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WISENET

Wireless Sensor Networks
VINN Excellence Center

WISENET

The impact of Wireless Sensor Networks on the society, industry and everyday life by is forecasted to be of the same scope as that of Internet.

Wireless sensor networks combine sensing, data processing and wireless communication into a coherent ensemble of tiny embedded devices. Peer-to-peer protocols then combine the individual devices into an interconnected system.

Wireless sensor networks - incorporating hundreds, even thousands, of tiny interconnected monitoring devices can be launched anywhere and almost instantly since there is no need for wiring. If this vision could be fulfilled an almost unimaginable number of new applications can be developed. For example: easy monitoring of wear inside machinery, precision environment monitoring at land and sea, and monitoring health care patients in daily life.

WISENET is a new research center on Wireless Sensor Networks. It is funded by VINNOVA, Uppsala university, SICS and industrial partners for the years 2007-2017. It is located at Uppsala university.

To reach our vision, a multidisciplinary research approach is necessary, combining expertise in networking, operating systems, sensor devices, micro-systems and wireless communication.

Our research is focused on how to:

- integrate sensing, data processing and communication into one sensor unit,
- manage and generate energy,
- make sensor networks self-configuring, robust and maintenance-free up to 10 years,
- attach sensors to Internet in a secure way,

with the objective to reach an integration size of 5x5x5mm and a manufacturing cost down to 1€ for a regular unit.

The WISENET general goals are:

- to become one of the leading multidisciplinary centers on wireless sensor networks in the world,
- to provide prototypes and other top level research results for further commercialization by industrial/other partners, and
- to create new study programs on wireless sensor networks for undergraduate as well as graduate students.

The overall annual budget for the Center, when fully funded, is expected to be more than 20 MSEK/year. Additional funding from EU and Swedish national funding are also expected, increasing the critical mass of researchers. Altogether about 200 researchers are expected to be involved in WISENET 2007-2017. It is governed by a board and a scientific director. International experts will advise the board on research directions.

The Center will combine the expertise of several groups from Uppsala university and SICS: wireless sensor networks, wireless ad hoc networking, networking security, micro-system technologies, sensorics, antennas, wireless communication, microwave technologies, energy harvesting, computer architectures, and signal processing.

Staffan Truvé
Chairman of the board

Per Gunningberg
Scientific Director

APPLICATIONS

Today's dynamic society demands a rapidly increasing range of sensing and monitoring services in every aspect of life, from control and automation of industrial production, traffic safety, durable ecosystems, public and home security through sustainable life and health care.

Wireless sensor networks have the potential to economically renew basic industries, such as process, transportation, forestry and agriculture industries, to create new industries in eco-system control and to ease the labor intensive health care monitoring. Individuals are also likely to benefit directly from sensor networks, both at home as well at work, simplifying day-to-day tasks.

Our Center will in the first phase work in the following application areas:

Transportation

Sensors are today frequently used in vehicles and aircrafts manufactured by Swedish industry. By using wireless and networks of sensors, heavy and complex wiring can be reduced, saving fuel and cost. Furthermore, wireless sensors in vehicles can easily interact with sensors outside the vehicle, *e.g.* at curbside for increased safety and more fuel-efficient driving.

Ecological sustainable society

Wireless sensor networks are very suitable for monitoring large geographical areas for contamination, for studying local eco systems and for controlling large biological recycling processes. Wireless sensor network can be used for monitoring sensitive aquatic environments, such as the Baltic Sea - think of an array of submerged nodes equipped with sensors for physical, chemical, and biological levels.

Public health

Public health care is seen as a huge beneficiary of wireless sensor networks. For example, small wireless sensors could be carried by patients measuring vital body data. This data could be transmitted to the hospital for evaluation. Furthermore, carrying monitoring equipment without wires would increase the mobility of patients without sacrificing the flow of data. Home care and increased quality of life is expected.

Defence and peacekeeping

Sensor networks will be of vital importance for Swedish defense and military industry. Peace keeping forces could launch a massive amount of sensors over areas to detect troop movements, detect vehicle noise signatures, explosives, chemical warfare, radio listening, etc. The information could propagate wirelessly, hop-by-hop per sensor node, back to head quarters.

Airborne radar for forest exploration. Courtesy FOI.

PARTNERS

The WISENET center consists of Uppsala university, SICS and partners from industry and public organizations.

The partners include large research institutes and small research and development companies, as well as a balanced mixture between public organizations and consulting companies. During the lifetime of the Center it is expected that new partners will join while others may leave at appropriate times. The partners for phase 1, 2007-2009, are:

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Uppsala university is the highest ranked research university in Sweden with a full range of faculties. The Ångström Laboratory at the university is world famous for its Material sciences while the department of Information Technology is among the highest ranked in Europe.

SICS

SICS, Swedish Institute of Computer Science, mission is to contribute to the competitive strength of Swedish industry by conducting advanced and focused research in strategic areas of computer science. It ac-

tively promotes industrial use of new research ideas and results in industry and society at large. SICS therefore works in a close collaboration with industry and the national and international research communities. SICS is a non-profit organization.

Founded in 1989, Hectronic is today one of Sweden's leading Embedded PC development and manufacturing companies. Hectronics advanced embedded solution expertise facilitates the development and manufactures the technology needed to support existing and future ICT-based products and solutions.
Interest: Low-power sensors and micro-scale WSN.

SenseAir AB is a development and production company within the gas analysis business. It has a unique high-level technical competence to find and design cost-efficient solutions using gas sensors.
Interest: Sensor power generation; infrared detectors.

Silex Microsystems AB is a dedicated provider of foundry services in MEMS. It is one of the leading MEMS manufactures that brings advanced process technologies and capacity to component manufacturing and other high-tech industries all over the world. The company participates in development projects at an early stage to make the customer collaboration process as efficient as possible.
Interest: Biotech micro sensors.

Personal CO_2 measurement instrument with alarm functionality. Courtesy SenseAir AB.

FOI, Swedish Defense Research Agency's core activities are research, methodology and technology development for defense purposes. FOI provides expertise in many fields: security policy studies, analysis of defense and security issues, threats assessment, crisis control and management, safe handling of hazardous substances, IT security and the potential use of new sensors.

Interest: Defense applications, data fusion, network security, scheduling of network resources, modulation schemes.

Banverket, The Swedish Railroad Adminstration is the authority responsible for rail traffic in Sweden. It oversees the development in the railway sector, assists the Government on railway issues, operates and manages state-track installations, coordinates local, regional and inter-regional railway services, and supports research and development in the rail sector.

Interest: Sensors for safe, punctual, fast and fairly-priced rail transports. How wireless sensor networks can support an ecologically sustainable society with rail traffic.

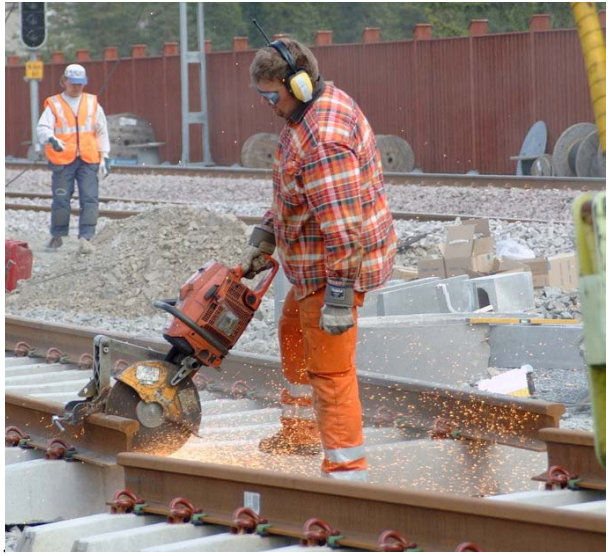
TNT-Elektronik AB has been involved in the electronics and data systems market since 1979. It has direct experience of energy management for wireless sensor networks and of problems in harsh environments. As a small company today, it cannot allocate large resources to research but need to keep its position in the forefront of the technological development. TNT Elektronik is the Winner of the 2007 SKAPA grant for wireless sensors.

Interest: Energy management, adaptation and specialization of sensor nodes.

TRIONA is an IT consultancy company with solid expertise in road and transport informatics. It also consults in distributed computer systems. The annual turnover is more than 62 MSEK and it has 70 highly experienced employees.

Interest: Sensor networks for railroad and road informatics.

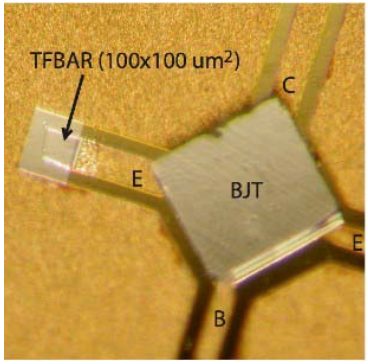
Wisenet Holding AB is partly owned by the Uppsala university researchers active in WISENET. The purpose of the company is to commercialize the academic research results.



NODE INTEGRATION & ENERGY PROJECTS

Imagine a generic family of autonomous sensor nodes, each the size of a sugar lump. Each such "lump" comprises layers of electronics, with a radio transceiver, antennas, computer, memory, batteries, solar panels, a multitude of sensors, e.g. constantly sniffing the environment for hazardous chemicals, monitoring pressure, or temperature. Putting so much electronics into such a small volume is a very challenging research task. It requires new technology for vertical interconnection between the individual layers.

We have developed a miniature sensor function "layer", see photo to the right. It is only 100 x100 µm and is much smaller than a transistor. We will do field-demonstration projects on long-lived wireless pressure and presence miniature sensors to be built in roads, rail tracks or bridges.



The power supply of very small autonomous systems is a very challenging issue which requires the consideration of several important aspects. They include energy generation from the environment, storage capacity and energy efficiency We will explore a thermoelectric generators connected to a compact battery charging module, built on our patented, through-the-foil thermocouple concept.

Contact: Ilia.Katardjiev@angstrom.uu.se

Adam Dunkels explains Contiki, an operating system for wireless sensor nodes, developed at SICS.

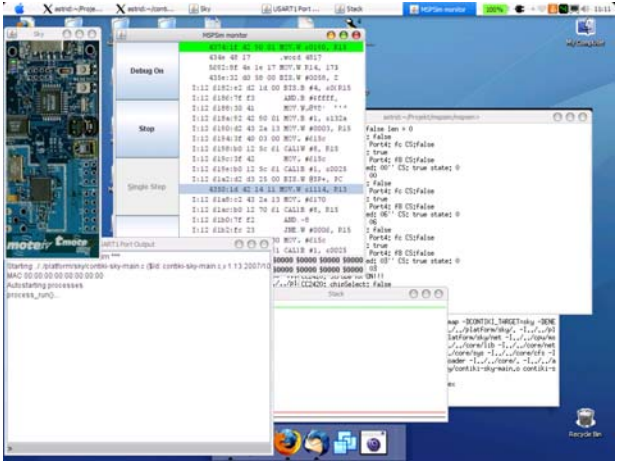
NETWORKING & SECURITY PROJECTS

We expect that most sensor data will be accessed through the Internet as a web service. Sensor networks must therefore be secured against malicious Internet attacks. Attackers might both modify measured data, but also drain the batteries, deeming the sensor network to become useless.

To ensure data quality, regular sensor calibration is needed because sensors tend to drift over time, in particular in harsh environments. During the lifetime of a sensor network, the tasks of the network might need to be modified which requires mechanisms to reprogram sensor networks and for the network to adapt to the environment.

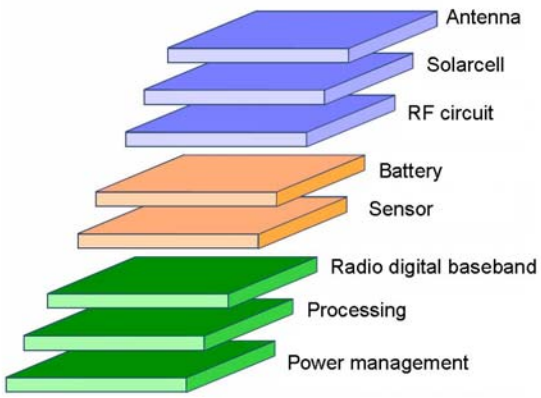
The networking and security projects tackle the challenges of Internet attachment, the programming of sensors and calibration in a self-configuring manner. These challenges must be solved despite the resource-constraints of individual sensor nodes and when they are not physically accessible for maintenance.

WISENET provides an evaluation platform including a remotely accessible testbed that enables WISENET researchers and practitioners to test their ideas, algorithms and applications. The testbed will also be used by students.



A simulation environment, based on SICS' Contiki simulator COOJA, assists in prototyping, testing, and debugging.

Contact: Thiemo.Voigt@sics.se



Layers of an integrated sensor node.

WIRELESS COMMUNICATION PROJECTS

Wireless sensor nodes are required to be small, versatile, inexpensive, and to have a long life time. The most energy demanding part of a node is the wireless communication.

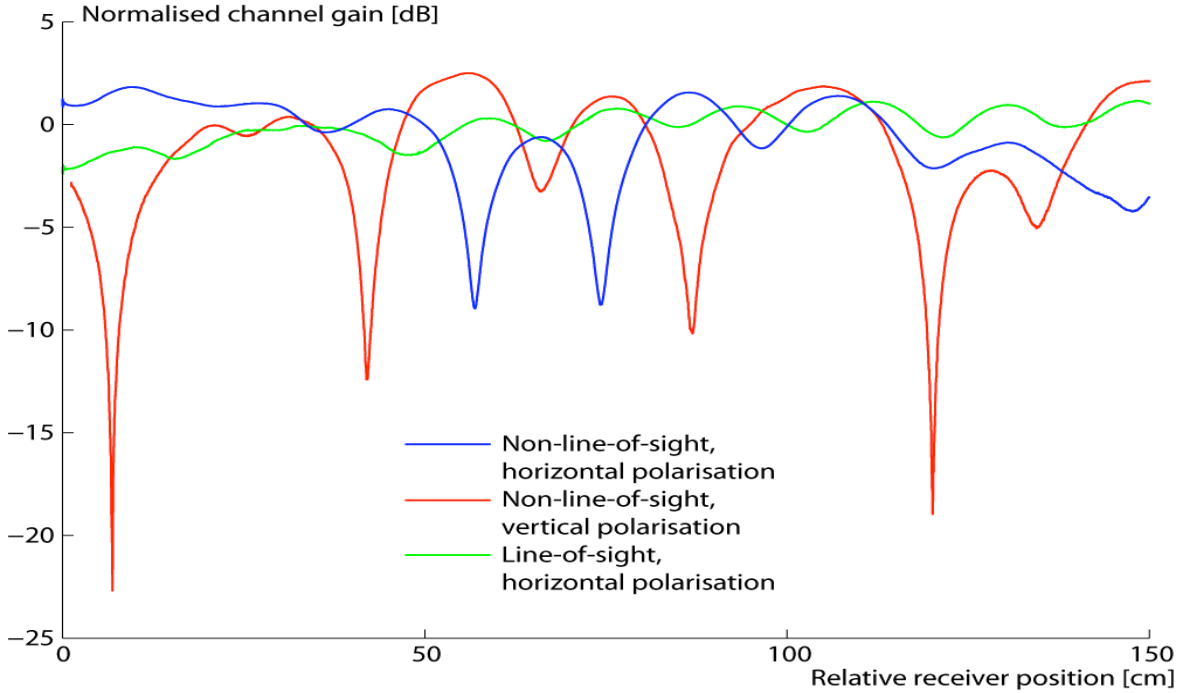
Communication energy is used both for transmission as well as for the electronics in the node. The electronic parts, which are also active during receiving, is the dominating part. The reason is that transmission distances are so small, i.e. it requires relative low energy. This means that the wireless nodes should turn off the electronics (go into "sleep mode") as much as they possibly to save energy and should not constantly listening on the radio for data. Also, when "awake", they should spend as little energy as possible when sending and receiving information.

To obtain efficient nodes we do research into scheduling of wake-ups, multi-hop routing and transmission techniques. On the hardware side, we investigate how antennas fit on a tiny nodes and how to make them efficient in varying environments.

An important issue for obtaining reliable communications is the radio channel properties. If the channel is static and we know the distances between nodes, then we can easily calculate how much energy we have to invest for transmitting or receiving our data.

A more difficult scenario arises if the radio channel quality is varying with time. This can happen if sensor nodes are operating in, for example, malls or along the side of roads with heavy traffic. In such cases we need to spend more energy to guard against information loss.
We will investigate the radio channel properties for typical wireless sensor network scenarios See figure for one of our measurements.

Contact: Anders.Ahlen@angstrom.uu.se



The channel gain at 868 MHz as a function of distance for three different scenarios in an office area. From the figure it is clear that the channel gain varies significantly between different polarizations and whether the channel is line or non-line of sight.

APPLICATION PROJECTS: WATER SENSING

With the increased human impact on our ecological system there is an higher demand for monitoring of water in lakes, rivers, and coastal waters. We need to understand more about our impact on submarine life and on water as an clean energy resource (waves and streams).

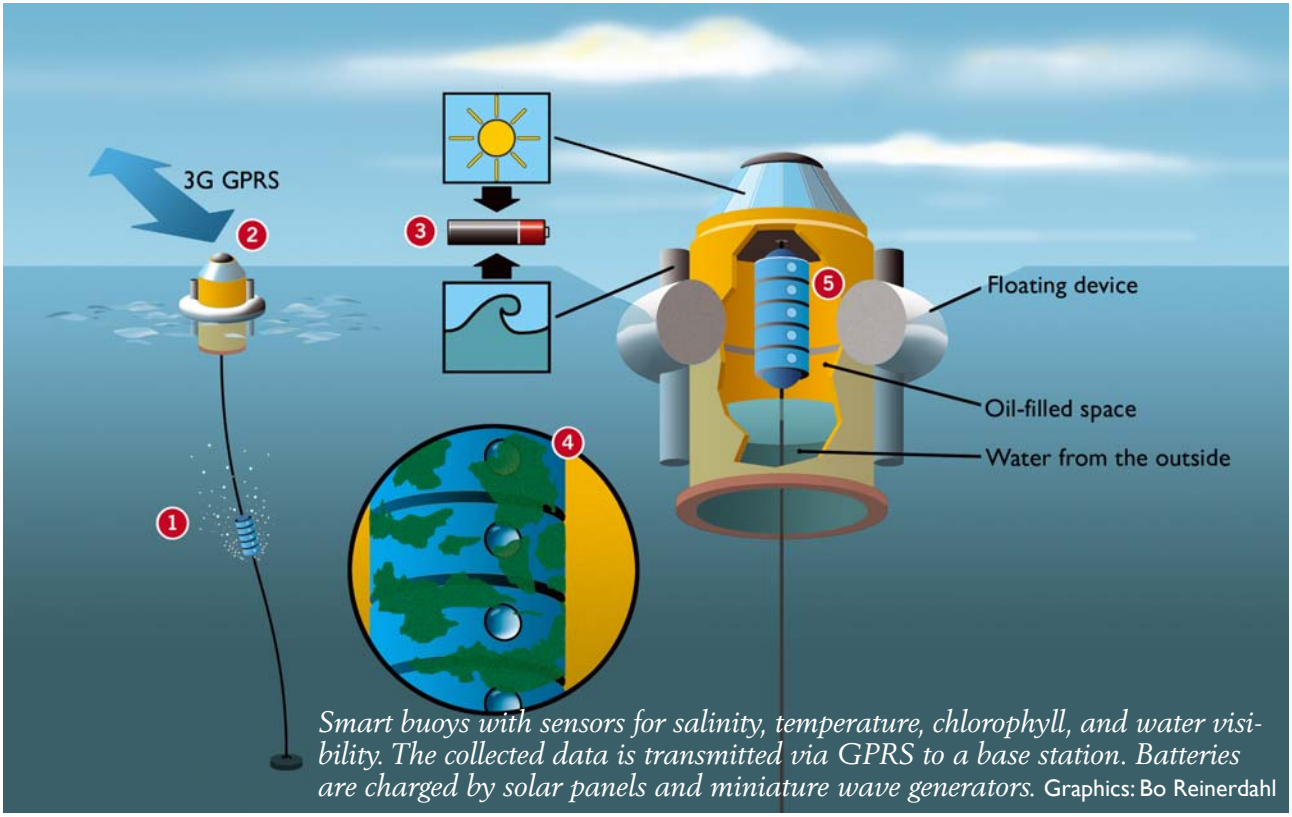
Our water bodies are poorly monitored. One reason for this is the high cost for monitoring. A modern research vessel at sea costs at least 10,000€ per day. Bad weather and technical problems are common reasons for poor efficiency in open-sea cruises which increases the cost.

Monitoring our freshwater resources usually does not require large research vessels. However, the number of lakes and rivers is so large, that the cost will be too high if based on regular field work. Wireless sensor networks can dramatically reduce these cost factors and provide very high precision.

The submarine world is, in large, unknown to us, since we have not been able to study marine water volumes with high resolution. One way to survey these vast volumes is with a large numbers of buoys with sensors communicating wirelessly. It is even possible to use small autonomous submarine vessels with sensors communicating in water.

The marine environment is a challenge for wireless sensor networks. There is a need to save and generate energy since it is costly to replace batteries. On the other hand, there are no size restrictions on nodes. Groups in WISENET currently participates with Stockholm University and Umeå Marine Sciences Centre on a project wireless sensor network systems on buoys and deep sea systems.

Contact: Klas.Hjort@angstrom.uu.se



Smart buoys with sensors for salinity, temperature, chlorophyll, and water visibility. The collected data is transmitted via GPRS to a base station. Batteries are charged by solar panels and miniature wave generators. Graphics: Bo Reinerdahl

APPLICATION PROJECTS: TRANSPORT SYSTEMS

Sensors for traffic management will pave the way for intelligent traffic systems making it possible to interface new types of sensors for classification of vehicles, road/rail conditions, wheel vibrations, traffic congestion information, etc.

Sensors are today used in railroad inspection, cart braking systems and other places in the railroad system. Sensors are also used to detect positions of trains to predict when they should arrive at checkpoints.

With wireless sensors the costly wiring along the track as well as inside the trains could be avoided. Track conditions could be transmitted directly to the train. This make it possible to monitor a set of new conditions, misaligned tracks, high water, snow slides, excessive rail stress, blocked culverts, climate and passenger comfort in mass transit vehicles and environmental pollution from goods transfer. Wireless sensors could also be attached to rotating wheels to detect vibrations and overheating.

The key objective with this project is to improve the cost effectiveness of road/rail management which will lead to a better utilisation of them. This can only be achieved by designing sensor nodes and systems that can operate with high reliability in the hostile environment of these applications. This is our main research challenge.

Contact: Anders.Rydberg@angstrom.uu.se


MIC
UPPSALA UNIVERSITET

CONTACT INFORMATION

Web: www.wisenet.uu.se
E-mail: info@wisenet.uu.se

Mailing address:

WISENET
Box 337
SE-75105 Uppsala
SWEDEN

Visiting Address:

Uppsala University
MIC/Polacksbacken
Lägerhyddsvägen 2
SE-752 37 Uppsala

Scientific Director:

Per Gunningberg
Phone: +46 (0)70 557 63 84
E-mail: Per.Gunningberg@it.uu.se

Assistant Director:

Roland Grönroos
Phone: +46 (0)18 471 68 47
E-mail: Roland.Gronroos@it.uu.se

Graphic design by Sara Gunningberg. Pictures: Aline Baggio, Roland Grönroos, Banverket, FOI, SenseAir, TNT Elektronik.