# Sensei-UU — A Relocatable WSN Testbed Supporting Repeatable Node Mobility

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**Abstract.** General purpose testbeds for Wireless Sensor Network (WSN) systems are often deployed in lab environments. This means that the testbed environment may differ considerably from the target environment of a system with respect to e.g. radio interference and sensory input. Furthermore, many WSN scenarios include mobile nodes, such as mobile sensors and mobile sinks, whose movements can affect the experimental results considerably. Both these features pose a challenge to achieving consistent and reliable experimental results during the evaluation and testing of a WSN system.

To attack this challenge, we are developing the Sensei-UU WSN testbed. It follows a light-weight, distributed design, so that instances of the testbed can be easily relocated; this enables experimenters to evaluate a system in different environments. To support scenarios including mobile nodes, Sensei-UU uses robots which carry out mobility patterns defined by the experimenter.

Our evaluation shows that our design supports repeatable experiments in various environments, even when the experiments involve mobile nodes.

## 1 Introduction

WSN systems are deployed in a variety of environments, ranging from e.g. forests, over hospitals, to industrial facilities, whereas many general purpose testbeds for WSNs are deployed in lab environments. In consequence, the behavior of a system in a testbed may be different from its behavior in situ, because of the different radio environments and sensory inputs. From this we conclude that it is desirable to be able to relocate a testbed. The presence of mobile sensor nodes in a WSN scenario further complicates the testing process, as the testbed needs to support node mobility, keep track of mobile nodes, and ensure repeatability of movements of mobile nodes. The latter is necessary to be able to draw conclusive results from repetitions of similar experiments.

We are developing the Sensei-UU Wireless Sensor Network testbed to attack these challenges. Our testbed differs from existing WSN testbeds in two important aspects. First, Sensei-UU may use a wireless control channel. This makes the testbed independent of existing network infrastructure and makes it easy to relocate an instance of the testbed into the intended target environment of the

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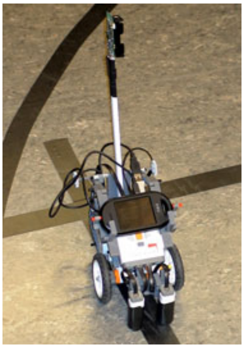

**Fig. 1.** A mobile node

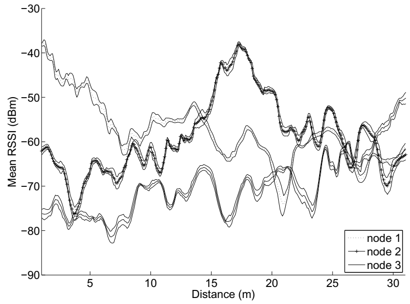


**Fig. 2.** Received signal strength from stationary nodes to a mobile node, averaged over multiple runs of one experiment

system under test. This flexibility distinguishes Sensei-UU from static testbeds, such as TWIST [2]. Second, Sensei-UU supports experiments involving mobile sensor nodes. Robots carry sensor nodes and follow pre-defined mobility patterns. In contrast to existing WSN testbeds with mobility support, Sensei-UU does not rely on existing infrastructure for node localization and robot navigation, but instead uses a simple line-following approach.

## 2 Design

Our testbed follows a light-weight, distributed design to make it largely independent of existing infrastructure. Every sensor node – we currently use TelosB [1] nodes – in the testbed is attached to one *sensor host*. A sensor host is responsible for managing the attached sensor nodes; it provides a means to reprogram attached nodes or collect log data from them. We are using WLAN access points as stationary sensor hosts, and OpenMoko FreeRunner [5] mobile phones as sensor hosts for mobile nodes. The FreeRunner's USB host capabilities make it possible to attach one or more sensor nodes to it. Our design is based completely on off-the-shelf components to make our testbed reproducible for other researchers.

Robots in the testbed are based on Lego NXT kits [4]. Robots navigate by following a tape that is laid out on the floor by the experimenter prior to the experiment (Fig. 1). While this approach constrains robot mobility, it increases the independence of the testbed of existing infrastructure such as ceiling-mounted cameras as they are used in, e.g., Mobile Emulab [3]. Each robot carries one mobile phone acting as a sensor host and one or more sensor nodes.

Sensor hosts forward log data from the sensor nodes to a *site manager* over a wireless IEEE 802.11b/g control channel. The site manager in turn delivers the data to an experimenter running a *monitor* software. The monitor also provides the experimenter with an interface to reprogram sensor nodes and control experiment parameters. The use of the site manager as an indirection point facilitates remote access to the testbed.

## 3 Evaluation

A wireless control channel may potentially interfere with the sensor nodes' radio if both operate in the same frequency band. To ensure that this is not the case in our testbed design, we have measured the interference between IEEE 802.11b/g and IEEE 802.15.4, the radio technology used by TelosB nodes. We have found that if both technologies use different frequencies, and if any two 802.11b/g and 802.15.4 transceivers are separated by at least 1 m, interference is negligible [6].

We further assessed the repeatability of experiments involving mobile nodes. We set up an experiment in which one mobile sensor node constantly measures the quality (in terms of RSSI) of its radio links to three stationary sensor nodes. Figure 2 shows the quality of the respective links to the stationary nodes averaged over multiple runs. For each link, the upper and lower line represent one standard deviation. The standard deviation characterizes the differences in link quality between different runs. From the fact that the standard deviation is reasonably low, we conclude that our testbed allows for repeatable experiments. We have repeated the described experiment in different environments, one of which was an anechoic chamber. There we also found the variance between runs to be low, from which we derive that our testbed itself does not have a substantial impact on the system being tested.

## 4 Conclusion and Future Work

We have presented our WSN testbed, called Sensei-UU, that is designed to be easily relocatable and to support mobile nodes.

We are currently considering to extend our testbed to incorporate mobile phones as part of the system to be tested. This would allow us to evaluate hybrid networks of sensor nodes and mobile phones. We will release the software components in Sensei-UU under an open source license soon.

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