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Information Society and Media Directorate – General

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SmartCoDe

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1 Introduction

This Deliverable gives a comprehensive overview of the publication activities of the SmartCoDe project. Altogether we have

- 13 Conference & journal publications
- A Springer Book
- Three workshops
- Several talks and other presentations at conferences, workshops and exhibitions.
- The participation in an on-going standardisation effort by the European Comission
- 4 PhD theses (on-going)
- 1 finished PhD thesis
- 1 Master thesis (on-going)
- 1 finished Master thesis
- An on-going bachelor thesis and a finished Bachelor project

We give the abstracts and/or links to the respective item where applicable.

Note: Prof. Grimm changed from the Vienna University of Technology (Austria) to the Kaiserslautern University of Technology (Germany) in May 2012. However, for simplicity, we list *all* his contributions to SmartCoDe as TUV in this document even if they were after April 2012.

2 Publications

In this Section we give an overview of the Journal and Conference publications done in SmartCoDe.

2.1 *INDIN 2010*

A Smartcard based approach for a secure energy management node architecture (8th IEEE International Conference on Industrial Informatics, Osaka, Japan, 13-16 July 2010.)

Authors:

Mahlknecht, Stefan; Damm, Markus; Grimm, Christoph; (TUV)

Abstract:

Future buildings and neighbourhoods are expected to combine a manifold of Energy using Products (“EuP”) ranging from electrical lighting to HVAC with locally available renewable energy sources and energy storages. Until now, advanced techniques for energy management are not yet applicable in an economically reasonable way in the smaller entities like in energy-positive buildings and neighbourhoods. The EC FP7 project SmartCoDe is trying to enable a low cost application for demand side management and smart metering in private homes and small commercial buildings and neighbourhoods. A new system architecture for secure wireless energy management nodes that specifically considers the requirements of Energy using Products in homes/offices is developed. The focus is the development of an inexpensive wireless System in Package (SiP) solution that allows to build up a fine grained infrastructure of wireless connected Energy using Products. The proposed architecture is a smartcard based solution which is scalable, highly secure, cheap and does not complicate node integration.

Links:

https://www.fp7-smartcode.eu/node/373

http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5549645&tag=1

2.2 *Smart Grids and Clean Power 2010*

Energy Forecasting for Distributed Generation in Local Energy Neighbourhoods (Smart Grids and Clean Power, Cambridge, England, Murray Edwards College, 24-25 June 2010)

Author:

Berténi, Tamás; (QR)

Abstract:

The SmartCoDe project is looking at the smart integration of local energy neighbourhoods and the grid, including local energy production (LEP) by small-scale distributed energy generation technologies such as photo-voltaic or wind energy. Including LEPs into the smart-grid integration equation makes the overall scenario more attractive. The ability to predict site-specific energy yield from the LEPs can translate into increased value for the building owner. Ultimately, it is hoped that energy forecasting can provide a route for greater degree of adoption of otherwise volatile renewable energy sources.

For purposes of demonstration, SmartCoDe is considering the specific example of a small-scale wind turbine. While the capability of predicting wind-resource dependant energy yield is becoming more common for large wind farms, the challenges are significantly increased for small-scale turbines located low in the boundary layer in areas of increased terrain roughness. The problem is compounded because these installations can rarely afford the time or resource to conduct a proper wind resource assessment.

Broadly speaking, the forecasting can be categorised by the time period: long-term energy forecasting is about predicting the energy performance over the course of years or even the lifetime of the product. This involves understanding of the turbine performance as well as the local wind. The approach taken is to combine available macro-scale wind resource maps with short-period measurements of the proposed installation site. Key measured characteristics of the wind resource can be used as a basis to correct for local variation. A properly constructed energy model can then be used to predict the resulting energy yield.

Meanwhile, short-term forecasting, on the order of tens of minutes or hours, can play a valuable role in smart grid integration strategies. The forecast of expected energy yields over a range of periods (bounded by measures of confidence) can form part of a local energy energy management approach together with demand side management of local energy using products and, optionally, local energy storage. Short-term forecasting builds upon the long-term forecasting by including statistical methods built on a database of local historical performance.

This talk presents on-going research in the area of energy forecasting for small-scale turbines, including correcting macro-scale wind resource for local micro-scale effects, energy yield modelling of systems, and statistical methods for predicting short-term energy yield.

Links:

https://www.fp7-smartcode.eu/node/361

2.3 *IEEE Robotics and Automation Magazine*

Communication aspects of robot-robot coordination for single task single robot wireless multi-hop networks (in "IEEE Robotics and Automation Magazine", ISSN: 1070-9932, published by IEEE Robotics and Automation Society)

Authors:

Ivan Mezei, Veljko Malbasa, and Ivan Stojmenovic (UNS and University of Ottawa, Canada)

Abstract:

Robots coordinate among themselves to select one of them to respond to an event reported to one of the robots, so that the communication cost of selecting the best robot, response time, and cost of performing the task are minimized. Existing solutions are either centralized, assuming a complete graph, or based on flooding with individual responses to a robot decision maker (simple auction

protocol), ignoring communication cost and response time bound. This article proposes auction aggregation protocols for task assignment in multi-hop wireless robot networks. A robot collector leads an auction and initiates a response tree construction by transmitting the search message. Each robot, after receiving the message, makes a decision on whether to retransmit a search message, based on the estimated response cost of its robots, up to k-hops away. Robots wait to receive the bids from its children in the search tree, then aggregates responses by selecting the best bid, and forward it back toward the robot collector (auctioning robot). When distance is used as the sole cost metrics, the traversal aggregation algorithm (RFT – routing toward the event with the traversal of the face containing the event) can be applied and is an optimal solution. Several other protocols and their enhancements are also described here.

2.4 *ISWC 2011*

Energy forecasting for distributed generation in local energy neighbourhoods (International Small Wind Conference, Gateshead, UK April 5-6)

Authors: Tamas Bertenyi, Tom Young and Chris Uglow (all QR)

Abstract:

The SmartCoDe project is looking at the smart integration of local energy neighbourhoods and the grid, including local energy production (LEP) by small-scale distributed energy generation technologies such as photo-voltaic or wind energy. Including LEPs into the smart-grid integration equation makes the overall scenario more attractive. The ability to predict site-specfic energy yield from the LEPs can translate into increased value for the building owner. Ultimately, it is hoped that energy forecasting can provide a route for greater degree of adoption of otherwise volatile renewable energy sources.

For purposes of demonstration, SmartCoDe is considering the specific example of a small-scale wind turbine. While the capability of predicting wind-resource dependant energy yield is becoming more common for large wind farms, the challenges are significantly increased for small-scale turbines located low in the boundary layer in areas of increased terrain roughness. The problem is compounded because these installations can rarely afford the time or resource to conduct a proper wind resource assessment.

Broadly speaking, the forecasting can be categorised by the time period: long-term energy forecasting is about predicting the energy performance over the course of years or even the lifetime of the product. This involves understanding of the turbine performance as well as the local wind. The approach taken is to combine available macro-scale wind resource maps with short-period measurements of the proposed installation site. Key measured characteristics of the wind resource can be used as a basis to correct for local variation. A properly constructed energy model can then be used to predict the resulting energy yield.

Meanwhile, short-term forecasting, on the order of tens of minutes or hours, can play a valuable role in smart grid integration strategies. The forecast of expected energy yields over a range of periods (bounded by measures of confidence) can form part of a local energy energy management approach together with demand side management of local energy using products and, optionally, local energy storage. Short-term forecasting builds upon the long-term forecasting by including statistical methods built on a database of local historical performance.

This talk presents on-going research in the area of energy forecasting for small-scale turbines, including correcting macro-scale wind resource for local micro-scale effects, energy yield modelling of systems, and statistical methods for predicting short-term energy yield.

Links:

http://www.renewable-uk.com/events/small-wind-conference/index.html

2.5 *Eletricidade Moderna 2011*

Gerenciamento de energia e medição com base em cartão inteligente (publication in the magazine Eletricidade Moderna, Issue 08-2011, Brazil)

Authors:

Mahlknecht, Stefan; Damm, Markus; Grimm, Christoph (all TUV)

Abstract:

As técnicas avançadas para o gerenciamento de energia ainda não são economicamente viáveis em edificações menores, com energia positiva - isto é, que produzem mais energia do que consomem. O objetivo do projeto “SmartCoDe” é justamente viabilizar o gerenciamento pelo lado da demanda e a medição inteligente em residências e pequenas edificações comerciais. A arquitetura proposta é baseada em cartões inteligentes.

Note:

This is a translation of paper 2.1 (Indin 2010) into Portuguese. The editors of the magazine Eletricidade Moderna read the paper and asked us to use a translated version of it. We also got such a request from them recently for paper 2.7 (CIB W078 – W102 2011), which we granted, but it has not been published yet.

From the publisher’s homepage: Published monthly since 1972, EM - ELETRICIDADE MODERNA is Brazil's leading magazine on electrical systems for buildings, industries and energy supply. EM has proved invaluable for keeping readers updated with practical information on applied engineering, electrical equipment, products and services, as well as technical standards and cutting edge technology.

Links:

http://www.arandanet.com.br/revistas/em/index2.html

2.6 *Smart Grid / Smart Metering 2011*

Security in Smart Grid Environment (Conference Smart grid/smart metering – trends in implementation of intelligent measuring systems in utilities. Expectations vs. reality in Slovakia, Bratislava, Slovakia, September 29, 2011)

Author: Juraj Hájek (ADO)

Abstract:

The gradual convergence of information and communication infrastructure with the electricity network represents an additional threat to the security and privacy.

Higher penetration of smart devices opens new opportunities to spread malware like viruses or worms. This paper discusses key security challenges for a smart grid system together with current customers preferences.

Link:

http://www.efocus.sk/white-papers/clanok/bezpecnost-v-prostredi-inteligentnych-elektroenergetickych-sieti/

2.7 *2nd workshop on EEBUILDINGS DATA MODELS at the CIB W078 – W102 2011*

An EuP classification for partially decentralized domestic energy management (2nd Workshop on eeBuildings Data Models, Sophia Antipolis, France, Oct. 26-28, 2011)

Authors: Christoph Grimm, Stefan Mahlknecht, Markus Damm (all TUV)

Abstract:

The general problem addressed in this paper is optimal utilisation of renewable energy resources by managing the demand of appliances in private neighbourhoods and small offices/businesses. The core idea is to use wireless sensor/actor nodes to control electrical appliances in a way that local renewable energy resources like wind energy and photo-voltaic are maximally exploited. Forecasts for the local renewable energy production are pre-processed by a central energy management unit which generates abstract cost functions. These cost functions might capture also other aspects like tariffs or load forecasts, and are then issued through the wireless network. The final decision making is then shifted to the sensor/actor nodes, and is based on these cost functions as well as the class of the appliance which is controlled. To this end, a classification of electrical appliances is presented which is suitable for the application scenario, and it is discussed how each class can be handled regarding energy management.

Links:

http://2011-cibw078-w102.cstb.fr/

2.8 *ISCAS 2011*

Cost Efficient Mains Powered Supply Concepts for Wireless Sensor Nodes (IEEE International Symposium on Circuits and System, Rio De Janeiro, Brasil, May 15-18, 2011)

Author: Franz Lukasch (TUV)

Abstract:

The general problem addressed in this paper is optimal utilisation of renewable energy resources by managing the demand of appliances in private neighbourhoods and small offices/businesses. The core idea is to use wireless sensor/actor nodes to control electrical appliances in a way that local renewable energy resources like wind energy and photo-voltaic are maximally exploited. Forecasts for the local renewable energy production are pre-processed by a central energy management unit which generates abstract cost functions. These cost functions might capture also other aspects like tariffs or load forecasts, and are then issued through the wireless network. The final decision making is then shifted to the sensor/actor nodes, and is based on these cost functions as well as the class of the appliance which is controlled. To this end, a classification of electrical appliances is presented which is suitable for the application scenario, and it is discussed how each class can be handled regarding energy management.

Links:

http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5937612&tag=1

2.9 *IEEE-PES ISGT Europe 2011*

A partially decentralized forecast-based Demand-Side-Management Approach (IEEE-PES Innovative Smart Grid Technologies Europe 2011, Manchester, United Kingdom, Dec 5-7, 2011)

Authors:

Markus Damm, Stefan Mahlknecht, Christoph Grimm (all TUV), Tamas Bertenyi Tom Young (all QR)

Abstract:

This paper presents a demand-side management approach for private homes and small businesses based on wireless sensor/actor nodes controlling appliances, taking into account available local

renewable energy resources like wind energy and photovoltaics. Forecasts for the local renewable energy production are preprocessed by a central energy management unit which generates abstract cost functions. The final decision making is then shifted to the sensor/actor nodes, and is based on these cost functions as well as the class of the appliance which is controlled. To this end, electrical appliances are classified appropriately. Also, an approach for wind turbine power generation is presented.

Links:

http://www.ieee-isgt-2011.eu/

2.10 *3rd workshop on EEBUILDINGS DATA MODELS at the ECPPM 2012*

A Simple Vocabulary for Semi-decentralised Management of Energy Demand in Households, (eWork and eBusiness in Architecture, Engineering and Construction, ECPPM 2012, Reykjavik, Iceland, July 25-27, 2012)

Authors:

Markus Damm, Stefan Mahlknecht, Christoph Grimm (all TUV)

Abstract:

This paper presents a demand-side management approach for electrical energy in households which can utilise locally available renewable energy resources like wind and photovoltaics. The concept which was developed gave rise to two kinds of vocabularies: The first one is a classification of household appliances which bundles appliances having similar interfaces, user interaction and demand side management opportunities.

In particular, the local control actions are the same for each appliance class. The second vocabulary is used for the communication between a central energy management unit and the appliances. Simple control signals are not sufficient here, since the energy management unit might need a lot of information about the specifics of the appliance and its current state of service. Therefore the EMU issues cost profiles for certain future time periods to be taken into account for the local control. We also give two examples on how these cost profiles are used in the case of schedulable and thermal services for local control planning.

Links:

http://ecppm.rabygg.is/

2.11 *FDL 2012*

Unified and Comprehensive Electronic System Level, Network and Physics Simulation for Wirelessly Networked Cyber Physical Systems

Authors:

Javier Moreno, Markus Damm, Jan Haase, Christoph Grimm (all TUV)

Abstract:

This paper presents a complete and comprehensive simulation of a Wireless Sensor Network (WSN), including an Electronic System Level (ESL) model of the nodes, a detailed network and radio propagation model and a model of the sensors interaction with the environment, based exclusively in SystemC and its extensions for Transaction Level Modeling (TLM) and Analog Mixed-Signal (AMS) design, with no need of co-simulation.

The simulator has been validated by using it to design a Cyber-Physical System (CPS) consisting of an energy management network and its application for controlling energy demand, in order to balance it and adjust it to the energy supply available from renewable energy sources.

Links:

http://www.ecsi.org/fdl

2.12 *IEEE-PES ISGT Europe 2012*

Shifting of Thermal and Schedulable Loads Based on Abstract Cost Profiles (IEEE-PES Innovative Smart Grid Technologies Europe 2012, Berlin, Germany, Oct 14-17, 2012)

Authors:

Markus Damm, Stefan Mahlknecht, Jan Haase, Christoph Grimm (all TUV), Milan Lukic, Veljko Malbasa (all UNS)

Abstract:

This paper presents a demand-side management approach based on cost profiles which are abstract in the sense that they not represent monetary costs, but aggregate information from several sources like tariffs, wind forecast or grid operator demand control signals. In particular, it is shown how these cost profiles are used for local control of thermal (e.g. freezers) and schedulable loads (e.g. washing machines).

Also, different variants for the global control in terms of protocols are discussed where a central energy management unit compiles these cost profiles depending not only on outside information, but also on load forecasts and load plans compiled locally at the appliances.

Links:

http://www.ieee-isgt-2012.eu/

2.13 **SEBUA-12**

Smart Energy Buildings and Neighbourhoods: Which Infrastructures, Which Platforms? (ICHMT International Symposium on Sustainable Energy in Buildings and Urban Areas October 14-20, 2012, Kusadasi, Turkey)

Authors:

Christoph Grimm, Stefan Mahlknecht, Markus Damm, Franz Lukasch (all TUV)

Abstract:

Management of electrical energy in buildings and environments enables a more efficient use of renewable energy sources that are located in its neighbourhood. For this purpose, IT infrastructure is required that networks appliances and that controls power consumption. The IT infrastructure is expected to be inexpensive, to consume low power, and to provide high security while being easy to deploy. Currently, no hardware/software platform fulfils these requirements. In this paper we give an overview of technologies and platforms to approach these goals. In particular, we summarize outcomes of the SmartCoDe Project.

Note:

This paper accompanied the keynote speech of Prof. Grimm at the SEBUA-12.

Links:

http://www.ichmt.org/sebua-12/images//final-program.pdf

3 Springer Book: Embedded Systems for Smart Appliances and Energy Management

Editors:

Christoph Grimm, Peter Neumann and Stefan Mahlknecht

Foreword (excerpt): Can Embedded Systems Reduce Carbon Dioxide Emissions?

The short answer to the question is “yes!” – provided that we can satisfy a key requirement: we must achieve the widespread deployment of intelligent, low-cost, distributed communications that operate down to the level of individual household and office appliances. To understand why we need such a communications infrastructure, we must first remind ourselves of the overall power generation challenge and its context.

Reducing carbon dioxide (CO_2) emissions is a global challenge. Clearly, lowcarbon/no-carbon renewable energy sources such as wind turbines and photovoltaics will play an important role in any future CO_2 reduction strategy. However, we operate under one non-negotiable constraint: the stability of the distribution grid is of primary importance. Consequently, the overall availability of electrical energy must match the overall consumption at all times. However, renewable energy production is volatile, so we must find a means to prevent this volatility from destabilising the grid. We must address such grid stability issues robustly if we are to avoid catastrophic failures such as the 2003 blackout in the Northeastern and Midwestern United States and in Ontario, Canada.

The solution to the problem of renewable energy volatility is intelligent management of both energy generation *and* its consumption, simultaneously. And we must ensure that energy consumption matches energy generation – the reverse of the *status quo* in industrialized countries today. This approach is already state-ofthe-art among large-scale energy consumers such as manufacturing industry. In contrast, small buildings and neighbourhoods have yet to adopt such an approach – and yet they consume approximately 30% of overall energy output and contribute approximately 20% to overall CO_2 emissions.

Until now, energy generation has very largely been centralized. However, renewable energy sources are becoming an increasingly important part of the overall energy generation mix. Consequently, the generation infrastructure will very rapidly evolve into a decentralized approach, with a huge number of small-scale generation facilities feeding local clusters of consumption facilities. The resulting increase in generation volatility clearly poses a stability risk to the grid. How do we solve this problem?

Information and Communication Technologies (ICT) are critical enabling mechanisms to handle these challenges. Using such technologies to link the energy generation facility with monitors/controllers embedded both in buildings and in individual household and office appliances enables the generation facility to know the magnitude and distribution of energy consumption in its local cluster, minute-by-minute. Without this real-time communication between energy generation, energy delivery and energy consumption entities, intelligent energy management is not possible – and the result would be energy grid instability, resulting in frequent blackouts.

Links:

http://dx.doi.org/10.1007/978-1-4419-8795-2

4 SmartCoDe Expert Cooperation workshops

The SmartCoDe project organized three workshops with international participation.

The first SmartCoDe Expert Cooperation workshop took place on Nov. 16, 2010, at Mercure Hotel, Vienna. It had 39 participants from 20 different companies and academic institutions. Three of the eight presentations were from external experts. Table 1 shows the workshop agenda. The full workshop proceedings as well as the video of the keynote presentation given by Prof. R. N. Nakicenovic are available online at: https://www.fp7-smartcode.eu/events/ecw2010.

Table 1 First *SmartCoDe Expert Cooperation Workshop Agenda*

Agenda

Start	Duration		Titel	Speaker	
8:30	1:00		Registration / Coffee		
9:30	0:10	edacentrum GmbH	Welcome	P. Neumann / Dr. C. Hansen	
9:40	0:45	Vienna University of Technology	**Global Energy Perspectives and the Role of New Technologies**	**Prof. Dr. N. Nakicenovic**	Keynote
10:25	0:30	Quiet Revolution Ltd.	**Energy Forecasting for Distributed Generation in Local Energy Neighbourhoods**	Dr. T. Bertényi	Project Paper
10:55	0:30		Coffee		
11:25	0:30	Austrian Institute of Technology	**Building Simulation and Control**	**Dr. G. Zucker**	Invited Paper
11:55	0:30	ennovatis GmbH	**Smart Energy Management**	**Prof. Dr. F. Schmidt**	Project Paper
12:25	1:20		Lunch / Coffee		
13:45	0:45	Next Energy	**Electric Energy Storage in Smart Buildings**	**Dr.-Ing. B. Lenz**	Keynote
14:30	0:30	Ardaco, s.a.	**Security Considerations for SmartCoDe Network**	J. Hájek	Project Paper
15:00	0:30		Coffee		
15:30	0:30	Vienna University of Technology	**An Architecture for Energy Management in Smart Appliances**	Prof. Dr. C. Grimm	Project Paper
16:00	0:30	Infineon Technologies Austria AG	SmartCoDe - On the Way to a Miniaturised Wireless Sensor Node for Monitoring and Control of Appliances	T. Herndl	Project Paper
16:30	0:10	Closing Words		Dr. C. Hansen	
16:40	0:00	End			

The second workshop was on Oct. 12, 2011, again at the Mercure Hotel, Vienna with 33 participants from 18 different companies and academic institutions. Three of the eight presentations were from external experts. Table 2 shows the workshop agenda.

Table 2 Second *SmartCoDe Expert Cooperation Workshop Agenda*

Agenda

Start	Duration		Titel	Speaker	
8:30	1:00		Registration / Coffee		
9:30	0:10	edacentrum GmbH	Welcome	P. Neumann / Dr. C. Pröfrock	
9:40	0:45	The University of Edinburgh	**Energy Management in Households and Built Environments: Assessment of PV and Wind Micro-generation Technologies**	**Dr. S. Djokic**	Invited Paper
10:25	0:30	Quiet Revolution Ltd.	Wind Energy Forecasting for Distributed Generation	Dr. T. Berténvi	Project Paper
10:55	0:30		Coffee Break		
11:25	0:30	Saarland University	**Short-term solar energy forecasting for network stability**	**Prof Dr. H. Hermanns**	Invited Paper
11:55	0:30	Vienna University of Technology	**Categorizing Energy using Products (EuPs) for partially decentralised Energy Management**	**M. Damm**	Project Paper
12:25	1:20		Lunch		
13:45	0:30	Tridonic AG	The SmartCoDe Node Functional Prototype	E. Holleis	Project Paper
14:15	0:30	Solintel	**Sounds for Energy-Efficient Buildings**	A. Barona	Invited Paper
14:45	0:30		Coffee Break		
15:15	0:45	University of Novi Sad	**The SmartCoDe Demonstrator - a testbed to evaluate energy management**	**Prof. Dr. V. Malbasa**	Project Paper
16:00	0:30	Infineon Technologies Austria AG	SmartCoDe - System-in-Package Considerations	T. Herndl	Project Paper
16:30	0:10	Closing Words		Dr. C. Pröfrock	
16:40		End			

During the second SmartCoDe review in Brussels in April 2012 it was suggested that instead of organizing a third dedicated workshop the project should target to cooperate with other events to foster dissemination of the results.

As a result of this suggestion SmartCoDe organized a special session on “Energy Management in Buildings” as part of the International Symposium on Sustainable Energy in Buildings and Urban Areas (SEBUA) 2012 from October 14-20 in Kusadasi, Turkey. The special SmartCoDe session was chaired by SmartCoDe project coordinator Peter Neumann. Also, Prof. Grimm from TUV gave a **keynote** at the conference the day before (see Section 2.13). The special session featured two talks from project partners and a talk by an associated partner:

- **Prof. Dr. Holger Hermanns, Saarland University:** Formal behavioural models of power grids with a substantial share of photovoltaic micro generation *(session keynote)*

  Abstract:
  Simulation studies show that the behaviour of the thus far installed hundreds of thousands of controllers on German rooftops might altogether induce severe frequency oscillations. This phenomenon is indeed recognized by the German Federal Network Agency responsible for overseeing the national power grids, and new regulations are currently being put in place to counter this phenomenon.

  We study the current proposal, and compare it with a set of alternative approaches that take up and combine ideas from communication protocol design, such as additive-increase/multiplicative decrease known from TCP, and exponential backoff used in CSMA variations. We classify these alternatives with respect to their availability and goodput.

- **Thomas Herndl, Infineon Technologies Austria AG:** Highly integrated microelectronic devices for energy management

  Abstract:
  This presentation concentrates on hardware integration issues for a SmartCoDe wireless node, which is supposed to provide functionality for wireless communication and power metering & control of appliances with the aim to enable the application of demand side management and smart metering in private and small commercial buildings and neighbourhoods. In order to address a new and potentially huge market in homes, business- and public buildings and offices these services must come for very little additional costs.

  Due to the number of hardware modules that need to be installed, one significant cost item of the total system costs (aside of maintenance-, operational- and service costs) are the hardware purchase and installation costs. Nowadays purchasable modules are bulky and expensive. While minimization of installation costs is addressed by providing a wireless communication interface, which even allows for retrofit without structural changes, for a successful future roll-out scenario one must additionally strive for cutting the hardware purchase costs down to an affordable level for everyone. For that reason highly integrated circuits and effective heterogeneous assembly-, packaging- and manufacturing technologies are discussed.

- **Roland Kopetzky, CEO ennovatis GmbH:** From theory to practice: Real world demonstrators for smart grid applications

  Abstract:
  A smart grid is an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. In order to evaluate new methods and to prove the efficiency of different algorithms, it is necessary to set up a demonstration site that allows the integration of local energy providers (LEP) and energy-using products (EuP) under real world conditions.

  The presentation will show with a specific focus on energy management optimization strategies and the verification of the optimized results, how this goal was addressed at the demonstration sites at Almersberg and Buchberg in Austria.

5 Further dissemination activities

This Section lists the dissemination activities not directly linked to a publication.

5.1 *Presentations*

- SmartCoDe partner ECN presented at the edaWorkshop in Hannover, Germany, 4.-5. May 2010.
- SmartCoDe partner ENO presented at the European Workshop on ICT for Energy-Efficiency in Buildings on June 8 in Dublin, initiated by the EC FP7 Call4 projects Fiemser, EnPROVE, and EnergyWarden (http://www.csi.ucd.ie/content/european-workshop-ict-energy-efficiency-buildings), the slides are available at https://www.fp7-smartcode.eu/node/376.
- SmartCoDe partner QR presented at Decentralised Small Scale Wind Energy on June 24, 25 at SmartGrid and CleanPower 2010, Cambridge, UK (http://bit.ly/cleanpower), the slides are available at http://www.cambridgeinvestmentresearch.com/uploads/Bertenyi.pdf and https://www.fp7-smartcode.eu/node/367.
- SmartCoDe project partner TA presented at Forschungszentrum Telekommunikation Wien GmbH (FTW), Energy WS for Industry and Academy, Nov. 8, 2010, “Out of the Lab, Into the World – Challenges for Wireless Building Automation Security”
- Prof. Grimm from SmartCoDe project partner TUV gave a talk at the edaWorkshop12 held in Hannover from May 8th-9th with the title “SmartCoDe: Design of a Microelectronic Platform for Smart Appliances Or: How EDA Reduces Carbon Dioxide Emissions”.

5.2 *Exhibitions booths and posters*

- SmartCoDe partner ECN and TUV presented at the Design Automation & Test in Europe Conference (DATE 2010) in Dresden, Germany, at the University Booth (http://www.date-conference.com/group/exhibition/u-booth)
- SmartCoDe project partner QR presented a poster promoting SmartCoDe research at the “Annual Symposium of the Energy Efficient Cities Initiative” at University of Cambridge on 27 September 2010.
- SmartCoDe project partner QR presented at the poster session of the *European Wind Energy Conference, EWEA 2011*; Brussels Expo, Brussels, Belgium, 14-17 March 2011, poster title: “*Energy forecasting for distributed generation in local energy neighbourhoods*”
- SmartCode partner ECN presented two posters at the *edaWorkshop*, May 10-12, 2011, Dresden, Germany
- The SmartCoDe project has been chosen by the European Commission for exhibiting in the context of the very prestigious and high profile event CEBIT in Hannover on 6-10 March 2012 (http://www.cebit.de/home). SmartCoDe contributed to a stand by the ICT4E2B Forum Project within the "Smarter Living" area of the exhibition.

5.3 *Standardisation efforts*

Prof. Grimm from SmartCoDe project partner TUV contributed to the organisation of the Workshop on a **roadmap for the standardisation of Smart Appliances** on September 17th 2012 in Brussels, hosted by the European Commission. This workshop is the start of an effort to “standardise the interface to EupP (Energy using or producing products) (…) in order to guarantee their interoperability with Facility Management Systems, Energy Management Systems, so-called Energy Boxes and other systems”. Link:

http://www.ectp.org/enewsportal/index.php?option=com_content&view=article&id=712:workshop-on-a-roadmap-for-the-standardisation-of-smart-appliances&catid=45:information&Itemid=53

Prof. Grimm will continue to work on these standardisation efforts, for example in the first quarter of 2013 there will be a follow-up workshop on this topic.

6 PhD Theses and other university projects

This section provides an overview on PhD-theses and other university-activities like Master-thesis or Bachelor-projects which are in the scope or at the fringe of the SmartCoDe project.

6.1 *PhD-Thesis: Topology Analysis of Indoor Wireless Networks using Deterministic Channel Simulation*

Author:

Edgar Holleis (TUV / Tridonic), on-going

Abstract:

A crucial step during commissioning of wireless sensor and automation networks is assigning node-addresses (such as MAC-addresses) to mounting locations. However it is done, it typically requires visiting every single node regardless of whether assignment happens prior to, during or after mounting. For large-scale networks it presents a considerable logistical effort. The thesis develops technology to automate the task by taking automated measurements of wireless channel characteristics and comparing them to simulation results.

Professional deployments produce layout and floor plans as by-product of documentation requirements. These plans, possibly augmented with information about relevant building-materials, serve as input to a deterministic wireless channel simulation which obtains characteristic figures such as path-loss or propagation delay between any two nodes. On the other hand, a preconfigured test program running on the nodes performs measurements on the live channel. It can function prior to commissioning and uses only standard facilities of typical wireless nodes. It obtains characteristic figures like RSSI (received signal strength indicator) and if present TOF (time of flight) between neighbouring nodes of the network.

In a third step, results from measurements and simulation are condensed into graphs and matched against each other. The resulting problem is solved heuristically, exhaustive search is intractable for all but very small networks. Points of interest are the conditions that lead to error-free assignments and how precise the simulation model needs to be with respect to factors such as geometry, materials, antenna characteristics and computational effort.

Note:

Tridonic is in the business of deploying large-scale lighting automation networks, currently at the verge of going wireless. These networks share many characteristics with SmartCoDe's wireless energy management approach. Further automating the commissioning procedure lends itself to industrial applications in both realms.

6.2 *PhD-Thesis: Power Supply Concepts for Wireless Sensor Nodes in Smart Appliances*

Author:

Franz Lukasch (TUV), on-going

Abstract:

Smart Appliances are gaining ground in the end consumer market as they did in the office sector earlier. They include lighting applications, heating and cooling applications, charging stations, consumer electronics and lots of other application fields. Every device is connected to a network and lots of them have to react instantaneously to user inputs.

Hence the devices cannot be separated completely from the power grid as they need to supply their transceiver and control systems to interact with the user which can be a central control system or a human being.

Because the number of devices is usually high in the smart appliance field the power consumption of each device has to be considerable low. Therefore the transceiver and control parts have to be designed very low-power. Usually the built-in power supply cannot operate at such light loads or is

very inefficient doing so. Hence a separate ultra-low-power and low-cost standby power supply is needed to supply the device during its off time.

Several concepts for a mains powered ultra-low power supply are described and evaluated. The two structures that are the base of the most promising concepts are a capacitive power supply approach and a concept that utilizes a high voltage MOSFET in linear mode. Both concepts are galvanically not isolated which is usually not necessary in wireless applications.

6.3 *PhD-Thesis: Localized energy-efficient and energy-balanced dispatch of robots to events in wireless sensor networks*

Author:

Milan Lukic (UNS), on-going

Abstract:

Static sensors monitor the environment and report events occurring in the sensing field. Mobile sensors (robots) are then dispatched to visit these event locations to conduct more advanced analysis. Given a set of events and a set of robots, the dispatch problem is to allocate one robot for each event to visit it. In a single round, each robot may be allowed to visit only one event (matching dispatch), or several events in a sequence (sequence dispatch problem). The distributed version of the problem is embedded into a sensor network field, where each event is discovered by a sensor and reported to a robot.

Existing centralized and distributed solutions suffer from the presence of long robot paths and unbalanced workload distribution. The main contribution of this thesis are new dispatch algorithms (both centralized and localized), which significantly outperform the existing solutions in terms of energy efficiency and system lifetime, by decreasing both total average length of robot travel paths and the messaging overhead.

6.4 *PhD-Thesis: Auction Agregation Algorithms for Task Assignment in Wireless Multihop Electronic Sensor and Actuator Networks*

Author:

Ivan Mezei (UNS), defended in 2012

Abstract:

Two improvements of the simple auction protocol (SAP) for the task assignment in wireless sensor and actuator networks is proposed in this dissertation (multi-hop communications and localization).

Five new auction aggregation algorithms for the task assignment are proposed with the goal to minimize the communication costs. One of the auction aggregation algorithms is also used to improve existing iMesh service discovery algorithm. Experimental results show the characteristics of the proposed algorithms and advantages over the existing ones.

6.5 *PhD-Thesis: Crossing Modelling Paradigms in System Models*

Author:

Markus Damm (TUV), on-going

Abstract:

For several years now, the electronic design community follows an agenda to automatize the design process as much as possible. Elaborate tools can transform an abstract model of an electronic system, for example coded in a hardware description language like VHDL, into a real chip; generally via several transformation steps. Some target architectures, like FPGA, offer complete automated design flows already today. For others, manual transformation or manual intrusion in semi-automated

transformation processes is still necessary. In any case, the means to describe a system will in general be different after each transformation step: A different tool, a different language, a different abstraction level. The analysis means might differ with each model stage as well, for example simulation or timing analysis.

Also, there is an on-going trend for tighter interaction between embedded hardware/software (HW/SW) systems and their analogue physical environment. This results in systems where digital HW/SW is functionally interwoven with analogue and mixed-signal blocks. Examples for such blocks are RF interfaces, power electronics, sensors and actuators. A challenge for the development of such systems is to understand the interaction between HW/SW and the analogue and mixed-signal subsystems at architecture level. This requires some means of modelling and simulating the interacting analog/mixed-signal systems and HW/SW systems at functional and architecture levels.

At the same time, the ever increasing complexity of systems like todays hand held devices requires models of high abstraction level in order to keep the model complexity (and, in turn, the simulation time) low. One possibility here is *Mixed Level Simulation*, which means that different subsystems are modelled in different abstraction levels, e.g. when changing to a lower (and more expensive) abstraction level for a certain sub-system of interest.

For a thorough theoretical treatment of these items, a mathematical framework is needed to fix the descriptional means of the different variants of system models. In this thesis, the term *Model of Computation (MoC)* is used to describe such a framework. MoCs arise also in other areas like computability theory, and also in the modelling and analysis of systems other than electronic ones. But in this thesis, the subject will be treated within the electronic system design setting described above, concentrating on a special issue: Conversion between different MoCs. MoCs can differ *within* a system model, maybe because different system parts lie within *different domains*, or because the design flow foresees the possibility to *mix different abstraction levels* within one system description. Consequently, the need arises to connect systems parts modelled in different MoCs. This is the central topic of this thesis.

Note:

The SmartCoDe simulation framework is an example where different MoCs were used: Transaction Level Modelling, discrete event, and timed data flow. Since we also modelled some physical effects (temperature), it provides an instance of a cyber-physical system model and will be used as a central example in the thesis.

6.6 *Diploma Thesis: A Lightweight Authentication System in Wireless Sensor Networks Using Physical Unclonable Functions (PUFs)*

Author:

Christian Krieg (TUV), on-going

Abstract:

A physical unclonable function (PUF) is a cryptographic function embodied in a device, typically an integrated circuit, a smart card or system on chip, that is easy to evaluate but hard to predict. It is a hardware analogue of a cryptographic one-way function, unique to the particular device and practically impossible to clone, even given the exact manufacturing process that produced it.

In the future, wireless sensor networks, inexpensive and ubiquitous, will be entrusted with handling sensitive data. State-of-the-art wireless security suites, such as WPA (Wi-Fi Protected Access), use computation- and overhead-heavy algorithms and protocols. PUFs on the other hand, can be inexpensively implemented in hardware and may at some point simplify complex key exchange procedures.

The goal of the thesis is to research ways in which PUFs can be integrated into a particular security suite – Kerberos – chosen for its use of low-complexity algorithms only. The combined Kerberos+PUF is prototyped on a commercial, off-the-shelf wireless sensor node platform using an emulated PUF.

Note:

The idea of Kerberos+PUF was initially born as part of the SmartCoDe security effort. It was then recognized as too speculative to produce a viable security solution within the project's time-frame and instead is disseminated as diploma thesis.

6.1 *Master thesis: Improvements of DV-Hop localization algorithm for wireless sensor networks*

Author:

Stefan Tomic (UNS), defended in 2012

Abstract:

In many applications of wireless sensor networks, knowledge of the location of sensor nodes within the network is critical for the successful operation and the functioning of the network. Usually we have a few sensor nodes with known locations which are reference, known as anchors so that other nodes can be self-positioned based on connectivity with them.

Localization of sensor nodes is very important for the identification and correlation of collected data, addressing and routing based on location. In this paper are presented two new improvements of DV-Hop localization algorithm. The results showed that the proposed algorithm can significantly reduce the error in localization.

6.2 *Bachelor Thesis: Wireless monitoring of respiratory equipment using ZigBee*

Supervisor:

Franz Lukasch (TUV), on-going

Overview:

Challenges from designing the SmartCoDe demonstrator nodes were reused for the purpose of a student project. Based on the same NXP/Jennic platform, a different set of sensors was chosen. Under guidance, the student did schematic, layout and production. He is currently writing a bachelor thesis about the experience.

6.3 *Bachelor Project: Simulation of a wireless energy-management network*

Supervisor:

Markus Damm (TUV), finished in 2011

Overview:

This was a so-called deepening project, where a Bachelor student worked with our simulation environment in order to develop a cost-profile dependent control algorithm for thermal service appliances like heaters or air-conditioning. The algorithm developed assumes that the appliance has several power states.