Energy-efficient wireless sensor networks for acoustic condition monitoring

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Motivation
The Maintenance System
Outlook
Lead Project 3: CoolSensornet
Wireless Sensors for Condition Monitoring

Scenario of LP3
• Composite materials allow light-weight components like wings for airplanes or wind turbines.
• But, the materials are prone to cracks that are hard to detect visually.

Idea of LP3
• Build-in wireless sensors can monitor the structural stability.
• To minimize maintenance, energy-harvesting is used as power source.

Limitations of LP3
• But, energy-harvesting provides only limited energy.

➢ Regular monitoring requires ultra-low power sensor networks
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<td><strong>Energy-efficient sensor hardware is creatable by adequate design.</strong></td>
<td><strong>Digital signal processing requires large computing / energy power.</strong></td>
<td><strong>Algorithms &amp; DSP-HW need to be harmonized for energy-efficiency.</strong></td>
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<td><strong>Distributed systems with redundant nodes increase system reliability.</strong></td>
<td><strong>Nodes need to be coordinated and clocks need to be synced for measurements.</strong></td>
<td><strong>Energy-efficient protocols for network management and clock synchronisation.</strong></td>
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<td><strong>Integrated, out-of-the-box solutions are easier to use.</strong></td>
<td><strong>Many modules on the nodes are required only for specific tasks (meas., commun., etc.)</strong></td>
<td><strong>Energy management modules that activate only required HW.</strong></td>
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<td><strong>Energy-Harvesting enables maintenance-free sensors without batteries.</strong></td>
<td><strong>Energy-Harvesting-modules are limited in size and do not provide constant energy.</strong></td>
<td><strong>Measurements and diagnosis tasks need to be scheduled due to the energy-resources.</strong></td>
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CoolConSens
Key-Components

Workpackage - Algorithms for energy-efficient acoustic signal processing

Workpackage - Communication and Synchronisation Infrastructure

Workpackage - Framework for energy-management

Workpackage - Management and Maintenance-System

Algorithms & DSP-HW need to be harmonized for energy-efficiency.

Energy-efficient protocols for network management and clock synchronisation.

Energy management modules that activate only required HW.

Measurements and diagnosis tasks need to be scheduled due to the energy-resources.
Institute of Applied Computer Science

Automation Systems’ Engineering
- Design of Building Automation Systems

Process Modelling & Control
- Advance Process Control & Identification, Virtual Sensors, Predictive Maintenance
- Test of automotive ECU

Test & Diagnosis
- Energy-efficient Wireless Sensor Networks
- Fault Diagnosis in Factory Control Systems
- Simulative Test of Factory Control Systems
Focus within CoolConSens

- Measurements control
- Results retrieval
- Network management
- Fault detection & diagnosis
- Failure recovery
Hard- and Software Platform

Hardware
• robust, reliable HW-basis
• permanent energy supply

Software
• long-term data access
• modular, distributable, redundant software architecture
• reconfigurable and reprogrammable for flexible modifications in the life cycle
• Coordinates measurements and sleep cycles in the network
• Energy-efficient protocols for adaptive result retrieval
• Realizes the trade-off between real-time requirements of measurements and the energy budget of nodes
• Measurements need to be error prone to transmission errors and node loss
Scheduling of Measurements

- Schedules measurements based on nodes' energy budgets
- Considers external information like flight plans or sunshine hours in which energy-harvesting intake is high to save energy for times with low intake
• Commissioning and self-organisation of the network via application and network management protocols
• Identity and address management of nodes within the network
• Grouping of nodes in measurement clusters
• Recovery after node loss
• Energy-efficient fault detection and diagnosis
• Defines reliability states for nodes and measurements
• System recovery from communication or node failures
Agent-based system design

- Maintenance System (Agent Container)
  - Scheduling Agent
  - User Interface Agent
  - Self-test Agent
  - Application & Network Mgmt Agent
  - Measurement Control Agent

- Network Access Agent
- Embedded PC

- WSN Gateways
- Ethernet Connections
CoolConSens Strategy
Reduce Scenario Complexity

- Analysis of airborne noise instead of solid-borne noise.
- Power supply from batteries.
- Uses commercially available components.

Fast research of an optimal cross-layer system solution for ultra-low power wireless sensor networks.
Many Applications Domains

Building Automation: Speaker localisation

Industrial Automation: Non-intrusive diagnosis of manufacturing systems