Abstract

Wireless Sensor Networks (WSNs) sit at the intersection between Data Acquisition and Automatic Control Systems, Computer Networks, Distributed Systems, and Mobile Embedded Systems. WSN systems feature strong constraints on energy consumption, from which constraints on computational and communication resources arise. Although WSN-based applications often integrate components that are connected to the Internet (especially IoT-oriented applications), the individual sensor nodes are rarely addressable directly in the Internet; because of the above-stated constraints, WSNs tend to use specific protocols that feature low energy requirements, with a single protocol usually spanning multiple standard OSI-stack levels. In research contexts, this leads to particularized experimental platforms that are difficult to extend and integrate; in practical contexts, this leads to competing vendor-specific technical solutions that are mutually incompatible. Rapid evolutionary cycles, especially in the contexts of Cloud technologies, the IoT, and personal mobile devices, lead to integration difficulties in complex systems based on heterogeneous WSNs.

The thesis approaches the **heterogeneity problem** in multiple stages. At first, we propose a technology-independent architecture for the remote monitoring and control of complex wireless sensor networks, in which lightweight adapters translate the monitoring and control data between various formats specific to mutually-incompatible low-level technologies and a general unified format conforming to a minimal representation model. Following this, we try formulating the main functionality of a given application as a generalization of the monitoring and control functions. We propose a general architecture for WSN applications that are described mainly at a high, technology-independent level. Finally we generalize this concept within the framework of a Services-Oriented Architecture, featuring a high degree of generality and wide applicability. The proposed architecture is based on a minimal service representation model, featuring dataflow-oriented service composition. The architecture supports self-reconfiguration of the WSN. This is described in a high-level, abstract fashion, which reflects into the lower abstraction levels. Both structural and parametric reconfiguration are discussed.

As a general research question, the thesis deals with the **relationship between architecture and capabilities / performance** in complex WSN-based applications. One aspect of this is the creation of new capabilities, such as the integration of mutually-incompatible technologies; another is performance optimization, such as when the system adapts to changing operating conditions through self-reconfiguration supported within the architecture. A particular example of performance increase through architectural optimization regards deriving the positions of mobile nodes through WSN-specific means. In the context of anchor-based multilateration, we propose a mathematical model for representing Dilution of Precision, a geometric-statistical effect. The model is optimized towards lowering computational effort. We propose an architecture that targets minimizing the DoP effect in WSN-based positioning applications. It integrates components for evaluating and visualizing a configuration of anchors, as well as feedback and self-reconfiguration components. The architecture also targets low energy consumption and fault-tolerance.