challenges. This thesis proposes i) a conceptual framework defining the building blocks of generic heterogeneous smart spaces and a system architecture supporting semantic interoperability, ii) novel service and resource monitoring and management mechanisms, and iii) an implementation in the context of smart lighting applications.

Firstly, the proposed smart space conceptual framework describes a recipe for forming smart spaces out of smart objects and basic modules therein, and for sharing meaningful (semantically compatible) information among smart objects, i.e. semantic interoperability. Semantic interoperability is crucial as it defines the ability of heterogeneous systems or system components to communicate and to share information by performing compatible transactions. Hence, a smart space semantic interoperability architecture is proposed, including an ontology model and the interactions among system components.

Secondly, in order to deal with problems arising from the dynamic nature of a smart space, e.g. due to hardware or software failures, changes in node physical location and topology, and fluctuations in the available resources, a mechanism for resource and service monitoring and management is introduced. The proposed mechanism continuously monitors the presence and the resources of smart objects in the smart space. It detects when a new smart object joins, and allocates resources and delegates services to it by means of service discovery and matching. Similarly, it detects when an existing smart object leaves or when a service of smart objects fails, and provides solutions for such circumstances.

Finally, the proposed semantic interoperability architecture has been implemented and tested using smart lighting applications based on two use cases, i.e. a smart home pilot and a power-managed smart lighting system. The smart home pilot was a joint effort of TU/e with the companies Philips Research, NXP Semiconductors and CONANTE Advanced Interface Solutions and it is largely based on the SOFIA (Artemis) Smart-M3 semantic interoperability architecture. The power-managed smart lighting system testbed was a joint effort of TU/e and NXP Semiconductors. This was an implementation of a smart space composed of various devices with different computing and communication platforms, forming a heterogeneous network. The goal was to test the proposed semantic interoperability and resource and service management concepts as well as performance in such a heterogeneous smart space.

The context of the work was the SOFIA project aimed at developing an interoperability platform (IOP) that enables collaboration and data exchange between multivendor devices in multiple target environments as well as new interaction paradigms between users and smart applications. Within SOFIA project and in the scope of this Ph.D. research, we collaborated closely with the TU/e department of Industrial Design, NXP Semiconductors, Philips Research, and CONANTE Advanced Interface Solutions, resulting in combined demonstrations and publications. A total of 3 conference contributions, 4 workshop contributions and 3 journal papers were published (all IEEE international) in the context of this thesis and of SOFIA. The SOFIA project was finalized successfully at the beginning of 2012 and received two Artemis exhibition awards.