An Interactive Testbed for Heterogeneous Wireless Sensor Networks

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***Abstract*—We demonstrate a flexible sensor network testbed. A design goal is to support comparison of different sensor node hardware as well as to allow user interaction with the sensor network. The two main requirements are thus that the testbed should support heterogeneous sensor hardware and provide an easily accessible interface. A wireless control channel makes it easy to deploy or reconfigure testbed setups.**

I. Introduction

A common approach to wireless sensor network (WSN) evaluation is indoor testbeds [3], [4], [6], [2]. A testbed can both be used to test sensor hardware, as well as evaluate software in a deployed WSN. We are currently building such a sensor network testbed and have a running prototype spread over four rooms, which we think shows great promise. We will present some of the requirements the testbed is designed to meet as well as the design.

A focus of the testbed is on user interaction. We have already done a project as a proof of concept, where we used a Bluetooth-enabled mobile phone to tap data from the WSN. As of now, users can query the state of the testbed using Bluetooth enabled devices without installing any custom software.

Due to the design of the testbed using a backbone as control channel our testbed is highly flexible. By using the Vendetta[5] software, the testbed can handle scheduled and unattended experiments as well as live monitoring of running experiments.

II. Requirements

The requirements the testbed should meet are both of a practical nature as well as derived from research we want to perform.

A. Testbed uses

There are different areas of research where we expect to use the testbed. One topic of interest is to perform comparisons between different sensor hardware. Examples could be to evaluate the same communication protocol with different radio hardware or to measure the same environment with different sensors. It is also important to support different types of sensor nodes to enable research on heterogeneous sensor networks.

A further topic we plan to research is how to enable users to easily interact with wireless sensor networks. While there are many interesting possibilities for user interaction, we will initially focus on developing interfaces for tapping data acquired by sensors. To evaluate such functionality, we will need mobile nodes within the testbed. Mobile nodes will make it harder to follow our decision to have all testbed nodes connected through a control channel, but we envision that such nodes will have multiple interfaces where one interface can be used for the control channel.

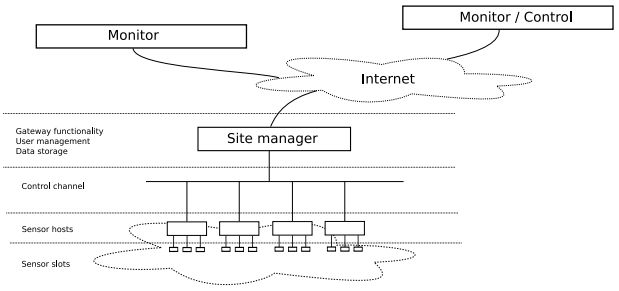

Fig. 1: High level design

B. Practical considerations

Experiences from previous experimental work has made us formulate requirements on the operation of the testbed. One such requirement is that it should be possible to perform a complete experiment without physical access to the testbed. That requirement limits the possibilities of how we can connect sensor nodes. For example, in order to reprogram some sensor nodes, an *in system programmer* (ISP) needs to be connected. And as we want to be able to reprogram sensor nodes remotely, such ISPs need to be part of the testbed.

Operating the testbed remotely also creates a need for user management, access control, and ways to distinguish between experiments. Those problems are far from trivial, but we have decided to take a bottom-up approach to the design and will not go further into these issues here.

We have also made the decision not to allow sensor nodes that are not connected to any control channel (e.g. a wired network). Although this makes the testbed more expensive

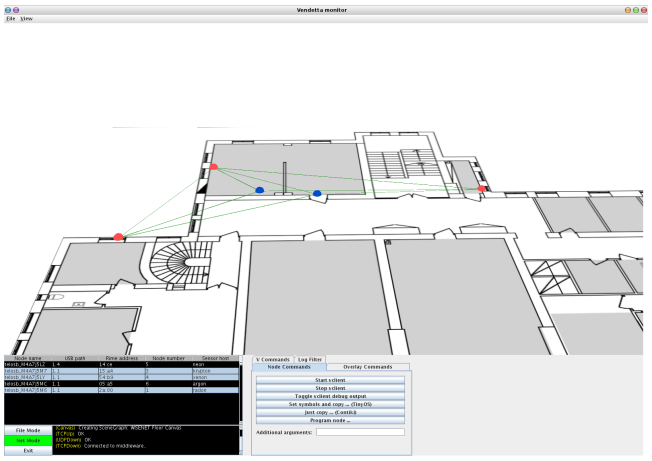

Fig. 2: The Vendetta monitor. An interface to the testbed

and harder to deploy, we believe that the increased control of testbed activities is worth that cost.

III. Design

There are many deployed WSN testbeds and we want to use as much as possible of what is available. For example, the TWIST[4] testbed seems to provide much of what we want, but we did not find it as flexible as desired. The MoteLab[6] testbed and the Re-Mote[2] testbed seem to have good interface functionality which we hope to benefit from. In our design, we have tried to use ideas and experience from these testbeds, but have modified them to suit our needs. A high level design of the testbed is presented in Figure 1. The testbed management and monitoring is solved by Vendetta, a tool designed for such tasks. Part of Vendetta is a graphical user interface called a *monitor* (Figure 2). The researcher can use the monitor for example to push code onto the sensor nodes, toggle them on and off, initiate experiments, and later collect logfiles.

A. Site manager

The *Site manager* acts as a gateway to the testbed and will solve two major problems. First, it will allow researchers from outside the testbed to gain control of sensor nodes for the duration of an experiment. Second, it will serve as the point to implement access control.

B. Control channel

To run experiments in the testbed, software needs to be distributed, the experiment initiated and stopped, and data collected. All these task are better kept away from the wireless interface of the sensor nodes. The main reason is that you do not want control traffic affecting measurements of the evaluated WSN. Our current prototype can use either an ordinary Ethernet network or a wireless IEEE 802.11 ad-hoc network as control channel. A wireless control channel allows for great flexibility in the testbed deployment; it is especially suitable for outdoor experiments and in other environments that do not have a pre-existing network infrastructure.

C. Sensor hosts

A *sensor host* is a machine connected to the control network hosting sensor nodes. In our implementation, we mainly use Asus WL-500G wireless access points as sensor hosts. The access points have USB ports where sensor nodes can be connected, as well as serial ports available with a minor modification. They can run a minimalistic distribution of Linux called OpenWrt [1]. The choice to use access points as sensor hosts are both based on the good price/performance they offer, as well as the appealing form factor. We further use ordinary laptops as sensor hosts. In combination with a wireless control channel, this enables us to evaluate WSNs in which some of the sensor nodes are mobile.

D. Sensor slots

We use the term *sensor slot* to describe the collection of connections between the sensor host and a sensor node. Connections could be USB, RS-232, power, In System Programmer (ISP) etc. Sensor slots are physically part of the sensor hosts.

Acknowledgements

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