Report on the Summer School on Wireless Sensor Networks and Smart Objects

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1 Introduction

Grounded in the belief that processors, sensors, and wireless radios are becoming extremely small and inexpensive, we can foresee a world where many everyday objects and physical environments are enriched by computational power. Wireless sensor networks and smart objects are two particular instances of such networked embedded sensing systems, which can perceive and control many aspects of the real world, and which may interact with humans. These technologies are currently receiving significant attention by researchers, potential users, and by people interested in the implications of the induced paradigm shift in the way we use computers.

The goal of the Summer School on Wireless Sensor Networks and Smart Objects, held August 29 - September 3, 2005 at Schloss Dagstuhl, Germany, was to provide a basic survey of the most relevant subfields, to present the perspectives and the underlying technologies, but also to identify the pertinent issues that form the field of wireless sensor networks and smart objects, as well as to identify important research themes. Furthermore, the school provided a good opportunity to get to know other people working in the field, to meet distinguished scholars, and to establish contacts that may lead to research collaborations in the future.

The audience consisted of 60 post-graduate students, PhD students, and young researchers from universities and industrial laboratories from 18 countries world-wide that were selected among 181 applicants. Ten distinguished lecturers from Germany, The Netherlands, Switzerland, and the U.S. delivered high-quality lectures and hands-on tutorials. The participants got involved through an application competition and a participants' workshop.

In the remainder of this document we provide detailed information about the summer school venue, the lecturers, the participants, the summer school program, and the financial aspects.

2 Location

The summer school took place in the inspiring atmosphere of Schloss Dagstuhl (Dagstuhl manor house), Germany, close to the border of Luxembourg and France. We succeeded in allocating the Dagstuhl facilities exclusively so that we could use the full capacity of 60 participants plus 10 lecturers.

Schloss Dagstuhl was built in 1760 and is used for seminars and conferences since 1990. Besides providing accommodation, a comprehensive computer science research library, and computer facilities, it offers a unique setting for inspiring discussions, informal exchange of ideas, and socializing.

3 Lecturers

In preparation for the summer school, it was decided to provide a broad view on wireless sensor networks and smart objects by covering a whole spectrum of topics ranging from hardware aspects and operating systems, over middleware and data processing, to interaction of humans with such systems and social aspects such as privacy. This broad set of topics had to be reflected by the competences of the lecturers. Hence, in addition to four consortium members, we invited 6 additional experts from Germany, The Netherlands, and the U.S. In the table below, consortium members are marked with an asterisk.

Lecturer	Affiliation	Topics
Jan Beutel	ETH Zurich, CH	Hardware, Deployment
Holger Karl	Univ. Paderborn, DE	Routing, Quality of Service
Koen Langendoen	TU Delft, NL	MAC, Localization, Deployment
Marc Langheinrich*	ETH Zurich, CH	Privacy
Pedro J. Marron*	Univ. Stuttgart, DE	Middleware
Friedemann Mattern*	ETH Zurich, CH	Technologies for Smart Objects
Joe Polastre	UC Berkeley, US	Hardware, Operating Systems
Kay Römer*	ETH Zurich, CH	Time Synchronization
Albrecht Schmidt	LMU Munich, DE	Context, HCI
Rob Szewczyk	UC Berkeley, US	Hardware, Operating Systems

4 Participants

In response to the call for participation, we received 181 online applications before the deadline (and numerous additional requests after the deadline). Every applicant had to submit a description of his or her background, focus of research or field of interest, expectations about the summer school, current status and affiliation. Based on these data, we selected 60 participants based on their general qualification, background, research interests, and geographical distribution. The following table summarizes the distribution of the applications and participants. The final list of participants is available online at [1].

Country/Category	Applications	Accepted Applications
Austria	2	2
Belgium	2	1
Bulgaria	3	-
Czech Republic	1	-
Denmark	5	3
Finland	8	2
France	6	1
Germany	37	11
Greece	1	1
Hungary	1	-
Ireland	8	4
Israel	1	1
Italy	20	8
Netherlands	11	4
Portugal	1	-
Romania	1	-
Russia	1	-
Spain	5	2
Sweden	7	-
Switzerland	15	6
Turkey	8	3
United Kingdom	20	8
Brazil	4	1
Canada	3	-
USA	4	1
India	1	-
Korea	1	-
Kuwait	1	-
Malaysia	1	-
Pakistan	1	1
Gambia	1	-
Consortium members	23	16
Industry	10	4
Women	21	12

5 Program

The summer school program consisted of lectures, a participant's workshop, a hands-on programming tutorial, an application competition, and an excursion as detailed below. Every participant received a folder with copies of all slides and further material. In addition, the slides and further material are available online at the summer school web

site as a resource for the preparation of future summer schools and other teaching activities. Note, however, that some lecturers asked us to limit availability of their material to the participants, hence some material is protected by password. A detailed program schedule is available at [4] with links to the abstracts and slides of the individual activities.

5.1 Lectures

The summer school featured 13 lectures with a typical duration of 1.5 hours. Titles and abstracts of the talks are given below.

Jan Beutel: Real-world Sensor Networks: Experiences in Design and Deployment

To a large part driven by the achievements in miniaturization, the advances in integration of complex wireless integrated products and the increase in performance and functionality of the design tools, the requirements and properties of a single device are today well understood. Yet it is not simple and straightforward to implement the wireless sensor network concepts into a functional prototype system or even a commercial product. The interaction of many devices is often underestimated and design, test, deployment and validation of wireless sensor networks today are in their infancy, posing hard research and technological questions. Especially wireless sensor networks are often proposed to follow a cross-layer approach, taking care of many design decisions and requirements from a unified standpoint. In the experience gained from the implementation of wireless sensor network experiments it has been shown that the system aspects are much more complex than initially anticipated. But development today is hard, error prone and repetitive.

In this tutorial, we discuss aspects of system design, development and deployment based on the experience of real wireless sensor network experiments. Basic paradigms and processes of embedded systems design are presented, including problems and pitfalls. Taking a closer look at the development process of prototypical applications we reveal that putting a functional and operable sensor network in place is currently an art relying on many soft factors that are hard to control/predict. We further discuss related and own work in the domain of wireless sensor networks that tries to close the gap between current proof-of-concept to real-world sensor networks. We argue that in order to fully understand the complexity of the matter from a system perspective it is necessary to not only model and/or simulate but also to implement and test on real world systems. A detailed example based on the BTnode platform shows how to account for prerequisites found in real devices.

Holger Karl: Transport Protocols and Quality of Service for Wireless Sensor Networks

The service obtained from "classical" networks like the Internet and from sensor networks differ. The Internet is supposed to transport independent byte streams and intermediate nodes do not know more. In a sensor network the nodes collaborate and interact with the environment, the nodes know the data they carry. A key requirement is reliability. In sensor networks reliability refers not only to the eventual delivery of data

packets (transport reliability), but also to the ability to detect physical phenomena in the first place. The coverage of a sensor network is thus an important consideration. This talk discusses protocols and approaches to deal with reliability in a sensor network; we refer to these somewhat sloppily as transport protocols. These protocols are not "cleanly" placed on top of some network layer protocol. Instead, the unique constraints of sensor networks call for careful cross-layer design.

Koen Langendoen: Energy-Efficient Medium Access Control

In contrast to typical WLAN designs, which optimize for latency, throughput and fairness, WSN-specific MAC protocols focus on energy consumption and memory footprint. Impressive energy savings can be obtained by putting the radio into sleep mode for long periods of time, and a wide range of new MAC protocols have been proposed in the last few years.

This tutorial surveys about 20 WSN-specific MAC protocols and classifies them according to three key issues: number of used channels, degree of organization, and notification mechanism. Four MAC protocols (S-MAC, T-MAC, Low-power listening and LMAC) will be studied in depth, including a head-to-head comparison on a common simulation framework. The tutorial concludes with a number of generic guidelines for energy-efficient MAC design.

Koen Langendoen: Distributed Localization Algorithms

This tutorial studies the problem of determining the node locations in ad-hoc sensor networks. We compare three distributed localization algorithms (Ad-hoc positioning, Robust positioning, and N-hop multilateration) on a single simulation platform. The algorithms share a common, three-phase structure: 1) determine node-anchor distances, 2) compute node positions, and 3) optionally refine the positions through an iterative procedure. We present a detailed analysis comparing the various alternatives for each phase, as well as a head-to-head comparison of the complete algorithms.

Koen Langendoen: Experiences from a Pilot Deployment in Precision Agriculture

This presentation is about experience with a real-world deployment of sensor networks for precision agriculture.

Marc Langheinrich: Privacy Aspects of Wireless Sensor Networks

Wireless sensor networks exemplify for many the grave threats inherent in ubiquitous computing, namely the comprehensive and invisible monitoring of our everyday lives. In my lecture I want to summarize the concept of personal privacy and its legal realities today, before moving on to illustrate the implications of widespread sensor networks deployment and discuss possible technical and social remedies.

Pedro J. Marron: Middleware Approaches for Wireless Sensor Networks

The increase in the complexity of application scenarios and the heterogeneity of available hardware for sensor networks have led to the development of a variety of middleware approaches that aim at providing the user with the right level of

abstraction for the underlying system. In this lecture, we will discuss the different types of middleware approaches available today and dwell in more depth into some of the more representative examples of each class, learning in the process how these systems deal with the typical characteristics of sensor networks.

Friedemann Mattern: Technologies for Smart Everyday Objects

The prospects of a world full of of smart things that "talk" to each other and that are able to communicate with us are fascinating, leading to many new applications and opportunities. However, we are moving only gradually towards this vision - much progress in computer science, communications engineering, material science and other research domains is necessary to render the vision of smart objects economically feasible and to overcome current technological hurdles.

In our presentation we will first take a broader view and identify some long-term technological trends which - by extrapolation - give us some hints on what to expect in the future in areas such as communication, computing, localization, and remote identification. We shall then take a closer look at some technologies (e.g., RFID). We will also discuss possible applications for cooperating everyday objects and try to analyze the social consequences of a world that is populated by smart things.

Joe Polastre and Rob Szewczyk: Introduction to TinyOS and Mote Experimentation

In this lecture, we give an overview of TinyOS, the Tmote sky hardware platform, and basics about how to use these technologies to implement sensor network applications.

Kay Römer: Time Synchronization for Sensor Networks

Time synchronization is a fundamental service in sensor networks, for example, to merge sensor data from different sensor nodes, or to coordinate sensor nodes for access to the communication channel. In this lecture we discuss fundamental challenges and approaches for time synchronization in sensor networks. We also present and discuss concrete synchronization algorithms used in sensor networks.

Albrecht Schmidt: From Sensors to Context

Building sensor network applications and smart objects is inherently connected to building systems that sense phenomena in the real world. In the lecture an overview of sensors commonly used and their properties will be given. To create meaningful information in the application domain raw sensor information is processed and abstracted. Mechanisms and methods for relating sensor information to context and situations will be shown. Additionally general problems that are associated with sensing context will be addressed.

Albrecht Schmidt: Embedded Interaction

Challenges for creating objects and systems that detect interaction and react appropriately are at the center of this lecture. Often interaction with augmented objects is implicit and closely connected to a task or action the user is doing in his or her non-computational environment. In this lecture selected models for interaction with

smart objects and intelligent environments will be discussed. Basic design principles, guidelines, tools, and methods for creating interactive systems on top of sensor and actuator systems will be presented.

Albrecht Schmidt: Videos and Exercise on Novel User Interfaces

In recent years different novel user interfaces that use embedded sensors and actuators have been built and published. Often research videos are used as a method to communicate the main concepts and findings to the research community. In this session selected videos will be shown and discussed. This aims to provide an overview of novel interactive systems, with a particular focus on sensor based user interfaces, smart objects, and tangible user interfaces. Additionally this session will show how videos can be used as an efficient form for presenting research results. After the session a practical exercise in making a concept video using still images will be offered.

5.2 Participants' Workshop

As part of the online application process, each applicant could indicate an interest to present his or her work. If interested, an abstract of the proposed talk had to be submitted. 34 of the 60 participants expressed an interest. Based on the abstracts, 23 participants were selected to actually give a 15 minutes presentation at the participants' workshop. Details about these talks can be found at [2].

5.3 TinyOS Hands-On Tutorial

Rob Szewczyk and Joe Polastre – core developers of the TinyOS operating system and co-founders of Moteiv Corp. (a leading sensor node manufacturer) – delivered a full-day hands-on tutorial about programming sensor networks. To maximize interactivity, the tutorial was given twice for about 25 participants each. Groups of two to three participants were formed. Each group received several Telos Sky Motes for experimentation. The tutorial covered building and deploying a single hop sensor network, enabling wireless sensor networking, as well as data collection and visualization. Details about the tutorial can be found at [5].

5.4 Application Competition

Based on an initiative of the project task "visions for innovative applications", an application competition was run at the summer school, where participants could submit their ideas about applications of smart objects and wireless sensor networks 10 years from now. Each submission should briefly describe the application idea, technical requirements, and social implications. We received a total of 28 submission.

For the evaluation, a committee was formed consisting of the lecturers. Each submission was read by at least two committee members and rated according to originality of concept and vision, innovation and technical progress, impact, and time frame. After reviewing the submissions, the committee met to select the two best submissions.

The authors of these two submissions were requested to spontaneously give a 5 minute presentation of their idea in front of the participants. Eventually, the participants could vote for their favorite. The first price was won by Zinaida Benenson, RWTH Aachen, Germany, for her submission entitled “Small Child Care”. The second price was given to Matthias Gauger, Univ. Stuttgart, Germany for his submission entitled “Sensor Pearls”. Funded by the project, the two winners were gifted Apple iPods. Details about the application competition can be found at [3].

The submissions received as part of this activity will be further evaluated by the project task “visions for innovative applications”.

5.5 Excursion and Social Activities

Half a day was devoted to an excursion, which featured a river cruise on the river Saar, a hike in a wine-growing district at the border triangle France, Germany, Luxembourg, and a dinner and wine tasting at a local winery. Apart from this excursion, the schedule included some leisure time for socializing.

6 Conclusions

Overall, the summer school can be considered very successful. We could attract expert lecturers from the US and Europe, and received an overwhelming number of applications from all over the world. Individual feedback from numerous participants after the summer school indicates that the program was very interesting and helpful. Several students noted the particular value of the hands-on part of the school, namely the TinyOS tutorial.

As indicated by the large number of applications, there is a clear need for such summer school events. Hence, we are currently planning a similar school for 2007.

References

[1] List of participants. www.vs.inf.ethz.ch/events/dag2005/participants.html.

[2] Participants’ workshop. www.vs.inf.ethz.ch/events/dag2005/program/ws.html.

[3] Results of the application competition. www.vs.inf.ethz.ch/events/dag2005/program/lectures/roemer-appcomp-2.pdf.

[4] Schedule. www.vs.inf.ethz.ch/events/dag2005/program/schedule.html.

[5] TinyOS hands-on tutorial. www.moteiv.com/training.