Chapter 7

Self-Adapting Event Configuration in Ubiquitous Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks are the key-enabler for low cost ubiquitous applications in the area of homeland security, health-care, and environmental monitoring. A necessary prerequisite is reliable and efficient event detection in spite of sudden failures and environmental changes. Due to the fact that the sensors need to be low cost, they have only scarce resources leading to a certain level of failures of sensor nodes or sensing devices attached to the nodes. Available fault tolerant solutions are mainly customized approaches that revealed several shortcomings, particularly in adaptability and energy efficiency. The authors present a complete event detection concept including all necessary steps from formal event definition to autonomous device configuration. It features an event definition language that allows defining complex events as well as enhance the reliability by tailor-made voting schemes and application constraints. Based on that, this paper introduces a novel approach for self-adapting on-node and in-network processing, called Event Decision Tree (EDT). EDT autonomously adapts to available resources and environmental conditions, even though it requires to (re-)organize collaboration between neighboring nodes for evaluation. The authors’ approach achieves fine-grained event-related fault tolerance with configurable adaptation rate while enhancing maintainability and energy efficiency.

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INTRODUCTION

Detection of real-world phenomena using wireless sensor networks (WSN) provides a basis for ubiquitous applications. Sensor networks supply habitat and environment monitoring, context-aware services, smart homes etc. (Mainwaring, Culler, Polastre, Szewczyk, & Anderson, 2002; Werner-Allen, Johnson, Ruiz, Lees, & Welsh, 2005; Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002; Aboelaze & Aloul, 2005). Their networks are to be deployed in large areas with high density where hundreds or thousands of nodes are used. Certainly that demands to use low cost devices with limited resources which in turn are prone to faulty behavior. Sudden changes in operational conditions, varying deployment and hazardous environments further affect the reliability of application. Above all, most sensor nodes are subject to strict energy constraints providing limited power only. Thus, inexpensive fault tolerant sensor networks that achieve a high reliability while remaining energy efficient are in great demand. Such sensor networks allow to execute safety- and mission-critical applications, e.g., for health-care, structural health monitoring or homeland security scenarios.

Sensor networks can identify real-world phenomena as events (Romer & Mattern, 2004) by detecting the exceedance of one or many sensor reading thresholds. Efficient information-fusion for complex events is already a challenge for single devices, but gets even harder if several nodes need to share required sensing features. For reliable event detection we consider it a necessity to enable sensor nodes to autonomously deal with different conditions as being expected in ubiquitous systems, i.e., distributed sensing capabilities, node mobility, changed network topology, failed sensors or sensing units etc. We demand a suitable concept for complex event detection to consider the following design criteria:

Adaptivity and Fault tolerance. The capability of sensor nodes and applications to continue event detection when the context changes, sensors fail or nodes move. We focus on (re-)adapting on-node as well as in-network processing for automatic resource-oriented event configuration. In addition, we exploit redundant and diversified data readings to enhance the reliability of event detection further.

Autonomy. In addition to the autonomous nature of sensor nodes, every node in the network must be enabled to perform all necessary tasks for event detection. Thus, a fully decentralized approach avoiding assignment of superior devices such as event gateways (Vu, Beyah, & Li, 2007) or fusion centers (Wang, Han, Varshney, & Chen, 2005) prevents from potential Single Point of Failures (SPoF).

Energy efficiency. Since collaboration requires energy-intensive communication between sensor nodes it reduces the maximum reachable lifetime. Thus, balancing the number of transmissions and the amount of exchanged data is of primary concern.

Convenience and Transparency. We are interested in providing means that enables non-professional users to apply sensor networks. Therefore a straightforward method to define events and configure sensor nodes without requiring knowledge about hard- or software or node deployment is in demand. Necessary adaptation and device configuration must remain fully transparent to the user. Especially in ubiquitous WSN we expect various sensors with similar capabilities. An automatic hard- and software abstraction can cover such heterogeneity.

We are aware of the fact that fulfilling all criteria up to a level of 100 percent is almost impossible but existing approaches usually tackle only a subset of those. We developed a concept for sensor network configuration considering all mentioned criteria. It allows for ignoring low-level details like node resources, network structures, node availability etc. and enables programmers to work on a high abstraction level only, i.e., the event itself including event-related constraints.