Wireless sensor systems for irrigation management in container grown crops

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Jochen Hemming, Frank Kempkes, Jos Balendonck

Wageningen University & Research Centre, the Netherlands

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Outline

- Introduction
- Wireless Sensor Networks (WSN)
- WSN requirements for container grown crops
- Flow-aid objectives for the WSN
- Flow-aid experiments
  - 2007/2008: Ce.Spe.Vi (IT)
  - 2009: Vredepeel (NL)
- Further possibilities wireless data transmission
- Conclusions

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Introduction

- Nurseries, especially in the Pistoia region, have hundreds of (relatively) small (less than 500 m^2) irrigation sectors
- For plot-based individual irrigation control sensors and controllers need to be installed at each plot
- Maintenance (labor) and wiring costs are high
- Wireless sensor networks might be a good way of overcoming these problems. Research must be conducted on open questions like
  - Power management
  - Network protocol
  - Data-communication reliability
  - Available Sensors
  - Costs

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Wireless Sensor Network (WSN)

- WSN is a network consisting of sensor nodes to cooperatively monitor physical or environmental conditions like e.g.:
  - Global radiation
  - Temperature
  - Soil properties
- A Sensor node is typically equipped
  - Radio transceiver
  - Antenna
  - Microcontroller for data processing
  - Energy source (battery, solar panel)
- The sink node (base station) receives the messages from the nodes
- Base station attached to a computer or the internet
- Access data for end user by computer programs or to visualize the data in graphs or tables.

Network topologies

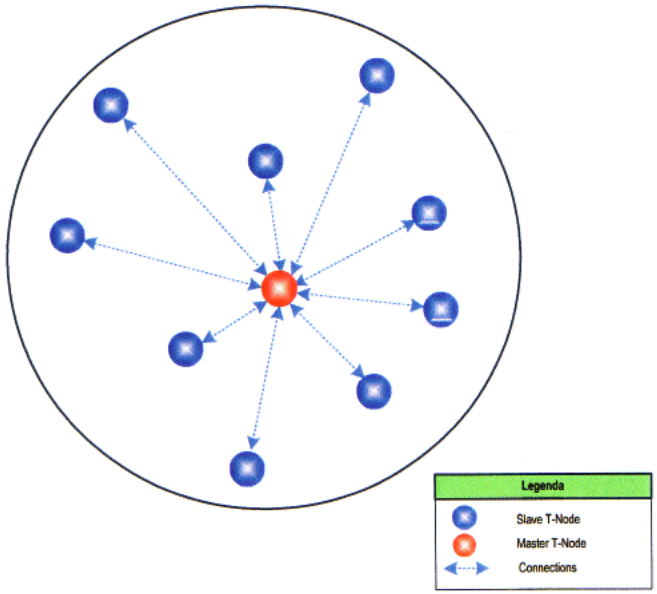
Star network

Advantages

- Simple, high bandwidth

Disadvantages

- Less robust (no alternative route)
- Limited range



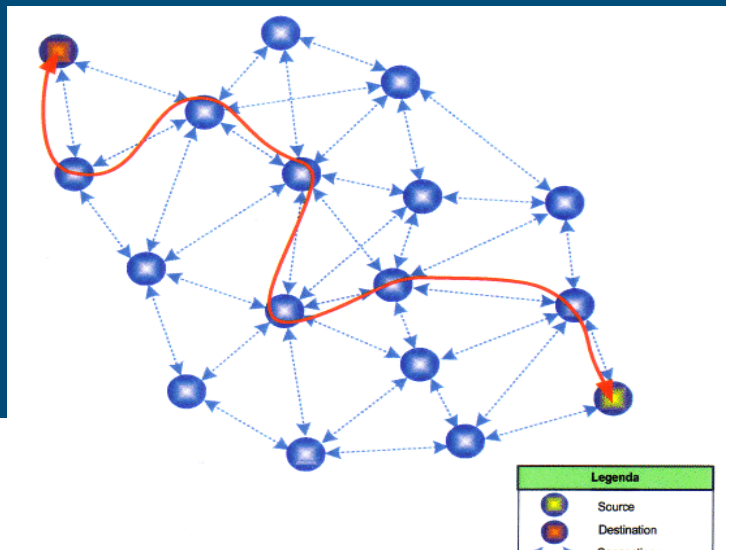
Mesh network

Advantages

- Robust
- Easily deployed
- Easily expanded

Disadvantages

- Higher power consumption
- Potentially less bandwidth



(Source: SOWNet-technolgies, 2007)

User demands for a WSN in container crops

- Wireless monitoring of soil moisture content and EC
- Maintenance free operation: 8 months under arid- or semi-arid conditions
- Low cost: 100€ per sensor node (10 year investment period)
  1 man year round on 20 ha.
- Sensor accuracy of better than 10%
- Flexible sampling frequency of 1 s/h down to 1 s/min (if used for control)
- Sensor density: 1 sensor per 100m^2, with a grid size of 10 x 10 m^2
  is 3 sensors per plot of 300m^2.
- Long-term robustness: maximum overall data loss of 5%.
- Easy (labor extensive) read-out and connectivity to management system.

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Objectives Flow-aid project

- EC project FLOW-AID (Farm Level Optimal Water management, Assistant for Irrigation under Deficit)
- Development of a prototype low-power transceiver for monitoring temperature and soil conditions (soil moisture and electrical conductivity) for irrigation management under field conditions
- Adapt or extend standard protocols and sensors for practical use for irrigation management
- Perform tests with multiple prototypes of these nodes under practical conditions

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Flow-aid experiments 2007/2008

- Field experiments with different types of WSN and sensors in container crops at Ce.Spe.Vi
  - Communication robustness
  - Maximum range
  - Power consumption
  - Outdoor suitability
  - Sensor performance

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Two different systems tested

- SowNet (8 nodes + repeaters) with SM200 sensors
- Crossbow wireless Eko system (8 nodes) with Watermark and Temperature/Humidity sensors
- Sownet:
  - Custom made node, star/hybrid network type
  - 866 Mhz frequency
  - SM200 sensor (dielectric soil moisture)
- Crossbow:
  - True mesh network
  - Solar powered
  - 2.4 Ghz frequency
  - Watermark sensor (soil matrix potential)

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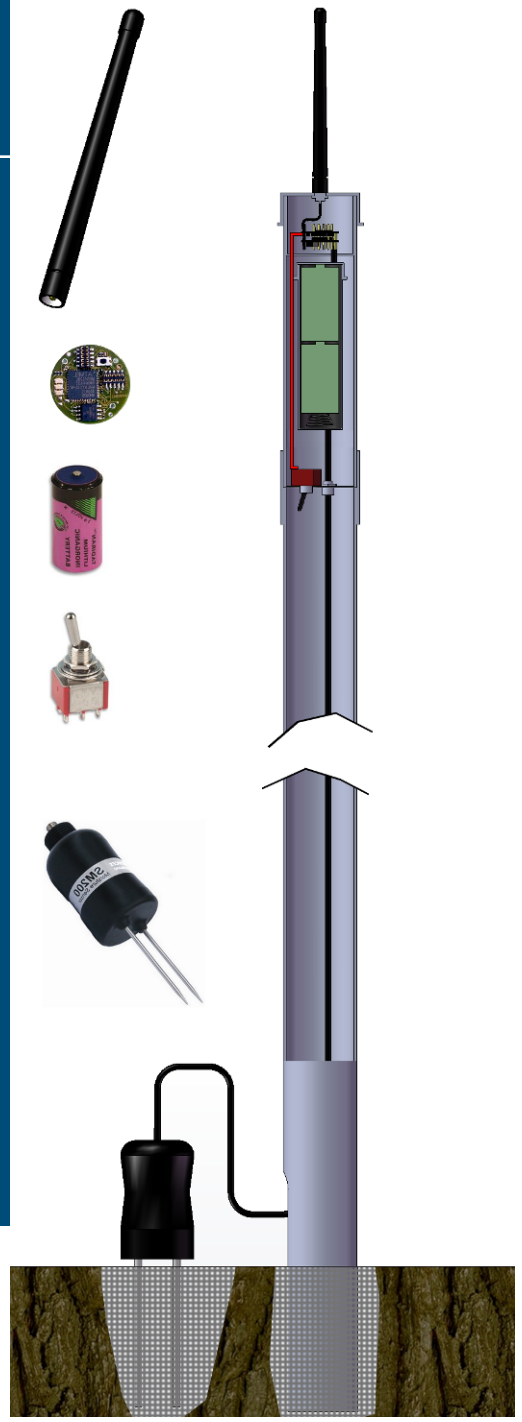
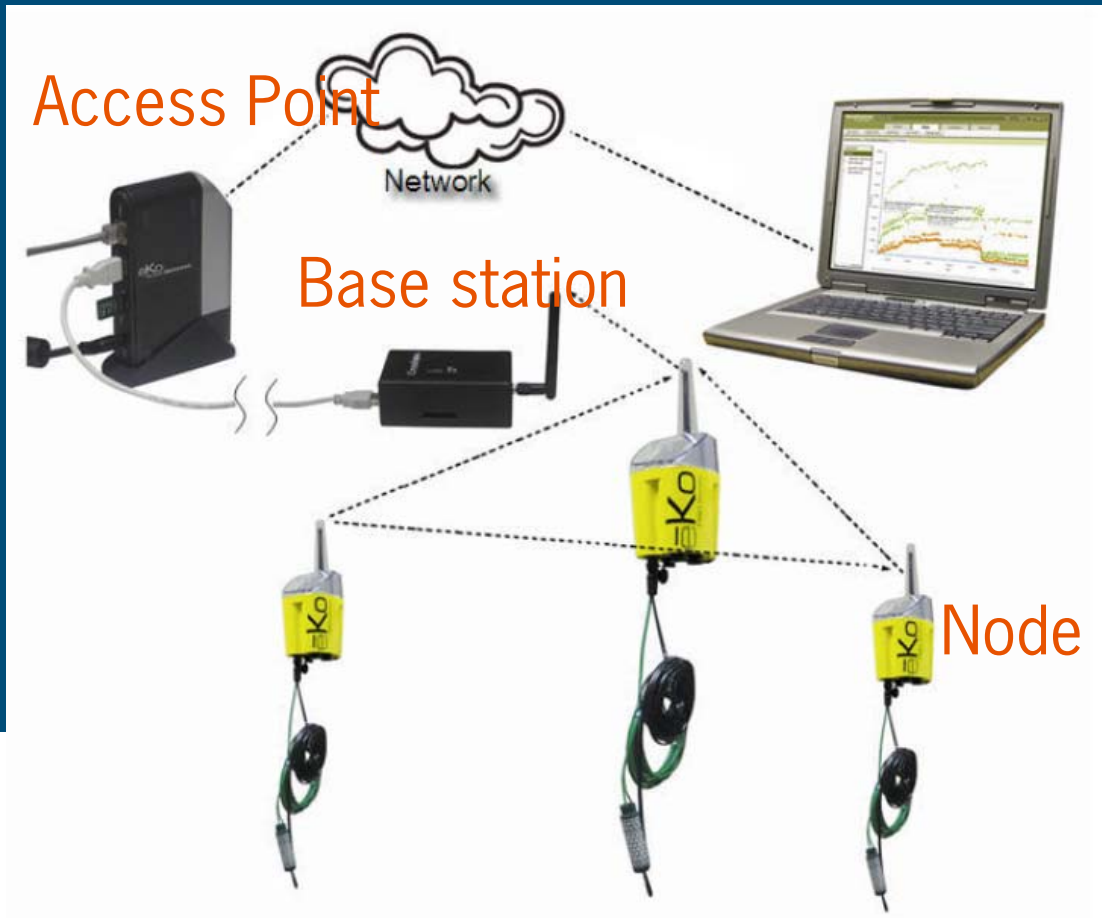
SowNet system (2007 & 2008)

- Semi-Mesh network
- External antenna (2008)
- Frequency: 866 MHz
- Thermal isolation (2008)
  - Extra outside shield (not shown)
- Increased radio power (software, 2008)
- SM200 sensors
- Power on/off switch
- Robust and simple mechanics



Crossbow Eko system

- True mesh network
- Solar powered
- Frequency: 2.4 GHz
- Watermark soil moisture sensor
- Internal and soil temperature
- Web-based data logger and GUI running on embedded Linux Access Point



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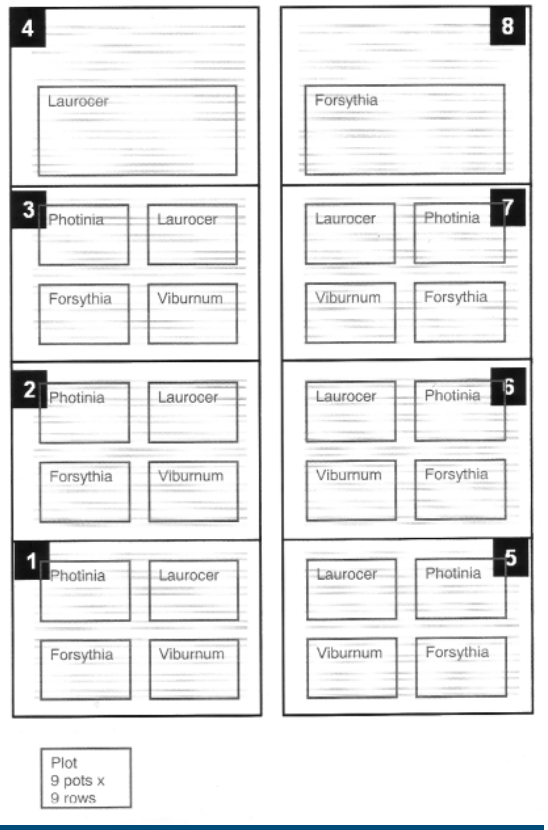
Deployment of WSN at Ce.Spe.Vi.



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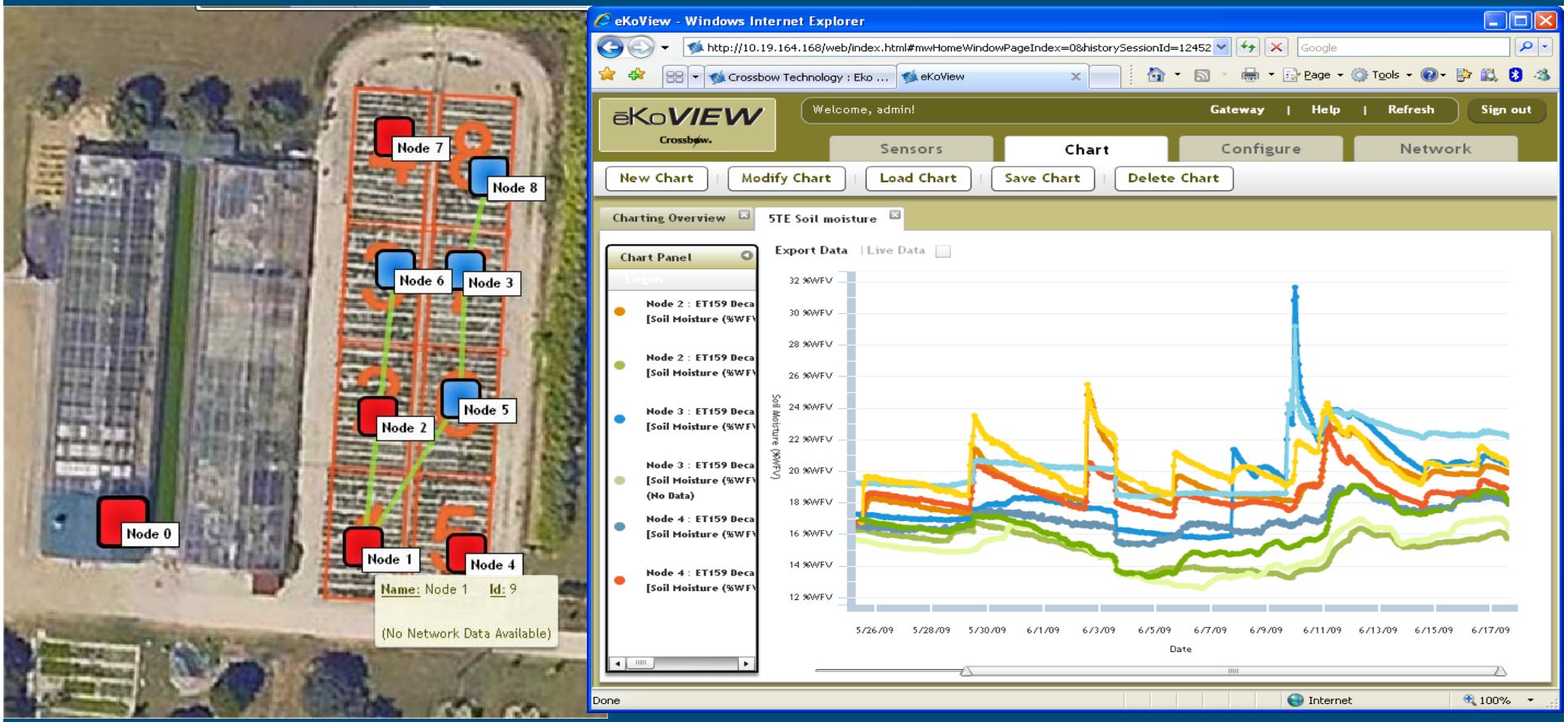
Web-based online access to data



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Different canopy situations

- Start (26-May-2008)

- End of experiment, plot 1 (6-Oct-2008)

- Affects reliability
  - Sownet –
  - Crossbow +

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Results

- Sownet:
  - Maximum range of about 100 meters
  - Some node failures
  - Reading of the SM200 sensors sometimes failed (condensation of water?)
- Crossbow:
  - Reliable operating range > 200 m per hop
  - Open sensor and data interface
  - Solar cell based power supply worked fine
  - Long-term experiment: very reliable
  - Watermark sensor not usable for container crop (too slow, gets saturated during irrigation event)

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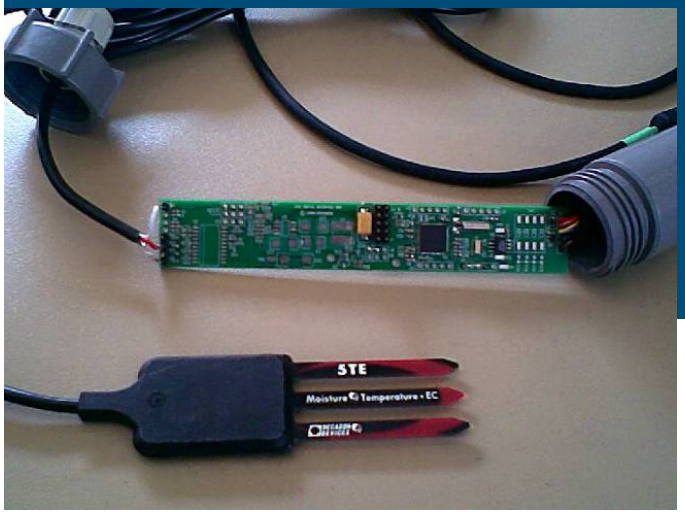
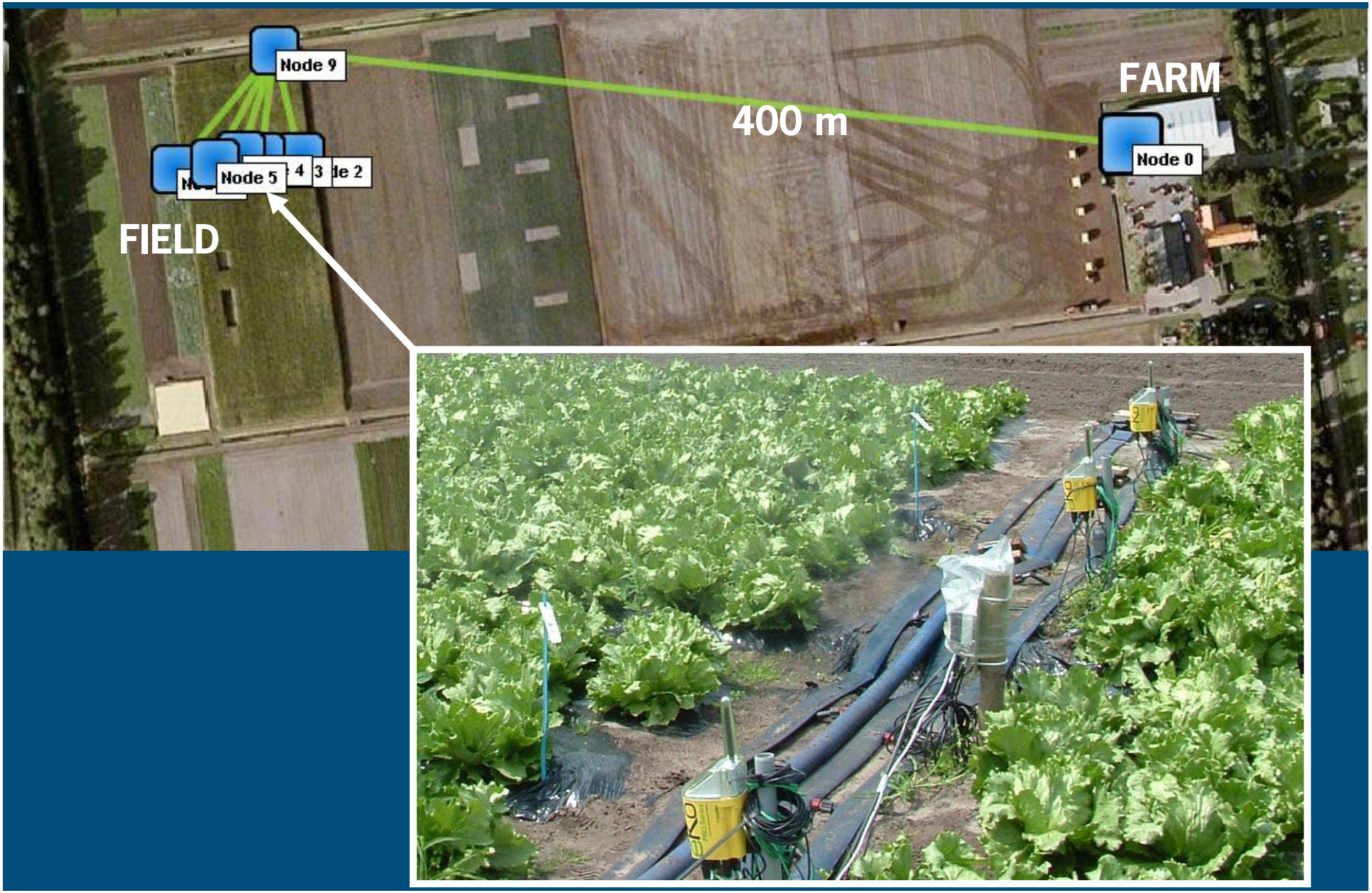
Flow-aid experiments 2009

- Additional Decagon 5TE sensor for soil temperature, moisture and EC
- Drip irrigation/fertigation trial in lettuce (*Iceberg*).
- Comparison of:
  - REFERENCE: controlled by farmer
  - DSS controlled irrigation (Decision Support System)
- Live data exchange with DSS via Internet
- Monitoring of Crop Yield
- Monitoring of Leaching
  - (begin and end season N-sampling)





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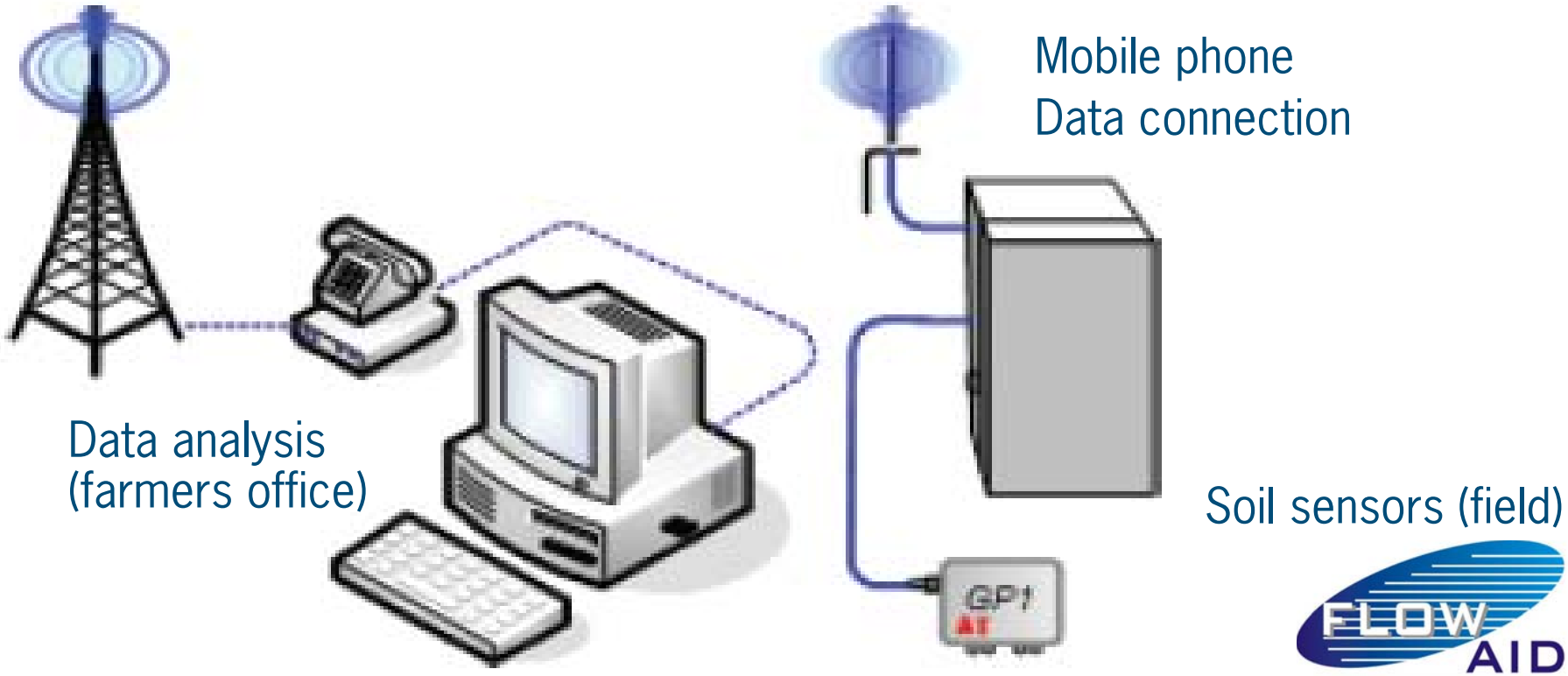
Further wireless possibilities

- Use of directional antenna for extended range
- Increased range from base to field
- Up to 15 km range free line of sight !!
- This technology develops fast

Mobile phone data service (GPRS/UMTS)

- Different concept: use of GSM network to transmit sensor values
- No range limitation
- Access to mobile phone network required (at countryside ?)



Conclusions

- Possible to monitor temperature, soil moisture and EC in a robust manner by means of a mesh network topology
- Distances up to 500 m in between the base station and the field and up to 200 m in-between 2 sensor nodes can be achieved
- The system is solar powered and self recharging
- Correct placement and calibration of the sensors for container crop is challenging and crucial (high in-pot and inter-pot variability)
- Sensors for the dry-end, like the Watermark sensor, are not suitable for irrigation control in container crops
- Sensors based on the dielectric measurement principle like the SM200, WET (Delta-T) or 5TE (Decagon Devices) perform better
- The costs of such a system are still high (about €750 per node). This is in opposition to the idea of having a high density of sensors in the field

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Conclusions

- So these systems are not yet suitable to control but useful for monitoring.
- In combination with models as for instance calculation of evaporation it can support to save water and nutrients.

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