SEVENTH FRAMEWORK PROGRAMME
THEME 3
Information and Communication Technologies

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Deliverable D5.5:

Final Report on Dissemination and Joint Research Activities

Project acronym: WISEBED
Project full title: Wireless Sensor Network Testbeds
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Contents

1 Introduction

This document contains the report on Deliverable D5.5 of the European project WISEBED. It is the final report on dissemination and joint research activities after the 36 months of the project and therefore summarizes all events and activities of the third year conducted in WP5.

In the course of the third year of WISEBED, a lot of progress could be observed with respect to the activities started in the first and second year. This is documented by the technical progress as reported in the respective deliverables and by a number of publications on important conferences.

Many of these achievements are a result of collaborations between the different WISEBED partners. These joint research activities include quickly organized phone / Skype / Bravis conferences, workshops organized by some partner, and bigger activities such as schools. In addition, members of WISEBED have been active in participating in a variety of activities of the FIRE coordination actions.

2 Web Portal

The Web Portal is actively maintained and updated to reflect the project's progress and the RTD results. This includes the main site (http://www.wisebed.eu), the Wiki and the Wiselib site (http://www.wiselib.org).

3 Publications

Partners	Title	Event	Ref.
UZL	Making Wireless Sensor Network Simulators Cooperate	Seventh ACM International Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks (ACM PE-WASUN 2010)	[25]
UZL	Experimentalumgebungen für das Internet der Dinge: Überblick, Taxonomie und praktische Nutzung	PIK – Praxis der Informationsverarbeitung und Kommunikation	[28]
CTI, TUD	Post-Processing in Wireless Sensor Networks: Benchmarking Sensor Trace Files	7th ACM workshop on Performance evaluation of wireless ad hoc, sensor, and ubiquitous networks	[11]
CTI, TUD	Post-processing in Wireless Sensor Networks: Benchmarking Sensor Trace Files for In-network Data Aggregation	Journal of Network and Computer Applications	[33]
UZL, TUBS	Topology Virtualization for Wireless Sensor Network Testbeds	The 6th International ICST Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities, Berlin, Germany, 2010	[10]

Partners	Title	Event	Ref.
ULANC	The Lorien dynamic component based OS	SenSys '10 Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems	[31]
ULANC	A comparison of static and dynamic component models for Wireless Sensor Networks	CONET 2010: Proceedings of the 1st International Workshop on Networks of Cooperating Objects	[30]
ULANC, UBERN	Towards Virtual Mobility Support in a Federated Testbed for Wireless Sensor Networks	6th Workshop on Wireless and Mobile Ad-Hoc Networks - WMAN 2011	[13]
ULANC	An overview of two wireless sensor network testbed projects and their extension into the future	Visions of Future Generation Networks (EuroView2010)	[15]
TUBS	Using a Sensor Network to Enhance a Standardized Medical Test (Demo)	8th European Conference on Wireless Sensor Networks (EWSN 11)	[9]
TUBS	Simultaneous Event Execution in Heterogeneous Wireless Sensor Networks	Journal of Networks, Academy Publisher (JNW)	[7]
TUBS	Hallway Monitoring: Distributed Data Processing with Wireless Sensor Networks	4th Workshop on Real-World Wireless Sensor Networks (REALWSN10)	[8]
TUBS, UZL	Bridging the Gap between Simulated Sensor Nodes and the Real World	4th Workshop on Real-World Wireless Sensor Networks (REALWSN10)	[6]
UPC, TUBS	A Protocol for Self-Synchronized Duty-Cycling in Sensor Networks: Generic Implementation in Wiselib	Proceedings of the 6th International Conference on Mobile Ad-hoc and Sensor Networks (MSN10)	[19]
UZL	RoombaNet - Testbed for Mobile Networks	In Proceedings of the Workshops der wissenschaftlichen Konferenz Kommunikation in verteilten Systemen 2011 (WowKiVS 2011)	[18]
CTI	A Web Services-oriented Architecture for Integrating Small Programmable Objects in the Web of Things	3rd International Conference on Developments in eSystems Engineering (DeSE 2010)	[1]
CTI	Distributed Game-Theoretic Vertex Coloring	14th International Conference On Principles Of Distributed Systems	[14]
FUB	Optimizing Duty-Cycle for Delay and Energy Bound WSN Applications	24th IEEE international conference on advanced information networking and applications (AINA 2010)	[23]
FUB	Performance Evaluation of AREA-MAC: A Cross-Layer Perspective	The Fifth International Conference on Mobile Computing and Ubiquitous Networking (ICMU 2010)	[24]
UBERN	BEAM: A Burst-aware Energy-efficient Adaptive MAC protocol for Wireless Sensor Networks	Seventh International Conference on Networked Sensing Systems (INSS 2010)	[2]
UBERN	On the Accuracy of Software-Based Energy Estimation Techniques	European Conference on Wireless Sensor Networks (EWSN)	[20]
UBERN	Geschichte und Entwicklung des Internets	Informatik-Spektrum	[12]
UBERN	An evaluation of compression schemes for wireless networks	ICUMT 2010	[16]
UBERN	Real-World Experiences with the Maximally Traffic Adaptive Medium Access Control Protocol	Technical Report, Institute for Computer Science and Applied Mathematics, University of Bern	[27]
UNIGE	A constant factor algorithm for scheduling with linear powers	2010 International Conference on Intelligent Network and Computing (ICINC)	[35]
UNIGE	Algorithms for Scheduling with Power Control in Wireless Networks	1st International ICST Conference on Theory and Practice of Algorithm in (Computer) Systems (TAPAS), 2011	[34]
UNIGE, CTI	Interference minimization in wireless networks	3rd International Workshop on Wireless Network Algorithm and Theory. WiNA2010: 444-449 Hong Kong, China 2010	[4]
UNIGE	Data propagation with guaranteed delivery for mobile networks	9th International Symposium of Experimental Algorithms. SEA2010: 386-397, Ischia Island, Italy 2010	[3]

Partners	Title	Event	Ref.
UNIGE, CTI	Randomly roving agents in wireless sensor networks	International Conference on Intelligent Network and Computing. ICINC2010: Volume 1, 257-261, Kuala Lumpur, Malaysia 2010	[5]
UNIGE	Randomly roving agents in wireless sensor networks	Passive target tracking: Application with mobile devices using an indoors Future Internet testbed. Barcelona, Spain, June 27,2011, 1st IEEE Workshop on Holistic Building Intelligence through Sensing Systems (HOBSENSE11)	[22]
ULANC	Type-Safe Updating for Modular WSN Software	DCOSS'11 Systems and Applications	[29]

4 Technical Report Series

To guarantee the dissemination of results, an important issue has been to document standards, APIs, tools, and software produced by WISEBED by means of a technical report series. These reports are available of the project's web site http://www.wisebed.eu. The following table provides an overview of the new technical reports of the third year.

Partners	Title	TR-Name	Ref.
UNIGE	Virtual Raw Anchor Coordinates: Theory #1	2010	[21]
UPC	Topology control and synchronization algorithms in wireless sensor networks	2011	[26]
UPC	Highway construction algorithms in Wireless Sensor Networks	2011	[32]
UPC	Development and experimental testing and comparison of topology-control algorithms in sensor networks	2010	[17]

5 Invited Talks and Presentations

Presenter	Title	Event
Torsten Braun	Wireless Sensor Network Testbeds (WISEBED)	Fireweek, July 1, 2010, Barcelona
Torsten Braun	Design and Evaluation of Energy-Efficient Wireless Sensor Network Protocols	Colloquium, Computer Science Department, Purdue University, January 28, 2011
Torsten Braun	Design and Evaluation of Energy-Efficient Wireless Sensor Network Protocols	Colloquium, Universidade Federal de So Carlos, December 13, 2010
Torsten Braun	Design and Evaluation of Energy-Efficient Wireless Sensor Network Protocols	Colloquium, Universidade de So Paulo So Carlos, December 2, 2010
Torsten Braun	Design and Evaluation of an Adaptive and Energy-Efficient MAC Protocol for Wireless Sensor Networks	WiSe/DACS colloquium, University of Twente, Enschede, November 24, 2010
Torsten Braun	Design and Evaluation of an Adaptive and Energy-Efficient MAC Protocol for Wireless Sensor Networks	Seminar on Wireless Sensing, St. Andrews University, November 11, 2010
Torsten Braun	An Adaptive and Energy-efficient MAC Protocol for Wireless Sensor Networks	CISUC - Invited Lecture, University of Coimbra, June 14, 2010

Presenter	Title	Event
Torsten Braun	Performance Evaluation of Adaptive and Energy-efficient MAC Protocols for Wireless Sensor Networks	COST Action IC0804 on Energy Efficiency in Large Scale Distributed Systems, FG Wireless Networks Meeting, Coimbra, November 9, 2011
Stefan Fischer	Experimental Facilities for Wireless Sensor Networks - the European WISEBED approach	16th Asia-Pacicfic Conference on Communications, Auckland, New Zealand, November 2011
Stefan Fischer	Experimentalplattformen fr Sensornetze und Internet-of-Things-Technologien	VDI-VDE-Kongress, Leipzig, Germany, November 2010
Stefan Fischer	WISEBED - Experimental Facilities for Wireless Sensor	FIA Ghent, December 2010
Dennis Pfisterer	Experimental Research for the Internet of Things	Fronts General Assembly, Thessaloniki, Greece, 2011
Dennis Pfisterer	The WISEBED FIRE facility	SenZations Summer School, Rijeka, Croatia, 2010
Dennis Pfisterer	FIRE and Linked Data	Future Internet Assembly (FIA), Ghent, Belgium, 2010
Maria Blesa and Jordi Petit	WISEBED: Experiences with a wireless sensor network experimental facility	Internet of Things (IoT) Week, Barcelona, Spain, 2011

6 Training Activities

6.1 Informal ALBCOM seminars (UPC, May-June 2011)

The UPC site organized internal seminars about the Wiselib and the implementation of topology control algorithms, time synchronization algorithms and highway construction algorithms in it. More information about these seminars at the UPC site can be found at http://albcom.lsi.upc.edu, under the topic *Activities*.

6.2 Semester course on Advanced Topics in Distributed Computation

On both the fall semester of 2009-2010 and 2010-2011, UPC organized a semester course on Advanced Topics in Distributed Computation on the master and PhD on Computing program of the Software Department. The course was equally divided into theoretical and practical classes. On both sides, the course aimed at providing a modern view of the distributed computation concepts and technologies. On the theoretical part, the students were taught about content delivery networks, distributed objects and mobility, wide-area and multi-core computing, and Internet and networks economics. In the practical classes, the students were trained to use Sun SPOT sensors on the study, adaptation and implementation of different algorithms for some well-known problems like vertex coloring, clustering and leader election, among others. Parts of the practical classes were also dedicated to the study and use of Google Web Technologies. The course provided 6 ECTS-credits. More information to be

found under https://postgrau.upc.edu/computing/gimaster/courses/advanced-topics-in-distributed-computation and http://www.lsi.upc.edu/~mjblesa/teaching.html.

6.3 Semester Programming workshop on Sun SPOTs and LEGO Mindstorms

UPC organized a semester programming workshop on Sun SPOTs and LEGO Mindstorms on the spring semester of the course 2010-2011. The course had a few theoretical sessions dealing with basic topics related to sensor networks like protocols for the MAC layer, power management and mobility models. However, as a programming workshop, the course is mostly practical. The programming sessions were divided into two parts: the first one dedicated to program Sun SPOT sensors, and the second one dedicated to program LEGO Mindstorms robots. The aim of the course is to study and implement ways for communicating between these two technologies. The goal is to build and use a global wireless sensor network platform composed by static agents (the Sun SPOT motes) and dynamic agents (the LEGO robots, equipped or not with additional spots). By the end of the course, the students are supposed to design and develop a project in such a platform. This was a free-choice course and it provided 3 ECTS-credits. More information to be found under http://albcom.lsi.upc.edu/tp-sunlego/.

In order to test the feasibility of this course, and integrated with one annual competition organized by UPC, a dozen of gifted students made a 24-hours programming session where, among other tasks, they had to integrate Sun SPOTs and LEGO Mindstorms. Information of the event can be found at http://concurs.lsi.upc.edu/archives/896 (including a video downloadable at http://concurs.lsi.upc.edu/video/challenge-2011.hi.wmv).

6.4 Semester course on Mobile Communications

UBERN organized a semester course for M.Sc. students on mobile communications during the spring semester 2011. The course investigated wireless communication networks and protocols. In particular it addressed topics relevant to WISEBED such as energy-efficiency, routing, MAC protocols, security, applications etc. The students had to develop an application using mobile / wireless communication technologies. Students can earn 5 ECTS points. 15 students attend the course. http://rvs.unibe.ch/teaching/fs11_mok.html

6.5 Semester course on Wireless Sensor Networks

UNIGE organized a semester course for M.Sc. students on Wireless Sensor Networks (Algorithmes distribus pour rseaux de capteurs sans fils). The course covered algorithmical aspects of Wireless Sensor Networks, including algorithms developed in Wiselib for geographic routing, localization and target tracking. The students had to study and understand several recent publications that cover algorithmical aspects of WSN research. 15 students attend the course. ECTS points:4. http://tcs.unige.ch/doku.php/lectures/wsn

6.6 Semester course on Distributed Computing

The RACTI site organized a semester course on Distributed Computing II, in cooperation with the Computer Engineering and Informatics Department of the University of Patras, Patras, Greece during the spring semester of 2009-2010. The course covered special topics of distributed computing such as cooperation, fault tolerance, security and mobility. The students were trained to use Wiselib to implement distributed algorithms. The theoretical contents were complemented with a practical project that used the technological platform provided by coalesenses in the shape of iSense devices in combination with Wiselib. This was a free-choice course and it provided 3 ECTS-credits. 22 students attended the course. Lecturers: Ioannis Chatzigiannakis and Paul Spirakis. http://www.ceid.upatras.gr/courses/katanemhmena/ds2/

6.7 Semester course on Wireless Sensor Networks

TUD organized a semester course for M.Sc. students on Wireless Sensor Networks. The objective of the course was that participants acquire knowledge and understanding of Wireless Sensor Networks (WSNs), in particular, of how the inherent need for energy-efficient operation requires a new approach to distributed computing. The course adopts a seminar format in which participants have to familiarize themselves with a specific topic and present the state-of-the-art to other participants. As such, a participant is expected to read several papers published in recent conference proceedings and journals, prepare a presentation, and write a short paper documenting his findings and analysis of the selected works and incorporating any feedback from the audience. In addition, the course provides a mandatory hands-on labwork in which the the participants are requested to write an implementation of the Collection Tree Protocol, which is then deployed on actual hardware utilizing the WISEBED infrastructure. This was a free-choice course and providing 5 ECTS. 18 students attended the course. Lectures: Koen Langendoen, Niels Brouwers, Ste-

fan Dulman, Kavitha Muthukrishnan, Andrei Pruteanu and Matthias Woehrle. http://www.st.ewi.tudelft.nl/~koen/in4316/

6.8 Programming Course: Introduction into Programming using Sensor Networks

UBERN developed an introductory course for introducing fundamentals of programming to high-school students. The course includes basic knowledge like function definition and invocation, loops, working with recursion, timers, but also teaches basic communication schemes used in wireless sensor networks. The course was held 3 times on the 6th of June 2010, 3 times on the 28th of June 2010 and 3 times on the 3rd of May 2011. It will be held another 2 times in the end of June 2011. UBERN utilized the UBERN WISEBED testbed for this course.

6.9 Programming Course: Programming Wireless Sensor Network

FUB developed a 6 ECTS-credits course for introducing WSN programming fundementals to students. In this course, students got an introduction into the programming of distributed embedded systems, using the MSB-A2 Wireless Sensor Node as experimentation platform. Participants also learned how to use embedded software development environments and how to take advantage of the hardware's capabilities including wireless data communication, while always keeping an eye on energy consumption and resource usage. Moreover, the DES-Testbed at FUB was also utilized for this course. The course was taught in the winter semester 2010/11. http://cst.mi.fu-berlin.de/teaching/WS1011/19579-P-PDS/index.html

6.10 Semester Course on Future Internet Technologies

As part of the lecture on Future Internet Technologies (http://www.itm.uni-luebeck.de/teaching/ss11/fit/), WISEBED technologies are taught and used for the accompanying exercises.

6.11 Diploma thesis: Evaluation of Wiselib as a Routing Framework for WSN

A diploma student, Rami Akkad, at FUB has started a diploma thesis on "*Evaluation of Wiselib as a Routing Framework for WSN*". The supervisor of the thesis is Mesut Gnes and Oliver Hahm. The aim of this thesis is to evaluate Wiselib routing framework for routing in wireless sensor nodes. (https://des-testbed.net/content/routing-framework-wsn)

6.12 SPITFIRE School (Braunschweig - October 11-13, 2010)

From October 11 to 13, 2010, we held a Winter School in Braunschweig. The school was divided into two parts: The Wiselib School on Monday and Tuesday, and the Spitfire Semantics Workshop on Wednesday. The goal was to introduce the Wiselib to the attendees, and to provide an overview of the Semantic Web vision.

The attendees were from several European projects: SPITFIRE, WISEBED, FRONTS, and SmartSantander. The program of the Wiselib school consisted of technical presentations and hands-on sessions. The School was organized along the following schedule:

Monday

- Introduction to Wiselib: Basic concepts and design aspects of the Wiselib, setting up the VMWare Image and compiling first Wiselib application
- Wiselib programming basics: Introduction into heterogeneity, provided generic data structures

Tuesday

- Advanced Wiselib programming: Usage of algorithms, combining algorithms into higher-level systems
- Wiselib internals: Insight into algorithm development, internals of platform abstraction

Wednesday

- The Semantic Web
- Distributed querying on the Semantic Web
- The Semantic Web and Sensors

7 Joint Research Activities (WISEBED Internal)

7.1 WISEBED Technical Meeting (Lübeck, March 21-23, 2011)

Within this 3-day technical meeting in Lübeck the focus was to finalize implementations of all WP2 parts, do integration tests and try federation of all sites.

The desired outcomes of the meeting are:

- Testing interoperability of the different iWSN, SNAA, RS implementations from all partners.
- Set up a joint federated experiment spanning multiple sites using virtual links.
- Create a proposal of what will be demonstrated during the final review.

7.2 Visit: UPC at TUBS (Braunschweig, July, 26-30, 2010)

Mr. Víctor López Ferrando from UPC visited TUBS from July 26-30 2010. The main purpose was to work on and re-factor parts of the Wiselib. The result was a more flexible design that enabled easier and more efficient algorithm combination. In addition, full documentation about the new design was added to the Wiselib Wiki.

7.3 Visit: UPC at TUBS (Barcelona, November, 17-19, 2010)

Mr. Hugo Hernández from UPC visited TUBS from November 17-19 2010. Apart from a talk by Mr. Hugo Hernández about his research, the main purpose was to work on an Wiselib algorithm implementation. In January 2010, UPC and TUBS ported a duty-cycling algorithm, developed by UPC, to the Wiselib. During this visit, Mr. Hugo Hernández and Mr. Tobias Baumgartner generalized their previous work, and adapted the algorithm to work on the TUBS' testbed (sensor floor).

7.4 Phone/Skype/Video Conferences

The partners have used a number of conferences using phone, Skype, video, and Bravis conferencing services to discuss important management and technical aspects. Due to the high number of conference calls and unbureaucratically setup chats, they are not listed here.

8 Joint Research Activities (WISEBED External, Coordination Actions)

8.1 Rector Gabriel Ferraté Library Meeting (Barcelona, January 13, 2011)

UPC had a meeting with the director of the UPC main library and the UPC responsible of energy preservation and sustainability of the campus buildings. The goal was collaboration with the WISEBED project, which includes the DEXMA industrial partner. The result is that the available sensor data gathered at the library is now available both as WiseML data set and a web service offering continuous readings in WiseML, see http://albcom.lsi.upc.edu/wisebed/?cmd=biblio.

8.2 SmartSantander Development Meeting (Lübeck, April 4-8, 2011)

The goal of the SmartSantander development meeting was to identify new requirements of the SmartSantander testbed, which are not yet possible with the WISEBED APIs and software implementations and to define a timeline for the integration process.

8.3 Collserola Park Consortium Meeting (Barcelona, April 8, 2011)

The UPC site has continued its collaboration with the Collserola Park Consortium in Barcelona, because of the interest of the later ones in the deployment of a sensor network in the Collserola Park. The Collserola Park is a protected natural area in the metropolitan area of Barcelona. The area of deployment would be a valley of about three square kilometers that is not very frequented by the public. Members of the UPC site had a couple of meetings with members of the Can Balasc Biological Station (representing the Collserola Park Consortium) to analyze the viability of the idea. A sensor network would benefit both the biologists working in Collserola Park and the WISEBED project, since it would allow us to have fine-grained real ambient data and real input information for testing our tracking and monitoring algorithms. Due to the rudimentary techniques that the biologist are using nowadays for monitoring the environment and keeping track of the wildlife, a deployment of a wireless sensor network with tracking and monitoring algorithms implemented on it, would represent an incredible improvement in their daily working procedures. Finally, the platform to be deployed was decided and we expect to finish the project by the end of the year.

8.4 Testbed users and collaborations

Several international organizations have asked for access to UBERN's Wisebed testbed site. These include University of Sao Paulo at Sao Carlos, Federal University of Sao Carlos, Federal University of Para (all Brazil), Swedish Institute of Computer Science, University of Cambridge (UK). University of Agder (Norway). Users of these organizations have been using UBERN's testbed site. Also partners from the European project FRONTS (project number 215270) have used extensively multiple Wisebed testbed sites for experimentally testing their software components. More specifically partners from: Ben-Gurion University of the Negev (BGU), Universita di Roma "La Sapienza" (UDRLS), Universita degli Studi di Salerno (UNISA), Universitat Politecnica de Catalunya (UPC) and Wroclaw University of Technology (WROC) have used the (UNIGE's UZL's and CTI's) testbed sites.

8.4.1 TUD/CONET

Within the CONET project, TU Delft is collaborating with the TU Berlin to bridge the CONET Testbed Federation Platform with the WISEBED testbed API. With this, the WISEBED testbeds can be integrated within the CONET Testbed Federation Platform. Additionally, users of the WISEBED architecture will have access to the CONET Testbed Federation Platform and users of the CONET architecture have access to the WISEBED testbeds.

8.4.2 FUB/OPNEX

Within the EU project OPNEX, FU Berlin ran extensive experiments using their DES-Testbed to study the long term experimentation using different aspects of WSN, e.g. sensors, routing, energy consumption etc. The experiments ran were for a minimum duration of two months.

9 Collaboration with Industry

UZL maintains close links to the Coalesenses GmbH (http://www.coalesenses.com) and the TraDav GmbH (http://www.tradav.de). The coalesenses GmbH, which is also the manufacturer of our iSense nodes, actually uses parts of our testbed to evaluate protocols and to test new software prototypes and provides valuable feedback for the development of the WISEBED software platform. The collaboration with TraDav

GmbH is also very intense and results of many discussions with this logistics provider help us shaping and refining the offering of the WISEBED testbed.

TUD continues to actively collaborate with SOWNet Technologies B.V. (http://www.sownet.nl), who delivered the nodes for the new testbed. They joined forces to exchange knowledge, developing the TinyOS infrastructure for the testbed as well as collectivily develop a test platform for emulating sensors and injecting faults. In addition, SOWNet Technologies now sells complete ready-to-deploy sensor testbeds that can be directly integrated into the WISEBED architecture and produce output in WiseML format.

UPC continues his collaboration with the company DEXMA (http://www.dexmatech.com/). DEXMA is a young company that deploys wireless sensor networks and provides real-time localization services on strategic environments like agriculture, logistics, industry and the sanitary sector. As a result, DEXMA is interested in adding the WiseML standard to the formats in which they deliver their data.

In order to get more data on the monitoring of the UPC buildings, UPC has also started a similar collaboration with the company Emitools (http://www.emitools.com/) who is in charge of other sensor networks installed in other parts of the UPC campus.

UBERN has started an Eurostars project with DFRC AG (Switzerland) and Wellness Telecom (Spain) on Location-Based Analyzer. The goal is to develop sensor technology assisting to locate users carrying mobile devices using Bluetooth and WLAN technology[1].

[1] http://www.eurekatourism.eu/2011/01/dfrcs-location-based-analysis-project.html

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