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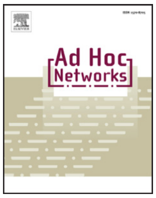

Deployment and evaluation of a fully applicable distributed event detection system in Wireless Sensor Networks

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ABSTRACT

Versatility and real world applicability are key features of Wireless Sensor Networks (WSNs). In order to achieve these benefits we have to face the challenges of high practical relevance during application. We deploy and evaluate the concrete example of a fence monitoring task to reveal how our distributed event detection system is able to perform under real application conditions.

The challenge is to bring both opposing aspects—high event detection accuracy and long service life—into one applicable ubiquitous system. If sensor nodes compose parts of events cooperatively, a comprehensive event assessment with low energy demands is possible. We propose a classifier based distributed event detection system consisting of two frameworks. The evaluation framework delivers a classification model and enables the theoretical evaluation of a given training set. The distributed event detection framework subsequently applies the classification model to assess, filter and classify events within the network. We evaluate our system by training and detecting events with our WSN composed of 49 nodes which are integrated in construction site fence elements.

We compare four different data application scenarios with varying data processing concepts and varying network sizes to analyze the resulting communication load as well as the system lifetime. We compare the results of our evaluation framework with the results of our application to show that the evaluation framework reflects the real world deployment results in a credible way. We show the full applicability of our approach by comparing the resulting increased event detection accuracy against our previous work. Compared to other information fusion scenarios, our distributed event detection system reduces energy consumption beyond a communication distance of two hops which yields a prolonged lifetime of the network while additionally achieving an improved event detection accuracy.

1. Introduction

Wireless Sensor Networks (WSNs) [1,2] are used in complex application scenarios such as vehicle tracking [3], coal mine monitoring [4], or classification of human motion sequences [5]. Sensor nodes equipped with sensors such as thermometers, gyroscopes or accelerometers can acquire environmental information to detect events like intrusions or damages. Distributed event detection enables evaluation of gathered data in a cooperative way within the network. In-network evaluation allows management of restricted resources including low computational power combined with limited memory to support energy saving, as our evaluations shown in Section 6.

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Distributed approaches are very promising for wireless in-network data aggregation. Complete implementations and evaluations of event detection algorithms applicable for real world WSNs by the use of distributed approaches are very rare [6,7]. We describe how to enhance network lifetime and detection accuracy and how to support a fully applicable distributed event detection system. The fence application evaluated in this paper is motivated by the need for a system to protect open and wide areas like construction sites, airports or concerts from unauthorized access. A fence equipped with such a wireless distributed event detection system is able to aggregate and evaluate sensor data based on multiple measurement points to classify and detect intrusion events.

Our investigated fence surveillance system follows a data driven approach. We want to reduce the amount of data needed to be transferred to the control center in order to lengthen the lifetime of specific sensor nodes which leads to an improved lifetime of the whole network. Typical approaches for WSNs to reduce communication are the following three technologies, which all need to be tailored to the application: in-network processing, data compression and data prediction [8]. A feasible data prediction is not possible for our fence surveillance as we want to distinguish critical intruding events from uncritical events like leaning on the fence or shaking the fence.

Our goal is to solve the classification problem of distinguishing trained events at a construction site fence within a WSN. Hence, we introduce an in-network processing solution that uses data compression methods based on a classical pattern recognition system. Our proposed in-network approach is a distributed event detection system which has the advantage of involving multiple sensor nodes to obtain an extended view of an event. In principle, it observes events from different perspectives with sensor nodes located at different positions at the fence to complement one another. An integrated classification model is used to define the diverse event descriptions. The final collaborative event detection process fuses the available environmental data within the network to achieve an increased event detection accuracy. In contrast, systems with only a local evaluation lack the ability to view events in their entirety. To develop a proper classification algorithm [9] for WSNs, it is important to take the required simplicity and the accumulating protocol overhead into account. Besides this, it is necessary to design and to evaluate application dependent *feature types* before deploying a system in order to describe the events in its complexity and their completeness. Descriptive features from several feature types like mean or histogram are used to distinguish different events from one another. We introduce a new *Evaluation Framework* for the supervised event training that supports the above mentioned requirements and extends the involved quantity and types of features of the feature pool to our needs.

We adopt the approach of [10], where the authors try to solve the intrusion problem within the network. Two adjacent sensor nodes are exposed to an intrusion event. Both sensor nodes perform the event classification by comparing the result with trained reference vectors. The reference vectors are created to represent each event class with one single version of a selected feature set. The classifications are performed by assuming that the events arise exactly at the respective node locations which lead to one correct and one incorrect classification. To distinguish between the correct and the incorrect classification it was assumed that incorrect classifications imply a higher Euclidean distance to the *reference vectors*. The results of [10] show that this approach does not deliver reliable results. On the contrary, every node that is affected by an event causes an increased communication load that puts a strain on the whole network.

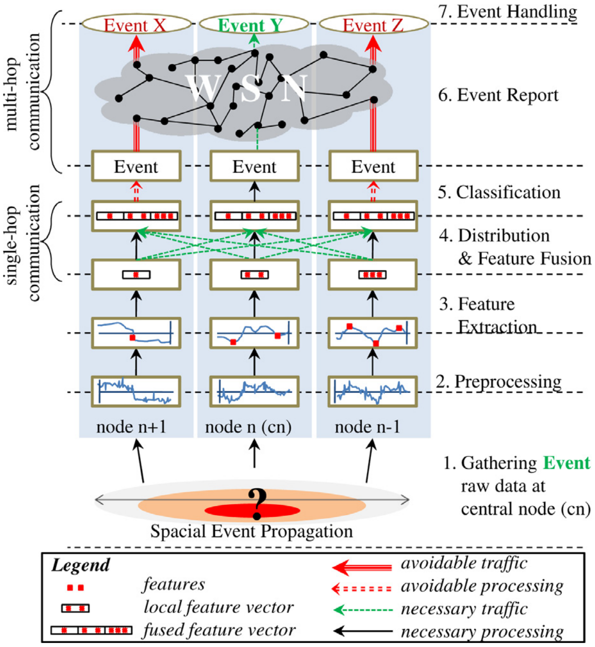

Fig. 1. Typical distributed event detection causes avoidable traffic in multi-hop networks during event reporting.

Energy consumption can be reduced by sending only one resulting classification to the control center. In Fig. 1, necessary traffic and the potential of avoidable traffic is depicted. Moreover, related classification processes can be avoided. While our general approach is transferable to different applications [5,11] we are focusing in this paper on the deployment and evaluation of a fully applicable distributed event detection system for fence monitoring. We evaluate acceleration sensor data of all triggered nodes for 10 event classes within the network to autonomously determine the sensor node with the most reliable classification result to ensure the lowest communication overhead possible.

As the sensor nodes do not know which topological part of the event is represented by each node, we add a *filter package* to identify the sole *central node* (CN) out of all affected nodes (see Fig. 2), which leads to reduced data communication within our WSN. Technically, the CN is the node closest to the event location in the scenario of fence surveillance. Multiple improvements allow us to detect events with high accuracy, even at untrained locations. Locating the CN helps to be independent from the fence-structure of the training. By adding a validation framework, we are able to examine different classification algorithms and features in theory to select an optimal classification model for real world