04122 Abstracts Collection
Wireless Sensor Networks and Applications
— Dagstuhl Seminar —

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Abstract. From 14.03.04 to 19.03.04, the Dagstuhl Seminar 04122 "Wireless Sensor Networks and Applications" was held in the International Conference and Research Center (IBFI), Schloss Dagstuhl. During the seminar, several participants presented their current research, and ongoing work and open problems were discussed. Abstracts of the presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this paper. The first section describes the seminar topics and goals in general. Links to extended abstracts or full papers are provided, if available.

Keywords. Energy-efficient training and self-organisation, failure recovery and recalibration, resource management and Connection Admission Control (CAC), Media Access (MAC) protocols for wireless sensor network, network management scenarios and solutions, integration of sensor and terrestrial/satellite networks

Development of Wireless Sensor Networks for Ambient Systems

Stephen John Bellis (University College Cork, IRL)

The goal of this work was to fabricate robust sensor modules aimed at being an enabling technology platform to conduct research in the Ambient Systems area of wireless sensor networks and their applications. The approach taken was to partition the module into a series of PCBs with 25mm form factor.

The modular approach taken has resulted in specification of a series of printed circuit boards forming the initial elements of the 25mm toolkit that can be programmed to be used with different sensors depending on application. This paper highlights the development of the module and discusses the roadmap towards it's miniaturisation.

Joint work of: Bellis, Stephen John; Delaney, Kieran; Barton, John; Razeeb, Kafil; O'Flynn, Brendan; Majeed, Bivragh

Robust Topology Discovery and Positioning Services using BTNodes

Jan Beutel (ETH Zürich, CH)

In this talk I will talk about the requirements for network topology discovery and positioning in wireless ad-hoc networks from a systems perspective. Additionally the BTnode platform will be introduced and I will give insights into the implementation details and idiosyncrasies of such services implemented on real devices.

Keywords: Tree construction, wireless Sensor Network, Bluetooth

Spontaneous Interaction

Alois Ferscha (University of Linz, A)

The growing availability of wireless communication technologies in the wide, local and personal area, and the maturing of miniaturized web technologies has fertilized the emergence of "smart appliances": wirelessly ad-hoc networked, mobile, autonomous special purpose computing devices, providing largely invisible support and services to users. Such smart appliances, usually operated under intuitive, rather implicit user interaction have started to populate the real world, demanding for new styles of interactions with the user and among each other.

We have proposed a "spontaneous interaction" thought model, in which things start to interact once they reach physical proximity to each other: Explained using the metaphor of an "aura", which like a subtle invisible emanation or exhalation radiates from the center of an object into its surrounding, a "digital aura" is built on technologies like Bluetooth radio, RFID or IrDA together with an XML based profile description, such that if an object detects the proximity (e.g. radio signal strength) of another object, it starts exchanging and comparing profile data, and, upon sufficient "similarity" of the two profiles, starts to interact with that object.

A "digital aura" depending on the implementation technology, is dense in the center of the object, and thins out towards its surrounding until it is no longer sensible by others. Profiles described as semistructured data and attached to the object, can be matched by a structural and semantic analysis. Peer-to-peer concepts can then be used to implement applications on top of the digital aura model for spontanous interaction.

A Service-Centric Architecture for Wireless Sensor Networks

Hans-Joachim Hof (Universität Karlsruhe, D)

Sensor networks consist of a potentially huge number of very small and resource limited self-organising devices.

Health care, office and home automation are possible scenarios for the use of sensor networks. The talk presents a general and flexible service-centric architecture for sensor networks. It allows interaction and collaboration of sensors and actuators.

Security issues in service-centric sensor networks are another research topic. The talk reviews security difficulties arising in sensor networks and presents the design of a secure distributed service directory. The talk summarises the work of the sensor network group at Institut of Telematics. The goal of this group is to combine theory and practical experience in the sensor lab.

Keywords: Service-centered sensor networks, security, sensor network middleware

Joint work of: Hof, Hans-Joachim ; Blass, Erik ; Hurler, Bernhard ; Zitterbart, Martina

Agents Solution for Data Integration in Mixed Sensor Networks

Ismail Khalil Ibrahim (University of Linz, A)

The number of sensors deployed for a myriad of applications is expected to increase dramatically in the coming few years. This is spurred by advances in wireless communications and the growing interest in wireless sensor networks. This growth will not only simplify the access to information sources but also will motivate the creation of numerous new ones. Paradoxically, this growth will make the task of getting a meaningful information obtained from disparate sensor nodes not a trivial one. On the one hand, traffic overheads and the increased probabilities of hardware failures makes it very difficult to maintain an always-on, ubiquitous service. On the other hand, the heterogeneity of the sensor nodes makes finding, extracting, and aggregating data at the processing elements and sink nodes much more harder.

These two issues (away from distribution, dynamicity, accuracy, and reliability issues) impose the need for a more efficient and reliable techniques for information integration of data collected from sensor nodes. The personalized, continuously running, and semi-autonomous properties of software agents make them well suited for data integration in wireless sensor nodes applications.

In this talk, we first address the issues related to data integration in wireless sensor networks with respect to heterogeneity, dynamicity, and distribution at both the technology and application levels. Second, we study the roles agents can perform to reduce network traffic overheads, improve scalability and extensibility of wireless networks and increase the stability and reliability of networks against hardware and software failures. Third, we discuss a scenario of what we believe a uniform interface to data collected from sensor nodes that will map sensor specific data to the global information source based on a context exported by software agents to the data integration system.

Joint work of: Kotsis, Gabriele; Khalil Ibrahim, Ismail; Kronsteiner, Reinhard

Communication between Peer Wireless Sensor Networks over 2.56/3G Networks

Srdjan Krco (Ericsson R & D Ireland, IRL)

Abstract: Research in the wireless sensor networks area so far has been mostly focused on various internal working principles issues of these networks (MAC layer issues, routing, data aggregation, etc.) while their interaction with external networks and especially interaction between several wireless sensors networks have been researched much less.

This presentation presents the initial results of a project focused on the latter two issues and specifically the following problems:

1. Design and development of software and protocol architecture of a wireless sensor network gateway and
2. Creation of a peer-to-peer sensor network over a 2.5G mobile network, where each sensor network represents one peer node.

The regular wireless sensor networks usage scenario envisages an arbitrary number of network users and one or more network gateways that facilitate establishment of communication between users and sensor nodes in the network. It is assumed that users and networks are members of one system, i.e. that users, in advance, know which sensor network they want to query, what type of data the network can provide, how to define a query and how to establish communication with an appropriate gateway.

We, however, assumed that this would not be always the case and that in the coming years many sensor networks with different purposes will be deployed (on permanent or temporarily basis) by various organizations and individuals in order to provide different types of services. Services that these networks provide will be accessible over mobile networks. Users will interact with these networks in an ad-hoc manner, depending on their specific needs at a given moment and location. They will not know sensor network characteristics, type or format of data the network provides in advance. Hence, a mechanism will be required to facilitate presentation of sensor network characteristics to users (types of sensors, their locations, data format, etc.) and to enable efficient sensor network querying based on the presented characteristics. We designed and implemented a wireless sensor network gateway that is seen as the entry point into a sensor network ? it provides wide area network access to a sensor network, hides internal organization of the sensor network from users and is aware of all sensor types present in the network and their characteristics. The gateway also exposes a set of high-level API methods that we designed to enable simple sensor querying and query response collection. The methods are independent of the underlying communication technology. XML is used for description of sensor characteristics and queries definition. Software architecture and communication protocol stack of the gateway are described in this presentation.

When a user detects a sensor network, communication with the gateway is established and information required for successful sensor network querying is exchanged. If a user and a sensor network are located in the same area, short-range wireless technologies and their discovery procedures (Bluetooth Inquiry procedure for example) can be used to set up communication links. If, however, user and sensor network are on different locations and are communicating over a mobile network some sort of service discovery protocol is required to enable set up of communication links between them. One solution would be for an operator or a service provider to maintain a server that provides relevant information. However, in scenario where numerous sensor networks are deployed in an ad-hoc manner it would present a very complicated task. A distributed network of service databases would be a more viable solution.

Therefore, we evaluated possibility of establishing a P2P network of wireless sensor networks over a 2.5G mobile network using JXTA framework that facilitates communication between sensor network gateways. Each gateway can store information about available services in the P2P network and can forward user queries (using JXTA services) to relevant gateways. The initial issues observed during implementation and deployment of such P2P network are described in the presentation.

Agents Solution for Data Integration in Mixed Sensor Networks

Reinhard Kronsteiner (University of Linz, A)

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Joint work of: Kotsis, Gabriele; Khalil Ibrahim, Ismail; Kronsteiner, Reinhard

Respecting Privacy in Wireless Sensor Networks

Marc Langheinrich (ETH Zürich, CH)

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 talk I want to briefly 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.

Interacting with Smart Objects: Application Scenarios with the BTnode Platform

Friedemann Mattern (ETH Zürich, CH)

The BTnode is a wireless sensor platform developed at ETH Zurich. A sensor node (slightly larger than a matchbox) may contain various sensors (such as acceleration sensors) and communicates via Bluetooth with other sensor nodes and user interface devices such as PDAs or mobile phones.

We show how BTnodes can be used to render everyday objects smart and interactive. For example, by shaking two small objects together, a common context and a private communication channel can be established - a simple theft alarm or smart products may be possible applications. We then give examples how to use RFID tags and optical 2D codes to make everyday objects smart and interactive. Examples are a smart card game and tagged paper that can be "sensed" with picture phones and thus used in simple augmented reality scenarios. Finally, we show how a mobile robot (a prototypical "smart vacuum cleaner") equipped with a small mobile RFID reader can find its way by interacting with a floor densely populated by sub-millimeter RFID tags

Securing Wireless Sensor Networks

Stephan Olariu (Old Dominion University - Norfolk, USA)

A wireless sensor network is only as good as the information it produces. In this respect, the most important concern is information security.

Indeed, in most application domains sensor networks will constitute a mission critical component requiring commensurate security protection. Sensor network communications must prevent disclosure and undetected modification of exchanged messages. Due to the fact that individual sensor nodes are anonymous and that communication among sensors is via wireless links, sensor networks are highly vulnerable to security attacks. If an adversary can thwart the work of the network by perturbing the information produced, stopping production, or pilfering information, then the perceived usefulness of sensor networks will be drastically curtailed. Thus, security is a major issue that must be resolved in order for the potential of wireless sensor networks to be fully exploited. This talk is concerned with a number of novel solutions to the important problem of securing wireless sensor networks.

Leveraging Virtual Infrastructure for Wireless Sensor Networks

Stephan Olariu (Old Dominion University - Norfolk, USA)

We discuss a general-purpose virtual infrastructure for wireless sensor networks and show how it can be leveraged for the purpose of designing lightweight and secure protocols.

Redundant Positioning

Tom Pfeifer (Waterford Institute of Technology, IRL)

Positioning has been a driving factor in the development of ubiquitous computing applications throughout the past two decades.

Numerous devices and techniques have been developed – few of them are actually used commercially. The precision is limited to specific applications, the availability limited to the provider of a specific service. Occasionally, two methods have been combined to recalibrate each other. Most recently, proposals have been made to combine hybrid positioning data from different technological sources, in order to obtain a higher probability for a certain position scan by principles of data fusion. With the penetration of everyday objects with pervasive devices to the cheapest level, advances in visual tracking and recognition, the arrival of biometric devices in every office, and wireless sensor networks of a variety of categories, a new quality of interworking position and context aware systems becomes available.

The massive redundancy of such nodes and the synergetic heterogeneity of their recognition principles allows to tailor the perceived positioning probability to the specific requirements of the target application, and a self-learning and self-healing approach to misleading, wrong and outdated pieces of information.

Time and Location in Sensor Networks

Kay Römer (ETH Zürich, CH)

A fundamental service in sensor networks is the determination of time and location of events in the real world. This task is complicated by various challenging characteristics of sensor networks, such as their large scale, high network dynamics, restricted resources, and restricted energy. We develop new approaches for determination of time and location under these constraints. We illustrate the practical feasibility of our approaches by a concrete application.

Scatterweb: A WSN platform for research and teaching

Jochen Schiller (FU Berlin, D)

ScatterWeb is a distributed, heterogeneous platform for teaching mobile and wireless ad-hoc networking from the physical layer up to the application layer. It was built by the CST (Computer Systems & Telematics) group at FU Berlin, Germany. Goals of ScatterWeb are (among others):

- Students should be able to derive system parameters from high-level requirements for certain technologies, e.g., QoS in Web Service - QoS in Network - QoS in wireless transmission.
- Students should understand the impact of transmission technology, network topology, hardware parameters etc. onto application layer services.
- The system serves as a test-bed for ad-hoc networking, peer-to-peer networks, power and resource constrained communication devices, and sensor networks.

After presenting the different components of ScattwerWeb (embedded webserver, embedded sensor board, over-the-air flashing USB stick), the talk gives an overview of research challenges and achievements in the areas of energy awareness, routing, management, code distribution, and scripting.

Keywords: Embedded Internet systems, wireless sensor networks, teaching wireless communication

Sensor Networks - A Resource for Novel Interactive Applications?

Albrecht Schmidt (Universität München, D)

In current research in sensor networks no clear application theme has yet emerged. The search for a "killer application" did until now not succeed. Our proposal is to see wireless sensor networks rather as a tool than a solution to a specific problem. Looking at the history of science and at scientific discoveries tools have always played the key role.

With the invention of the microscope new scientific discoveries have been enabled. Similarly wireless sensor networks may enable new observations that were not possible before. However for this to happen, cooperation with other disciplines is inevitable.

In the domain of tangible and physical user interfaces wireless sensor networks are an enabling technology. In this area the use of sensors in devices, clothing, and everyday objects provides new ways for creating interactive systems. The user experience created by such novel interfaces is hardly predictable and therefore trying them out is essential. In both areas it is important to have a quick and easy way of building prototypes that allow doing experiments to acquire real data. This was one main motivation to develop the DIY- Smart-Its platform. It is designed to allow easy extensibility and tailoring for a specific application domain.

Keywords: Interaction, User Interface, Research Tools, Sensor Networks

How to Deal With MAC Shortcomings for Sensor Networks or: Sensor Network Self Organization With Rendezvous Clustering Algorithm

Katayoun Sohrabi (Sensoria Corporation, USA)

We look at some of the limitations inherent in various medium access control (MAC) mechanisms for wireless networks. The problem of network self-organization encountered at layer 2 is discussed. The case is made that these systems are not adequate for formation of multihop topologies for ad-hoc sensor networks of interest. This and the need for remote and/or large-scale deployments motivate using topology management mechanisms for actively forming multihop topologies in networks that use conventional radios. The Rendezvous Clustering Algorithm (RCA) is described. This mechanism allows formation of interconnected clusters in parallel to induce a connected ad-hoc wireless backbone over arbitrary node deployments. Details of the algorithm, and some emulation results characterizing its behavior are discussed.

Keywords: Wireless Ad-hoc Network, Medium Access Control, Self Organization

Scalability of Ad hoc Routing Protocols

Leonidas Tzevelekas (University of Athens, GR)

1. Scalability of Ad hoc Routing Protocols: Definition of scalability for ad hoc networks, examples of Scalability Factors, family of Fuzzy Sighted Link State protocols (FSLS), Hazy Sighted Link State protocol (HSLS)

2. On multi-hop extensions of WLANs: Multi hop Cellullar Network (MCN) architectures, Simulations of MCNs on ns-2, performance evaluation, performance of "doughnout"-shaped architectures
3. The IST Broadway Project and Centralized Ad hoc Network Architectures (CANA)
4. Wireless Sensor Networks: related projects and future work

Routing in Sensor and Ad-Hoc Networks

Roger Wattenhofer (ETH Zürich, CH)

In my talk I present three algorithmic aspects that can be related to routing in ad-hoc and sensor networks. I start by presenting the first local clustering algorithm that provably manages to compute a non-trivial connected dominating set approximation in a constant number of rounds for general graphs. Then I explain a worst-case optimal geometric routing algorithm known as GOAFR which uses the idea of face routing in an efficient manner. And finally I present a series of new results in topology control, in particular I present the XTC algorithm, and I show that all classic topology control algorithms do not optimize interference.