Wireless sensor networks for large scale environmental monitoring – integration and deployment in the field

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Outline

Deployment examples

• Precison agriculture
  • Vineyard irrigation
  • Carrot farm
• Bush fire warning system
• Infrastructure monitoring
• Underground wireless network
Vineyard irrigation

- Development of a soil moisture monitoring and irrigation control system for vineyards
- Vineyard irrigation in Germany allowed since 2003
Vineyard

Drip irrigation
System overview

Wireless sensor network

Soil moisture sensors at each node → GPRS uplink → Geographical information system → Irrigation management
Soil moisture sensor

Transmission line in soil

Micro-controller

Divider

Temp.
Sensor installation

20 locations with 4 different depths
Sensor installation
Node placement
Web based data visualization
Radio propagation experiment (2.4 GHz)
Nodes at 5 different heights
Node height above ground: 10 cm
Node height above ground: 60 cm
Node height above ground: 110 cm
Node height above ground: 160 cm
Node height above ground: 210 cm
Lessons learned

• 2.4 GHz too much attenuation, 868 MHz prefered
• Temperature range: -20°C to 60°C required
• Battery change every 1.5 years acceptable by farmer (4xAA for 2€)
• Solar panels will be stolen or damaged by leaf cutter
• Suitable outdoor enclosures required (enclosure sometimes more expensive than electronics)
• No need for miniaturization (large connectors for easy field installation, battery change)
• Robust design and long term reliability most important
Carrot farm project

- Planete végétale largest independent carrot producer in France near Bordeaux
- Concept and realisation of a flexible wireless infrastructure on 1500 ha for
  - sensing (weather, soil moisture)
  - irrigation control
  - near real time machine control
  - alarm systems
Farm site with 1500 ha of carrots
Wetting front

Hydrological simulation (Institute for Agriculture, University of Hohenheim)
Sensor installation
Field station

directional and sector antennas
Field station installation
Lessons learned

- Farmer requested universal network infrastructure for many different applications
- Reliable 5 GHz backbone with low cost off the shelf components
- Field stations with ruggedized embedded linux systems for complete flexibility
- Remote stations without microwave link connected by cell phone
Bushfire warning system

- Temperature sensors
- Up to a few km range
- Very low cost
- Long lifetime

Bushfire 2009, Kings Park, Perth, Western Australia
Range measurements Kings Park (900 MHz)
Topography and radio range calculation
Range measurements (DNA tower)
Range measurements (DNA tower)
Topography (DNA tower along broadway)
Range measurements (native bushland)
Range measurements (native bushland)
40 MHz base station (UWA, CSSE building)
UWA campus range test
40 MHz transmitter installation
40 MHz very low cost transmitter
Software defined radio multichannel receiver
Schriesheim sensor deployment
Schriesheim sensor deployment
Lessons learned

• 2.4 GHz, 900 MHz and 868 MHz offer only limited range in native bushland
• Lower frequencies typically perform better
• 40 MHz ISM band is a new option (in Australia 1 W power)
• 169 MHz recently opened in Europe for metering (may be an option in Europe)
Infrastructure monitoring
Moisture sensor

380 Ω in air

120 Ω in water

Requires transformer to connect to coaxial line

with spacer

without spacer
Laboratory sensor evaluation
Sensor installation
Instrumentation and data acquisition
Lessons learned

• Sensors itself can be distributed (moisture profile, pressure profile)
• Instruments sometimes have non-negligible power requirements
• Civil engineering applications require rock-solid design of sensor, data acquisition and transmission
Beach underground wireless sensor

Radio range about 250 m
40 MHz node with helical antenna
Radio range experiments

range > 500 m with 1 m deep antenna over hilly terrain
Energy harvesting with thermogenerator

ΔT=50°C

prototype thermal generator
Lessons learned

• Underground (invisible) wireless sensor networks very attractive for agriculture and civil engineering
• Low frequencies preferred -> long antennas
• Long term power supply extremely important (thermogenerator, fuel cell?)
Conclusions

• Large scale wireless sensor networks attractive for environmental monitoring, precision agriculture and infrastructure monitoring

• Application specific choice of frequency, transmit-only or transceive, topology, power supply and many more parameters

• Flexible hardware platforms and software modules required