# Demo Abstract: Distributed Energy Measurements in Wireless Sensor Networks

Anton Hergenröder, Jens Horneber, Detlev Meier, Patrick Armbruster and Martina Zitterbart
Institute of Telematics, Universität Karlsruhe (TH)
Zirkel 2, 76128 Karlsruhe, Germany
{hergen|horneber|meier|armbruster|zit}@tm.uka.de

## Abstract

Energy efficiency is a common requirement for most WSN applications. We present our approach utilizing precise distributed monitoring of energy consumption to support the development of energy efficient protocols. Therefore we designed dedicated energy monitoring and management hardware for a wireless sensor network testbed. In our demonstration we show distributed energy measurement in a typical sensor network application based on an area monitoring scenario.

## Categories and Subject Descriptors

B.4.5 [**Input/Output and Data Communications**]: Reliability, Testing, and Fault-Tolerance; C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*Distributed networks, Wireless communication*

## General Terms

Management, Experimentation, Measurement

## Keywords

Distributed Energy Measurement, Sensor Network, Testbed

## 1 Motivation

Desired qualities of sensor nodes are often a capability of autonomous operation and a small node size. Therefore suitable energy sources are desired, e.g. batteries and solar panels. These energy resources are constrained making design of energy efficient protocols a major research topic for wireless sensor networks.

Proper design of energy efficient protocols often suffers by lack of precise knowledge about how protocol mechanisms affect network-wide energy consumption. Most communication protocols in sensor networks can induce energy consumption not only on sender and receiver of a message but also on forwarding nodes, e.g. in multi-hop scenarios. Computation intensive applications and sensing activities cause additional non negligible energy consumption.

To minimize energy wasting and to pinpoint potential optimizations measuring the consumed energy of sensor nodes is essential. This ought to be realized with high temporal resolution and in distributed fashion. With this intention we have developed a testbed for wireless **S**ensor **A**ctuator **N**etwork **D**evelopment called *SANDbed* [3]. The testbed design geared towards evaluation and optimization of energy-aware applications on real hardware. SANDbed provides us with real energy measurements in contrast to simulative energy evaluations. We use SANDbed as a tool enabling us to monitor not only single nodes but the energy consumption of a full operating sensor network without any side effects.

This work is funded by Landesstiftung Baden-Württemberg as part of the *ZeuS* project [1] researching gradual customizable communication in wireless sensor networks regarding reliability, integrity, authenticity and accuracy. One of the ZeuS topics is the evaluation of a security-energy trade-off for authentic aggregation in sensor networks [2] in SANDbed.

To demonstrate how distributed energy monitoring can be used in protocol evaluation we show live energy measurements in a scenario of area surveillance with a wireless energy constrained sensor network. Energy consumption can be influenced by the audience raising events by shadowing light sensors on the sensor nodes.

## 2 System Description

This demonstration is built upon our testbed SANDbed and we present it's core features described below. SANDbed's architecture allows side-effect free monitoring in a controlled testbed environment resulting in precise measurements of energy consumption without impact on the resources of sensor nodes. In fact there is no need of adapting existing WSN-applications and the sensor nodes don't need any mandatory knowledge about being monitored in a testbed at all. For energy measurements we developed a special monitoring and management device called **S**ensor **N**ode **M**anagement **D**evice (*SNMD*).

### 2.1 Energy Measurement Device

We developed the SNMD with the intention to analyze the energy consumption behavior of sensor nodes running in a real sensor network. In this demonstration we analyze a sensor network consisting of MicaZ nodes. The nodes are equipped with power supply by an attached battery or by simulating a battery using USB as a power source. Each SNMD is capable of performing measurements of current and voltage with a maximum sampling rate of about $20kHz$ live and $400kHz$ in buffered mode. The current measurement range is selectable between $0-100/200/500mA$ and the corresponding voltage measurement range is $0-10V$. In


*SenSys'09*, November 4–6, 2009, Berkeley, CA, USA.
ACM 978-1-60558-748-6

all cases the measurement resolution is 16 bit. Up to 448.000 samples can be held by the internal buffer of 896$kB$ RAM. Taking the samples with high accuracy tends to a fault deviation of about only 2%. Furthermore, the SNMD is able to load the mote's battery and it's mote programming capability enables us an easy and fast way of deploying applications in our sensor network testbed. In addition, the SNMD provides a comprehensive extension interface which can be used for attaching add-ons like displays, SD-cards for longtime measurements, etc.

## 2.2 System Architecture

An overview of the SANDbed architecture is shown in Figure 1. SANDbed consists of 3 levels of hardware components organized in a hierarchical tree. The root level comprises the user interface, where the management of the testbed and configuration of the experiments is taking place. Management nodes connected to the Internet form the second level. They are responsible for managing the testbed nodes and controlling the execution of experiments. The leaves of the tree are the testbed nodes, consisting of a mote and the SNMD.

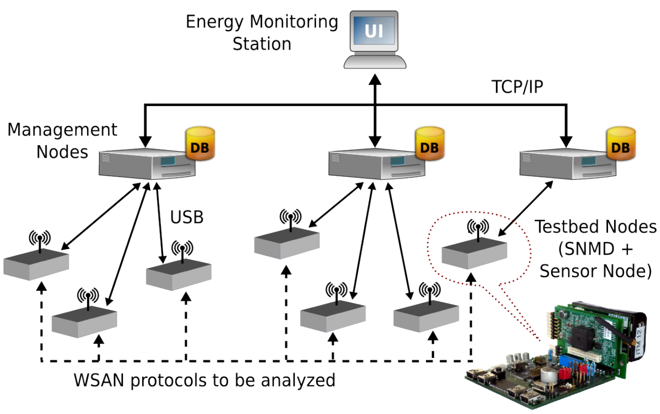


**Figure 1. Architecture of the SANDbed testbed**

To provide side-effect free monitoring capabilities, we distinguish between two orthogonal, non-interfering communication infrastructures. The wireless in-sensor-network communication is controlled by the researched protocol only. Whereas SANDbed's management and monitoring communication infrastructure uses TCP/IP and wired USB.

# 3 Demonstration

We are demonstrating a live energy measurement of an area surveillance WSN-application with the purpose to detect occurring events in the monitored area. Events occur in case of significant change of light conditions. Our intention is to show the evaluation of energy efficiency of the utilized event reporting protocol. Therefore the energy consumption of the sensor network is graphically displayed.

## 3.1 Scenario

The monitored area contains a sensor network placed in a grid topology as shown in Figure 2. Each sensor node is equipped with light sensors to detect changing light conditions. In case a person shadows the light sensor of a sensor node, it generates an event and sends an event notification to the sinks using a flooding protocol. The sinks are connected to a terminal computer where all incoming events are reported and indicated.

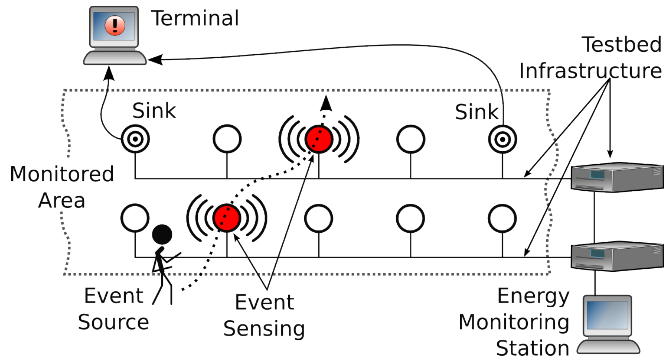


**Figure 2. Area surveillance scenario with live energy measurement**

## 3.2 Protocol Evaluation

In contrast to the flooding protocol we also demonstrate a simple aggregation protocol for delivering event notifications to the sinks. This protocol is similar to flooding, but differs in the manner of forwarding the event notifications by the nodes. If a node receives more than one event in a certain time period, the events are aggregated into a single event message. Otherwise the events are forwarded as done in flooding protocol. The expected effect of this aggregation of events is a noticeable reduction of messages being sent in case of several detected events. This supposedly results in reduction of energy consumption. This assumption implies the radio being turned of during inactivity since this leads to significant energy savings. We want to determine and show these energy savings on the energy monitoring station as shown in Figure 2.

## 3.3 Audience Interaction

The audience can interact with our demonstrator by shadowing the sensor nodes and thus cause the nodes to send events to the sinks. During this activity the energy consumption of the sensor network is permanently monitored. Varying between using simple flooding and the approach of aggregated events, we show the difference of the energy consumption behavior, providing a confirmation of our assumptions.

# 4 References


[1] ZeuS - Zuverlässige Informationsbereitstellung in Energiebewussten Ubiquitären Systemen. http://www.zeus-bw-fit.de/. Webpage.

[2] E.-O. Blaß, J. Wilke, and M. Zitterbart. A security–energy trade-off for authentic aggregation in sensor networks. In *Proceedings of the Second IEEE Workshop on Wireless Mesh Networks (WiMesh 2006)*, pages 135–137, Washington D.C., USA, Sept. 2006. IEEE Press.

[3] A. Hergenröder, J. Horneber, and J. Wilke. SANDbed: A WSAN Testbed for Network Management and Energy Monitoring. Hamburg, Germany, Aug. 2009. 8. GI/ITG KuVS Fachgespräch "Drahtlose Sensornetze".