Ultra-Low Energy Wireless Sensor Networks in Practice
Tampere University of Technology (TUT)

- Established in 1965
- 12,200 students (2007)
DACI research group

Department of Computer Systems
Faculty of Computing and Electrical Engineering

- Prof. Marko Hännikäinen, Prof. Timo D. Hämäläinen,
  - Personnel ca. 30: researchers (PhD students) and research assistants (MSc students)

- Competence
  - Wireless Sensor Networks
  - Wireless LANs
  - Web applications and services
  - Multi-processor embedded system design methods

- Outcome 1997-2008
  - 200+ international publications
  - 8 PhD theses, 50+ MSc theses

- Major funding from subcontracted industry projects
WSN research efforts by DACI

- Large national industry and public funded projects 2000-2008
  - 50 PY (researchers and research assistants) + supervision
- Currently 10+ persons involved in WSN research
Introduction to WSNs

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Low-Energy Wireless Sensor Networks (1/2)

- WSN is a new topic in research and development as the term is used today.
- WSN consists of a large number of nodes that organise autonomously.
- WSN nodes are resource constrained (limited computing, communication, and energy).
- WSN targets at low price, small size with high embedding.
Low-Energy Wireless Sensor Networks (2/2)

- WSN applications are versatile
  - Measure environment
  - Control other systems
  - Identify, locate persons and assets
  - Transfer, save, and refine information

- Main emerging standards are ZigBee (IEEE 802.15.4), (Ultra Low Power) Bluetooth, WirelessHart, 6LoWPAN, RFIDs, TinyOS, and Prorietary
IEEE articles containing "Wireless Sensor Network"

Comparison: 2006
- Processor architecture: 100
- Internet protocol: 221
- Optimization algorithm: 469
- Wireless network: 1694

JulkaisuJa/kpl

IEEE

Hannikainen

IEEE

N

Hannikainen

2

4

5

1

0

500

1000

1500

2000

2500


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Low-Energy WSNs in Practice

1. WSN technology
   - Getting the core technology working

2. Design tools and infrastructure integration
   - Integration and extending exiting systems
   - Tools for design, simulation, diagnostics

3. Applications
   - What can be done/should be done with WSNs?
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WSN Technology
Building of a wireless sensor node

- Wired starting point

Physical sensors and interfaces

wire
Building of a wireless sensor node

1. Wireless temperature sensor
Building of a wireless sensor node (2)

- Ad-hoc mesh protocols
- Multi-hop routing
Building of a wireless sensor node (3)

- Embedded applications
  - Measuring
  - Data processing (filtering, aggregating, compressing, ...)
  - Storing
  - Actuating
Building of a wireless sensor node (4)

- Gateways to auxiliary hosts & networks
- Interface to any new sensor element
- Energy sources
TUTWSN node

- Node is an embedded system running protocols and several applications
  - Senses environment or controls other devices
- Different types and number of physical sensor attached to a node
  - e.g. IR and piezo (motion detection), G-3D sensor, humidity, temperature, GPS, luminance, CO2, magnetic, compass
- Interfaces for RS232, I/O, Ethernet (TCP/IP), GPRS
- TUTWSN is optimised for low power consumption - lifetime up to years with AA-batteries
TUTWSN research in brief

- Dynamic autonomous mesh networking and data centric routing
- TUTWSN research is not a single network – a family of platforms and protocols in modular HW/SW components
- Implementable with commercial off-the-shelf components
TUTWSN main features

- Energy efficiency also in router nodes
- Mutual mobility of nodes (fast neighbour discovery and re-routing)
- Several gateways to/from other networks
- Network is programmable and firmware can be updated on-the-field
- Used in real application deployments
TUTWSN hardware example

- Does not place extensive functional and non-functional requirements on HW
- The features are achieved by algorithms
TUTWSN nodes

2.4 GHz TUTWSN
- Hop distance 100–300m
- Avg. Power 150-500 uW
- Sampling interval 30s–10 min
- Lifetime up to 2 years (2xAA)

433 MHz TUTWSN
- Hop distance 0.5 – 2 km
- Avg. Power 2 mW
- Sampling interval 30s – 10 min
- Lifetime up to 1 year (2xAA)
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Tools and infrastructure integration
TUTWSN infrastructure

TUTWSN application server

Customer application servers

3rd party service integration (e.g. Google)

Internet Delivery

Java Messaging Service

XML messaging (SOAP)

TCP/IP sockets

Gateway Software (WSN & IP Proxy)

SQL/ODBC

DB

JMS

XML

TUTWSN nodes

TUTWSN ethernet gateway

TCP/IP

GPRS gateway

Customer application servers

TUTWSN nodes

TUTWSN ethernet gateway

TCP/IP

GPRS gateway

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Web Applications
Application control

Select services

Measurement services

- Multisensor services
  - Humidity
  - Illuminance
  - Acceleration
  - Compass
- Temperature
- Humidity
- Illuminance
- Acceleration
- Compass
- GPS
  - Basic data collection
  - Extended data collection
- Motion detection
- Carbon dioxide

Other services

- Location receiver
- Global time
- Diagnostics
  - Generic node information (buffering, voltage, events)
  - Neighbors
  - Received cluster traffic
  - Transmitted traffic
- Network information
  - Routes
  - Neighbors
- Network delays

How often

Options

30 seconds

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Design tools and simulations

\[ P_m = \frac{P_{RX}}{T_s} \left( T_{st} + \frac{1}{f_{btx}} \right) + E_{tx} f_{btx} + E_{rx} f_{brx} \]

Theoretical models

Simulations

Database

Physical Deployment

Diagnostics

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Examples of realtime diagnostics
Voltage / 5 days
Single hop TX reliability (node to node)
RF channel and TDMA slot scheduling
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Applications
Applications areas and drivers

- **WSN optimises** current processes and enables new potential applications
- Energy saving by the green movement
  - From personal level to city-wide WSNs
- Security
  - Personal security, asset management, security enhancing information
- Fault and condition monitoring
  - Home & industry
- Environment monitoring
  - Safe living surroundings, urban air quality
TUTWSN application deployments

- Monitoring applications
  - Indoors & outdoors

- Tracking applications
  - Person and asset tracking
Frost and snow temp monitoring

- Finnish Lapland, 07-08
- Utilized by the Finnish Meteorological Institute’s Research Centre to verify satellite measurements
- WSN monitors
  - frost depth
  - snow depth
  - air, soil and tree trunks temperatures
Ultra-Low Energy Wireless Sensor Networks in Practice

Example: TUTWSN at home
“20 minute” home WSN

• According to OnWorld, WSNs reduce installation costs by up to 80%
• No dust, paint, wires, waiting
Ethernet Gateway Node

- Casing holder
- Pushbutton
- Red led
- Green led
- AC connector
- Ethernet port
Ethernet Gateway attached to ADSL modem
Online web services
Example

Multipoint temperature inside fridge
Example
Conclusions and future work
Challenges in WSN research and adoption

- Two fields of engineering: computers and communications
- Piece-wise solutions, lack of common interfaces
- Lack of killer application & strong belief in killer application
- Strong belief in the near future standard
Cross-layer design

- Design time tailoring
- Runtime configuration
- Runtime adaptation

Temperature monitoring network

- Delay
- Mobility
- Throughput
- Security
- Energy
- Autonomy
- Reactivity
- Scalability
- Availability

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Key topics for future research work

- Methods and tools for managing the WSN design space
  - Increased abstraction for efficient integration
  - Cross-layer design tools

- Architectural compatibility
  - TCP/IP, XML, Web, SOA/SOAP, Java, Mobile
  - “Realistic” APIs

- Physical deployments and piloting
  - Required for technological development and user acceptance
Conclusions summary

- Moving from the potential enabling technology phase into efficient adoption of the technology
- Not the standard – the efficient utilization of standard components
- Integration of WSN just in case for various purposes – without single killer application?
- TUTWSN is available for co-operation research projects