PermaSense Research @ TIK

Ultra Low-Power Wireless Networking in the Alps

Jan Beutel, ETH Zurich
PermaSense

- Consortium of several projects, start in 2006
- Multiple disciplines (geo-science, engineering)
- Fundamental as well as applied research
- More than 25 people, 13 PhD students

http://www.permasense.ch
Science Objective: Understanding Root Causes of Catastrophes

Eiger east-face rockfall, July 2006, images courtesy of Arte Television
Ice-filled Clefts in Permafrost

L. Trucco
B. Jelk
Permafrost Thaw Leading to Severe Natural Hazards
Our patient does not fit into a laboratory
So the laboratory has to go on the mountain
Location: Matterhorn, Switzerland
Competence in Outdoor Sensing

- Wireless systems, low-latency data transmission
- Customized sensors
- Ruggedized equipment
- Data management
- Planning, installing, operating (years) large deployments
Simple Low-Power Wireless Sensors

- Static, low-rate sensing (120 sec)
- Simple scalar values: temperature, resistivity
- 4 years operation (~200 µA avg. power)
- < 0.1 Mbyte/node/day

4+ years experience, ~350’000’000 data points

In relation to other well-known WSN projects
- Comparable to many environmental monitoring apps
  - GDI [Szewczyk], Glacsweb [Martinez], Volcanoes [Welsh], SensorScope [Vetterli], Redwoods [Culler]
- Lower data rate
- Harsher environment, longer lifetime
- Higher yield requirement
- Focus on data quality/integrity

[Beutel IPSN2009]
PermaSense System Architecture
Ruggedized for Alpine Extremes
WLAN Long-haul Communication

- WLAN (802.11a) backbone using directional links
- Leased fiber/DSL from Zermatt Bergbahnen AG to mountaintop
- Commercial components (Mikrotik)
- Weatherproofed, protected
Online Data Management

- Global Sensor Network (GSN)
  - Data streaming framework from EPFL (K. Aberer)
  - Organized in “virtual sensors”, i.e. data types/semantics
  - Hierarchies and concatenation of virtual sensors enable on-line processing
  - Dual architecture translates data from machine representation to SI values, adds metadata
Vizzly: Visualization of Large Data

- Fast access to millions of data samples
- Pan, zoom, channel selection
- Combination of historic and real-time data

[Keller SenSys2009, SenseApp 2012]
PermaSense Science

Computer Science
Low-power WSN Technology

• Shockfish TinyNode184
  – MSP430, 16-bit, 8MHz, 8k SRAM, 92k Flash
  – LP Radio: SX1211 @ 868 MHz

• Sensor interface board
  – Precision DAQ & 1 GB local storage

• Dozer - ultra low-power data gathering system
  – Multi-hop, beacon based, 1-hop synchronized TDMA
  – Optimized for ultra-low duty cycles
  – 0.167% duty-cycle, 0.032mA

• 13Ah primary battery → multi-year life-time
FlockLab Testbed

- Wired and wireless observation layer
  - Fast, distributed tracing and actuation of logic
  - Synchronized power tracing
- Sensor stimuli and references
- Time synchronization to ~ μs

Roman Lim, Federico Ferrari, Marco Zimmerling, Christoph Walser, Philipp Sommer and Jan Beutel: FlockLab: A Testbed for Distributed, Synchronized Tracing and Profiling of Wireless Embedded Systems, IPSN 2013.
Challenge: The Physical Environment

- Strong daily variation of temperature
  - $-30^\circ C$ to $+40^\circ C$
  - $\Delta T \leq 20^\circ C$/hour

- Impact on
  - timing, energy availability, fatigue, SOFTWARE, ...

![Temperature Graph]

- Node 1
- Node 2
- Node 3

[Graph showing temperature variations over time for different nodes]
Impact of Environmental Extremes

- Tighter guard times increase energy efficiency
- Software testing in a climate chamber
  - Clock drift compensation yields ± 5ppm
- Validation of correct function
Sensor Networks and Time Information

- Often global reference time (UTC) is not available
  - Implications on data usage
- Solution: Elapsed time on arrival
  - Sensor nodes measure/accumulate sojourn time
  - Base station annotates data with arrival time (e.g. UTC)
  - Generation time is calculated as difference
- Model-based data analysis/quality control

\[ \tilde{t}_g = t_b - \tilde{t}_s \]

2011/04/14 10:03:31 – 7 sec
= 2011/04/14 10:03:24
• ETH Zurich
  – Computer Engineering and Networks Lab
  – Geodesy and Geodynamics Lab
  – Micro and Nanosystems

• University of Zurich
  – Department of Geography

• EPFL
  – Distributed Information Systems Laboratory

• University of Basel
  – Department Computer Science

Interested in more?
http://www.permasense.ch
New Lecture in HS 2014

Low-Power System Design

Lecturer: Jan Beutel
Monday 13-15h, 15-17h
Number: 227-0781-00 V

- Low-power and low-energy design techniques from a systems perspective
- Aspects both from hard- and software
- Technology oriented
- Cutting across a number of related fields