A Platform for Distributed Event Detection in Wireless Sensor Networks

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Abstract. Distributed event detection in wireless sensor networks is an approach to increase event recognition accuracy by fusing correlated parts of events, recognized by multiple sensor nodes. Events range from simple threshold detection to complex events requiring pattern analysis. Our previous deployment in this area of research investigates the possibility to recognize intrusion events, breaching security of wireless sensor network guarded areas.

We present a new platform, consisting of an improved system layer and application layer that advances distributed event detection in wireless sensor networks. We improve the event detection accuracy, by applying an ARM7-based sensor board with more precise acceleration sensors. In addition, the threaded fire-kernel and adjusted routing take the restricted resources on wireless sensor nodes into account. In order to gain a higher reliability in the detection results, we employ a distributed data quality estimator. The architecture's goal is to carry out large-scale deployments on fences of construction sites that detect events as stated above.

Key words: wireless sensor network, distributed event detection

1 Introduction

Distributed event detection (DED) in wireless sensor networks (WSNs) [1] introduced in [7], makes an attempt to support security infrastructures on fences of construction sites. Instead of sending raw data to a base station and statistically evaluating recognized events centrally, we fuse small descriptive feature vectors directly on the corresponding nodes. The base station only receives the final event. To set up a proper event detection system in WSNs, we perform in-network data aggregation on semantically enhanced data by classifying this data with an embedded event detection algorithm. Several events like opening a fence, climbing over a fence or stealing parts of the fence have to be detected in this scenario. For DED we adopted algorithms from the field of pattern recognition. The collaborative in-network classification system is driven by a supervised

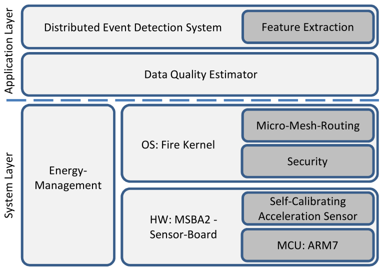

Fig. 1. Platform Architecture

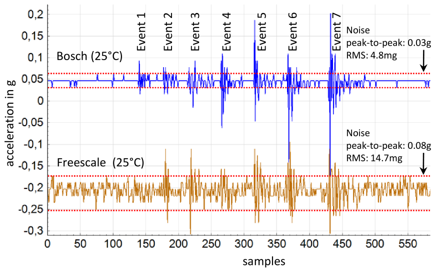

Fig. 2. Bosch and Freescale sensors, exposed to increasing intensity of shock events

training for events based on acceleration data. For data evaluation, raw data is compressed by calculating descriptive features. We present the ongoing work on our improved DED system. The main limitations (MSP-430, software-based sensor calibration, broadcast routing, no security and data quality layer) of our previous deployed DED system, will be reduced by a new ARM7-based platform, mainly designed for the special requirements of in-network DED.

Additionally, we evaluate two different, self-calibrating sensors and present an extended software architecture in order to enhance the detection accuracy of the system. As suggested in [5], we add a data quality estimator that allows us to rate the reliability of measured sensor data.

2 Architecture

In regard to the shortcomings of our previous system, we designed a new platform that improves the ability to use enhanced algorithms to detect events distributively. The improved components leverage pre- and post-processing of raw data, like self-calibration or data quality estimation. These system modifications are integrated in an updated system- and application-layer (see Fig. 1).

In the system layer, we shifted the hardware platform from MSB-430 node [2] based on the TI MSP-430 micro-controller to the ARM7-based MSB-A2 platform [2]. This hardware update increases the performance and enables us to evaluate more descriptive features, e.g., parzen window, wavelet transform or fast fourier transform, [7]. There, we implemented a devised calibration routine on top of the previously used DED system using a Freescale MMA7260Q [7] acceleration sensor. As an improvement we chose an acceleration sensor that is able to perform the calibration in its own hardware. A g-range beyond 6 g is required, because some events exceeded this limitations in our previous field tests. For evaluation, we selected two different sensors, the SMB380 from Bosch [3] and the MMA7455L from Freescale [4]. Both sensors support sensitivity settings of 2 g, 4 g and 8 g. The results are compared in detail in Section 3.

As an increased energy consumption is expected by moving from the MSB-430 to the MSB-A2, power management plays a key role. The usage of the ARM7 requires a customized energy management system. This is based on two new approaches: (1) integration of the Fire-Kernel [6] and (2) independent surveillance by acceleration sensors with integrated primitive logic functions. The multithreaded micro kernel supports automatic activation of power saving modes. If threads are suspended, the kernel alternates to the Idle Task, which puts the MCU into a power saving mode. In contrast, our previous Scatterweb-OS [2] sequentially polled for active tasks. This principle weakened the effectiveness of the power saving modes. The transceiver and the acceleration sensors are able to reactivate the MCU, thus enabling it to wake up on incoming tasks.

In our previous DED system, we employed a simple flooding algorithm to send notifications when an event has occurred. Intuitively, proactive routing may arise as an alternative. As long as proactive routing causes more maintenance traffic than the sending of events does, flooding is more efficient. Now we chose for routing the Micro-Mesh-Protocol (MMP), as it minimizes radio communication by establishing routes only when required. Furthermore, it caches routes until they become invalid. In contrast to purely reactive approaches, MMP updates its routing table by analyzing packets to be forwarded. We are still investigating whether the micro-mesh-protocol is superior to the mentioned flooding approach in an event detection environment.

The platform needs to support high level security, yet, it is aimed at minimizing extra costs, regarding computational and memory demands. Hence we realize this by employing Message Authentication Codes and data encryption on the link-layer using a CBC-mode block cipher. In comparison to stream ciphers, CBC-mode block ciphers delivers a higher security level on cipher attacks.

As commonly used sensors are cheap and tend to fail in rough environments, measured data samples are not fully reliable. Adapted from Dempster Shafer [5], we provide a data quality rating system that makes use of application dependent heuristics. The subsequent fusion algorithm takes the assessed quality of raw data into account, thus leading to more reliable and more precise results.

Our recognition system uses the DED-Algorithm of [7] that makes use of a typical pattern recognition architecture and consists out of three core components: sampling, feature extraction and classification. To take account for the limited resources of sensor nodes, the suggested prototype modeler [7] is used.

3 Acceleration Sensor Comparison and Results

We acquire movement data with acceleration sensors to get a proper data basis for the events. Further, we investigate, the SMB380 and the MMA7455L, both sensors are triaxial sensors which allow measurements of acceleration.

The SMB380 samples with 3 kHz, while all lower sampling rates can be emulated via an integrated filter routine, while the MMA7455L supports two possible sampling settings, 125 Hz and 250 Hz. The SMB380 consumes 1 μA in standby mode and 200 μA in operation mode, while the MMA7455L consumes 490 μA in operation mode and 10 μA in standby mode. We mounted both acceleration sensors on a common board extension and attached them to an

MSB-A2, to achieve ideal comparability. We chose a sensitivity of 8 *g* for both sensors in order to capture all environmental effects.

We compared the Bosch and the Freescale sensor by exposing them to shock events of increasing intensity . The measurements do have a slight offset, due to minimal differences of the sensor position on the board. As acceleration noise is not affected by orientation, the offset does not influence our evaluation. As shown in Fig. 2, the SMB380 shows lower noise (root mean square (RMS): 4.8 *mg*) than the MMA7455L (RMS 17.7 *mg*). For small bandwidth values, events are easier to detect for the SMB380 than for the MMA7455L, while the latter is more sensitive. The SMB380 allows to save more energy and delivers a higher detection resolution. We expect to get more descriptive features using the Bosch in our platform.

4 Conclusion and Outlook

In this paper, we have presented a new platform for event detection in WSNs that enables high standards in minimizing energy consumption and maximizing event detection accuracy. The platform itself, consisting out of a high performance MSB-A2 hardware and an extensible kernel, enables us to evaluate event detection accuracy in WSNs with serious environmental effects. We plan to set up a deployment for about 100 sensor nodes at the construction site of the Berlin Brandenburg International Airport (BBI). This research is conducted in the context of project AVS-Extrem funded in part by the German Federal Ministry of Education and Research (BMBF). The focus of this project is to handle extreme environmental conditions like moving and distorting obstacles and to provide reliable reporting of security incidents.

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