Teaching a practical Ubicomp course with Smart-Its

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Abstract
We propose the Smart-Its platform as a platform for teaching Ubicomp in practical student courses. We present four experiments that were undertaken during summer term 2002 and show some outcome. Applications, context, sensor and Wireless ad-hoc communication are the key issues in these experiments. We also introduce the use of the Smart-Its hardware and development platform as a tool for such teaching activities.

Keywords
Teaching, smart devices, context, sensors, communication.

INTRODUCTION
Teaching Ubiquitous computing topics in a practical student course requires a platform that can be easily used but is still realistic enough to collect experiences with real-world problems while experimenting. This paper presents Smart-Its as a platform for conducting experiments in student courses. Smart-Its [1] are small devices (1.5x4 cm) containing sensing (various), computing (5 MIPS) and communication (via RF) capabilities. These Smart-Its are intended to be attached to everyday objects to enhance the functionality of the object, to deliver information (collected through sensors) to other devices and to do some acoustic or visual output. The Smart-Its platform also includes a software library and development support that is simple to program for implementing Ubiquitous Computing scenarios. The platform is powerful enough to let programmers implement algorithms and rather complex context detection. Smart-Its provides access to functionality like sensors and communication through libraries and operating system functions. For our practical course we identified four main topics where Smart-Its are helpful. Smart-Its are used in the experiments as **Smart-Its nodes** for sensing data in the environment, for computing context out of these sensor data, for communicating these data to other nodes, and for building and testing applications. For the experiments Smart-Its nodes have to be attached to everyday objects by students and then have to be programmed. The paper describes shortly the content of the course held first in summer term 2002, experience collected and also the development environment and technical parameters.

Related Work
Up to now there are only a few platforms available that can serve as a basis for a practical course. One of them is the Berkley Mots [2] system and the TinyOS. In contrast to the Mots Smart-Its provide some better performance values (e.g. faster communication) and also a development environment including wireless programming with systems in place over the RF channel. Smart-its also support analysis of context and sensor data via backend systems. First ideas for tools for building Ubiquitous computing systems were also presented in the first workshop on Ubicomp Tools at Ubicomp 2001 [3]. Of these only a minority is available for use now, e.g. the CoolBase or the Phidget system. The drawback of these systems is that they still rely on a wired or simple IR-base communication architecture, which restricts its application range.

Teaching a practical course in Ubicomp
In an example practical course we identified four main topics to be taught; the premier topic was based on building and testing applications in the area of ubiquitous computing, while the other three topics demonstrated Ubicomp-enabling technologies. The second dealt with context and sensor technology, the third with context communication between different nodes in a network and the fourth with basic communication and energy issues. The students conducted general experiments for topics 2-4, followed by a more detailed experiment based on topic 1. The motivation to use the Smart-Its platform and the expected outcome of these topics are described in the paragraphs below:

Ad-hoc application experiments
This part of the course is dedicated to collecting practical experiences with applying technology into the everyday environment. In the experiment students are faced with a complex and distributed application, where multiple nodes work together to fulfill a task. One major outcome is that students learn to develop distributed applications, how to address security and privacy issues and learn where to implement Smart-Its nodes. The student will also have to solve practical problems associated with attaching Smart-its nodes to objects and collecting information. The advantage of using Smart-Its is that small and medium-sized application settings can be implemented within a short time. Such settings require nodes that are not bound to wired sensor structures (with long set-up times) and are not reliant on a complicated infrastructure. Because computation of Smart-Its can be processed at the Smart-It itself, applications and experiments are not confined to the lab and can be implemented within a restricted time frame, without previous knowledge of the technology.

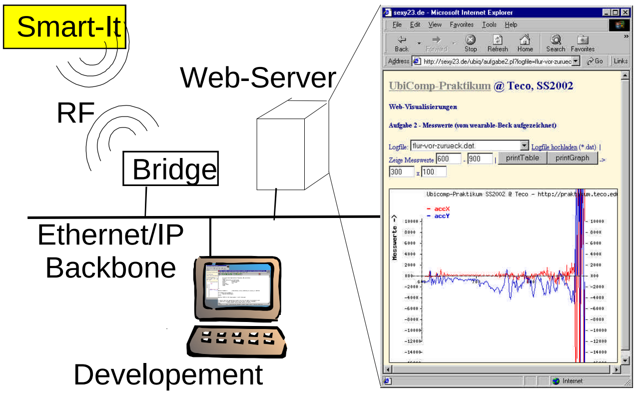
Context and sensors
In this experiment students learn which sensors are available, what sensors or combination of sensors can be used to retrieve a context and what algorithms are appropriate for use in small sensor nodes. They also become familiar with the characteristics of sensors, e.g. their required sampling rate, the energy consumption and their error rate. The Smart-Its sensor board provides a general set of sensors that can be used for sensor based applications and for experiments on deriving context from sensor data. Such experiments always require information retrieval yet, due to the data transmission deficiencies of wireless networks, they often require processing of data at the sensors‘ location. Smart-its support this by providing a complete computing and sensor infrastructure integrated into the boards.

Abstract context aware communication
The outcome of this experiment is a general understanding of how to express context information for use in other applications, how to filter and combine them into new (richer) types of contexts and how to communicate them between applications. Smart-Its sup-

port this through a context protocol layer and an application programming interface (API). This layer is intended to be extended by new types of contexts that may result from former work retrieving contexts on Smart-Its.

Network and energy issues

As most of the energy in a node is spent on communication, another consideration in the experiment is the implementation of energy saving and energy aware protocol extensions. A major outcome of the experiment is the understanding of communication issues for ubiquitous computing networks, their characteristics and solution strategies. Smart-Its support access to different layers of communication; In Smart-Its the network layer can be accessed through a simple API providing all functionality to implement various types of algorithms including energy aware protocol enhancements.



Smart-Its Development and Technology

The Smart-Its hardware consists of a generic RF communication board connected over I²C to a sensor board (total size: 4x1.5x1 cm), on which application development is done. Wireless broadcast communication facilitates interaction with other Smart-Its in their vicinity (at 125kbit/s), and optionally with servers over a RF-Ethernet/IP bridge. The backend is used for analyzing sensor data through a tool running on a Web-Server (figure 1) while the experimentation process is running. The programming environment (also connected via Internet) consists of the Smart-Its Software Development Toolkit (SDK), compiler and program download utility. The latter one allows you to download compiled programs directly onto a Smart-Its from the development PC.

Smart-Its provide sensors for collecting light, pressure, temperature, acceleration and audio information. The freely programmable microprocessor on the Smart-Its provides about 12kbyte space for programs and about 8kbyte for data. Sensor values can be accessed by simple functions using the SDK. To share information with other Smart-Its, programs can communicate and express sensor values and contexts via APIs. A subscription mechanism of the communication subsystem allows one to watch for selected or all information on the communication channel.

Experiences with Experiments and outlook

During the practical course 4 experiments were carried out. In "Night&Day" students automatically adjusted the time-of-day setting of the Smart-It by observing the environment through the sensors and deriving the context. In "F1 Skates" Smart-Its were attached to inline skates and a kickboard; context had to be retrieved and communicated to a second Smart-It attached to the body of the user for output status (Figure 2). In a third experiment a protocol enhancement for energy aware communication of context had to be implemented. The fourth and last experiment, spaces of trust, was about using context collected in a room to generate areas of trust and keys for exchanging documents among those present.

For many of the technologies in Ubicomp students had no previous knowledge. Although we thought this would be a major problem, we found out it was not. E.g. the programming language for Smart-Its is plain C. None of the students was familiar with C, but all were able to run programs successfully after 2 weeks. The provided example code and code-parts were enough to have a quick start into the environment. Also, although there was no previous knowledge of dealing with hardware, the students also managed to acquire this skill, e.g. built cables for connecting sensors and batteries to Smart-Its, soldered additional piezos for acoustic output etc. Instead, the major problems appeared when implementing Smart-Its in the physical world. Cable deterioration and inappropriate housings without damping were found as the major sources of error during the run of the course.

Figure 2. Practical Course Experiment

Before the next course held in 2003 we will especially improve these parts of the system. We will also look into using Smart-Its as a platform for other Ubicomp topics like network routing and HCI studies.

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