Wireless soil moisture sensor networks for environmental monitoring and agricultural irrigation

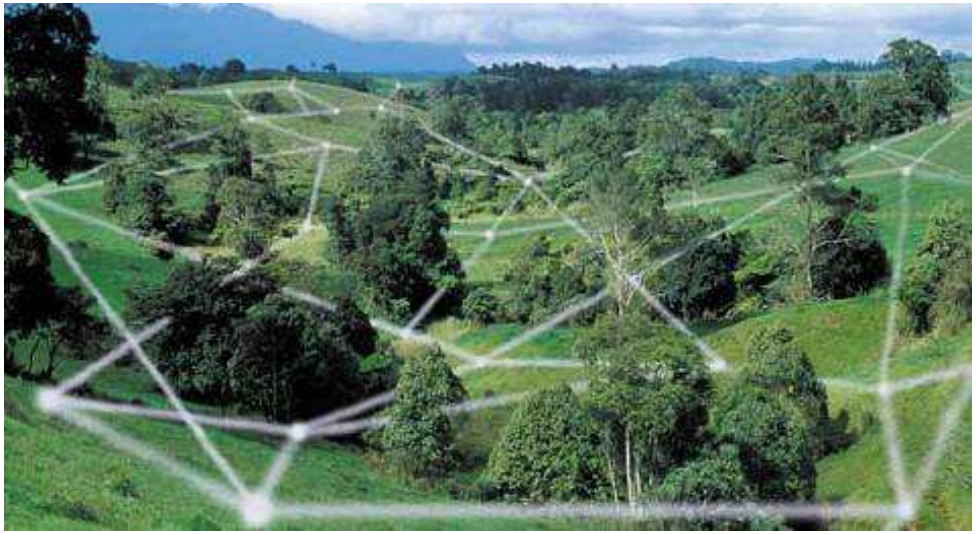
Christof Hübner[1], Rachel Cardell-Oliver[2]

[1]University of Applied Sciences Mannheim
[2]University of Western Australia, Perth

Outline

- Motivation
- System overview
- Sensor design
- Wireless nodes
- Radio propagation
- Conclusions

The outdoor „Internet of Things“



Motivation

Precision agriculture requirements

- soil moisture measurement with high spatial resolution
- real time data availability for irrigation control
- low total costs
- low maintenance

Vineyard irrigation project

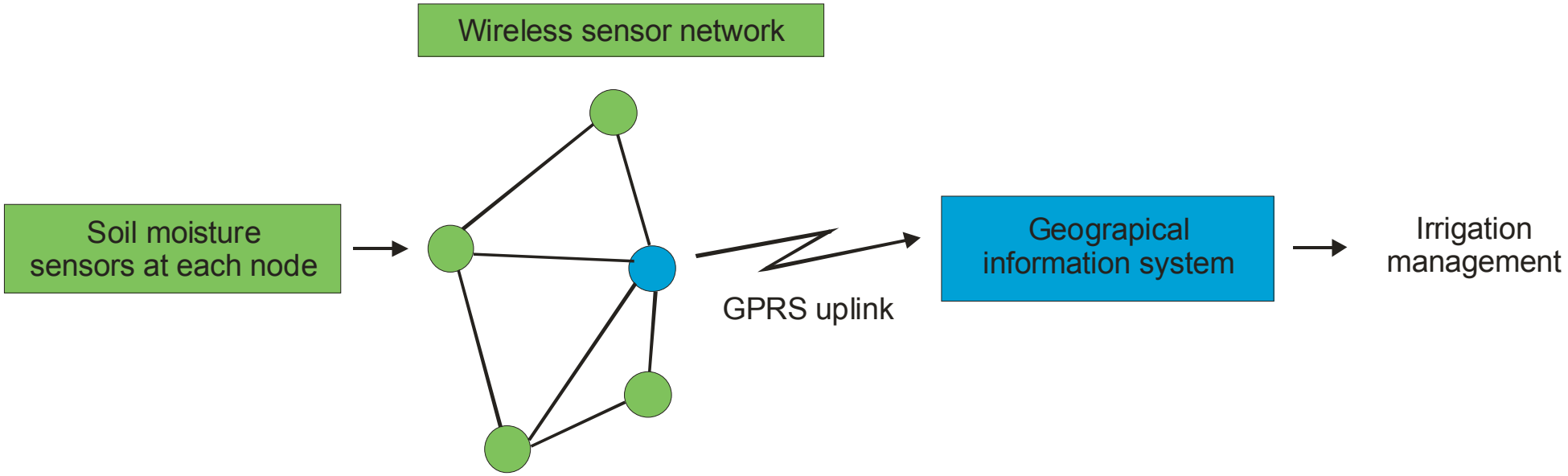
- Development of a soil moisture monitoring and irrigation control system for vineyards
- Vineyard irrigation in Germany allowed since 2003

Funded by the
German Federal Agency
for Agriculture and Food (BLE)

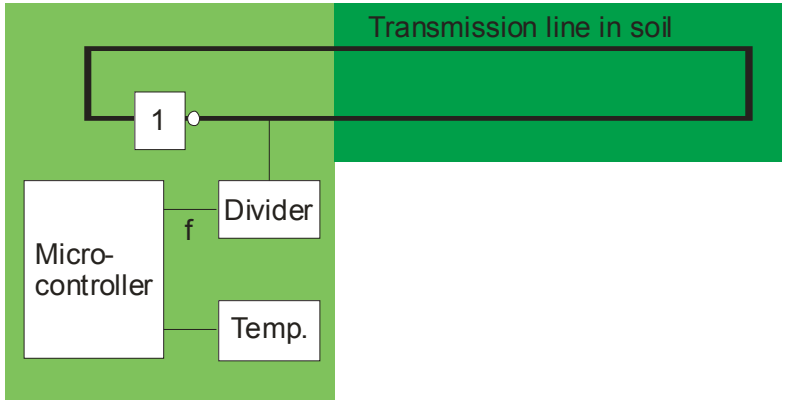
Vineyard

Drip irrigation

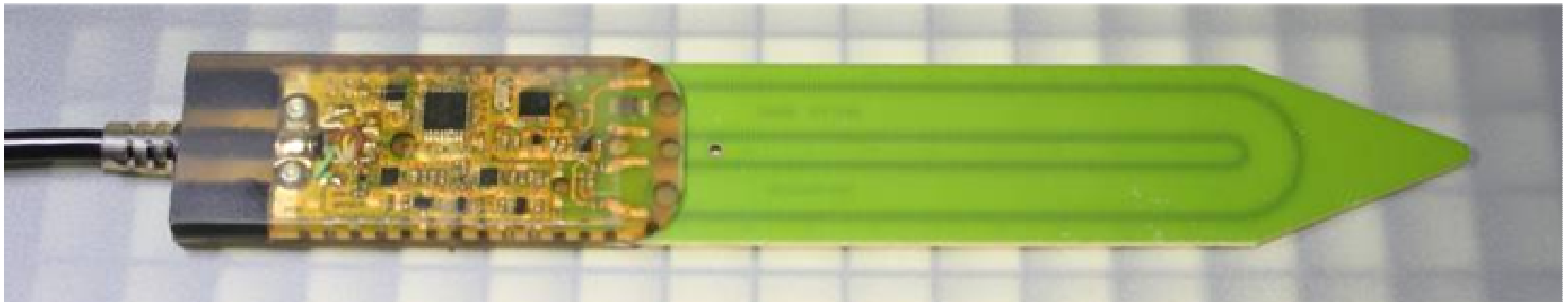
System overview



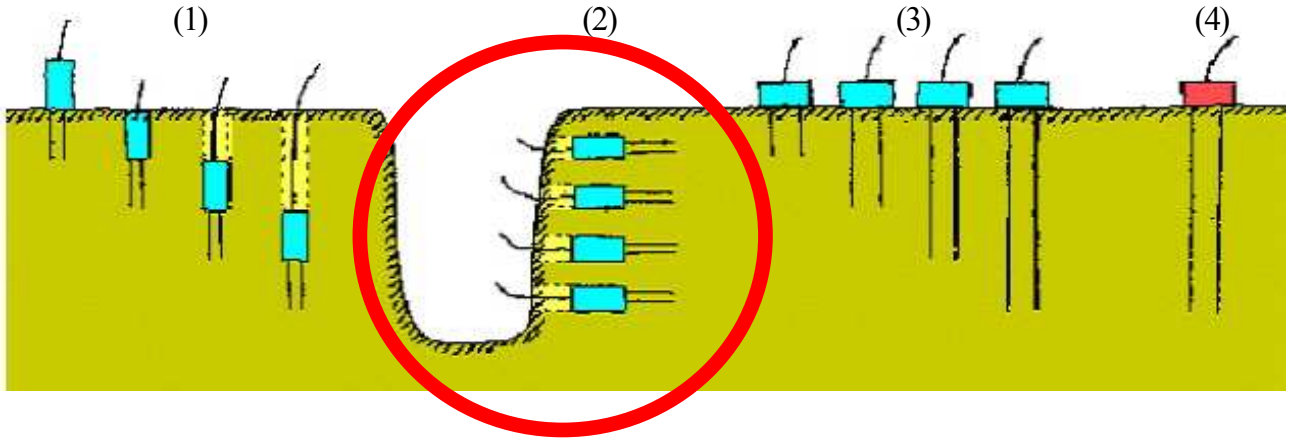
Low cost moisture sensor



- soil
- building materials (concrete)
- powders, grains, emulsions
- compost, woodchips
- custom design for other applications



Soil moisture sensor placement

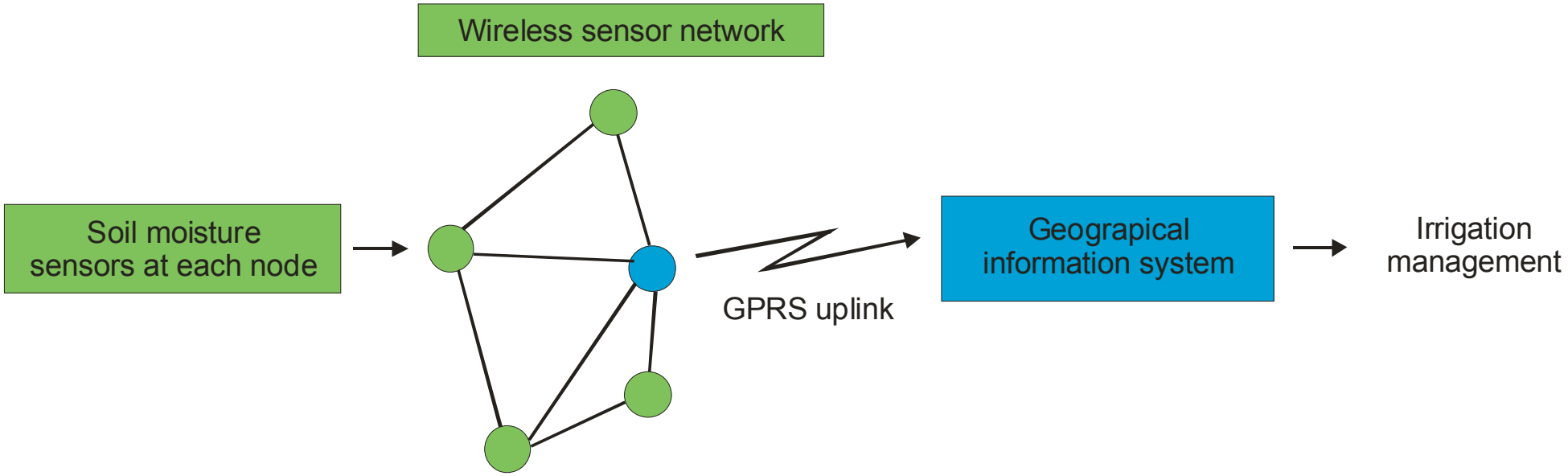


Sensor installation I

20 positions with each 4 sensors in different depths

Sensor installation II

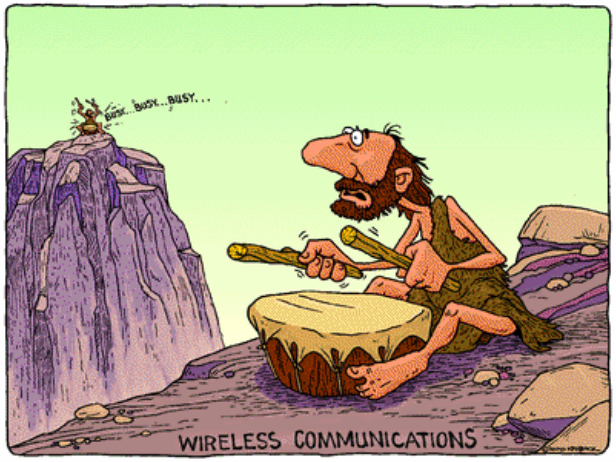
System overview



Wireless nodes in the vineyard

Wireless sensor networks

- Sensor nodes monitor and control the environment
- Nodes process data and forward data via radio
- Attachment to other networks with a gateway
- Energy efficient (e.g. 5 mAh per day with a pair of AA batteries)
- Potentially a very high number of nodes at very low cost per node



Selection criteria for the radio chip

- Long range (> 500 m line of sight), unlicensed operation
- Low power consumption and low data rate (kbps range)
- Preferably mesh networking (depending on protocol stack)

SILICON LABS
AXSEM
Melexis
Infineon
ATMEL
ANALOG DEVICES
MICREL
Innovation Through Technology
Texas Instruments
NORDIC SEMICONDUCTOR

How important is the radio chip?

Manufacturer	Part Number	Supply Voltage (V)	Sleep Current (uA)	Tx Current (mA)	Rx Current (mA)	Tx Power (dBm)	Rx Sensitivity (dBm)	Security	Package	Dimensions (mm)	Temperature Range (deg C)	Comments
Atmel	AT86RF230	1.8-3.6	.02 (typ)	16.5 @ 3dBm	15.5	3	-101	None	32 QFN	5x5	-40 to 85	Nice specs
Freesc				30 @ 0dBm	37	4	-91	None	32 QFN	5x5	-40 to 85	MC13201 = non-ZigBee/802.15.4 apps, PA and LNA output pins for ext amps, Tx/Rx switch
	MC13202/3	2.0-3.4	1 (typ)	30 @	37	4	-91	None	32 QFN	5x5	-40 to 85	MC13202 = 802.15.4 only MC1303 = 802.15.4 + ZigBee stack
	MC13191		6 (max)	0dBm		4	-92	None	32 QFN	5x5	-40 to 85	MC13191 = non 802.15.4/ ZigBee, MC13192 = 802.15.4 only, MC13193 = 802.15.4 + ZigBee
Texas Instruments	CC2420	2.1-3.6 (VREG) 1.6-3.6 (IO)					-95	CTR CCM AES	48 QLP	7x7	-40 to 85	One of the first 802.15.4 chips out
	CC2520	1.8-3.8	.03(LPM1) .175(LPM2)	25. 0D 33. 5D					28 QFN	5x5	-40 to 125	See my review about this chip's specs
OKI	ML7065	2.5	No Info	No Info	No Info	0	-90	AES	48 QFN	7x7	-25 to 70	Possible bug on website where datasheet link gives product intro only.
UB												
MI												ter compatible too.

TX current

RX current

TX power

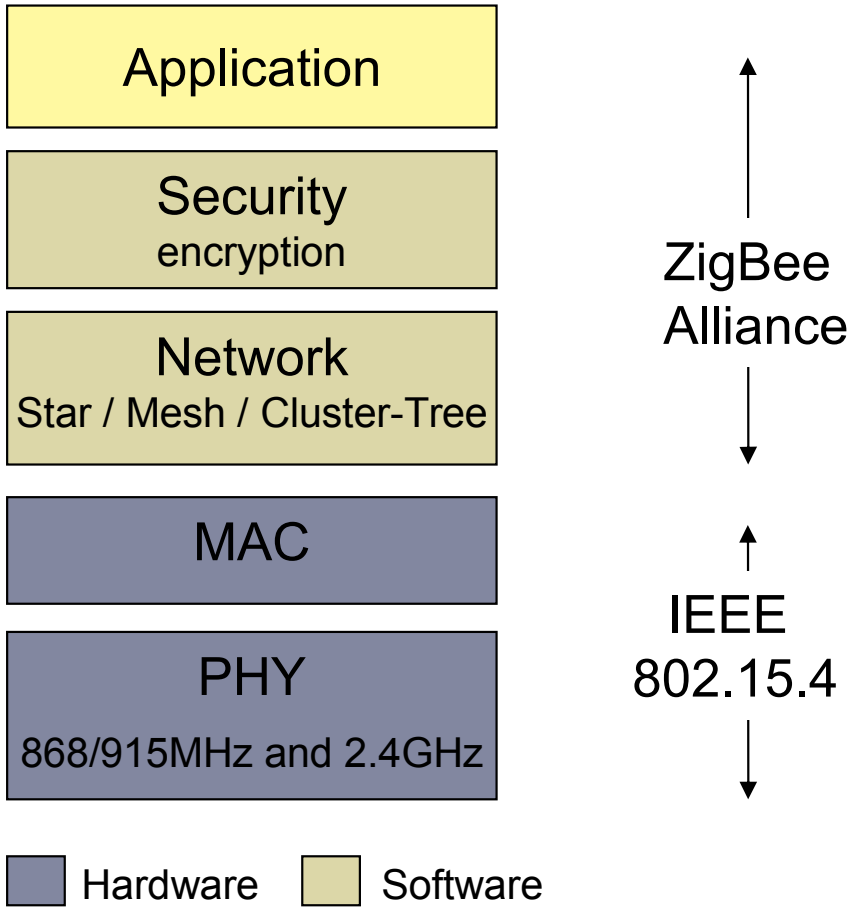
RX sensitivity

Maximize link budget, minimize current consumption

6dB means 4x power !

http://freaklabs.org

Zigbee



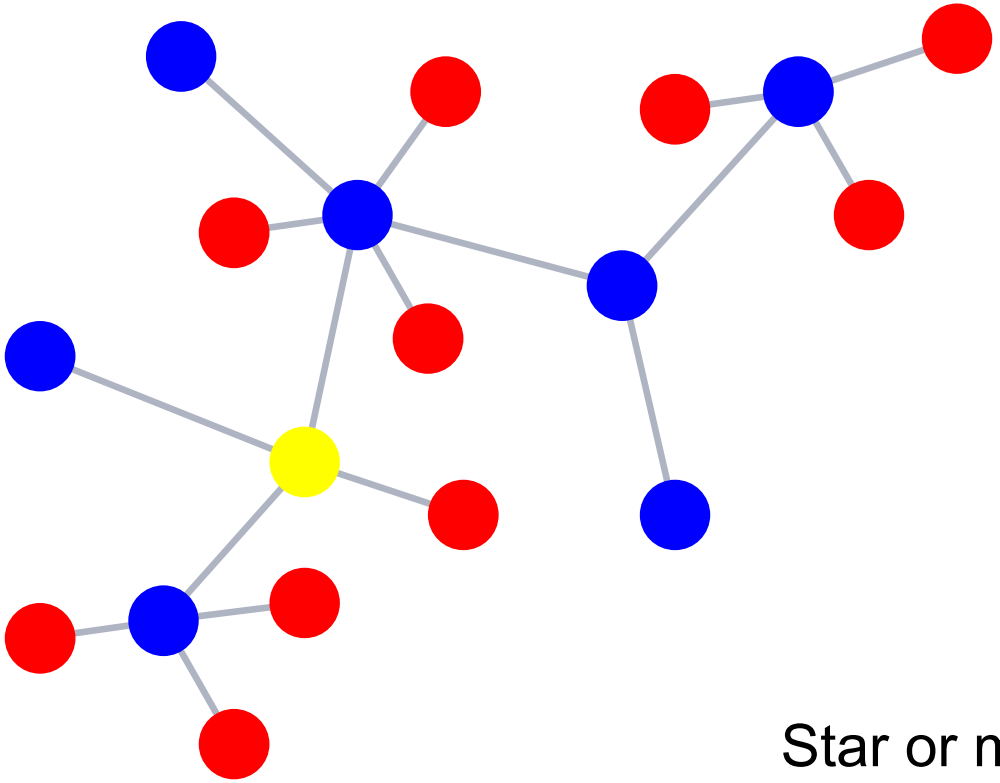
ZigBee Alliance

- "the software"
- Network, Security & Application layers

IEEE 802.15.4

- "the hardware"
- Physical & Media Access Control layers

Zigbee topology (cluster tree)



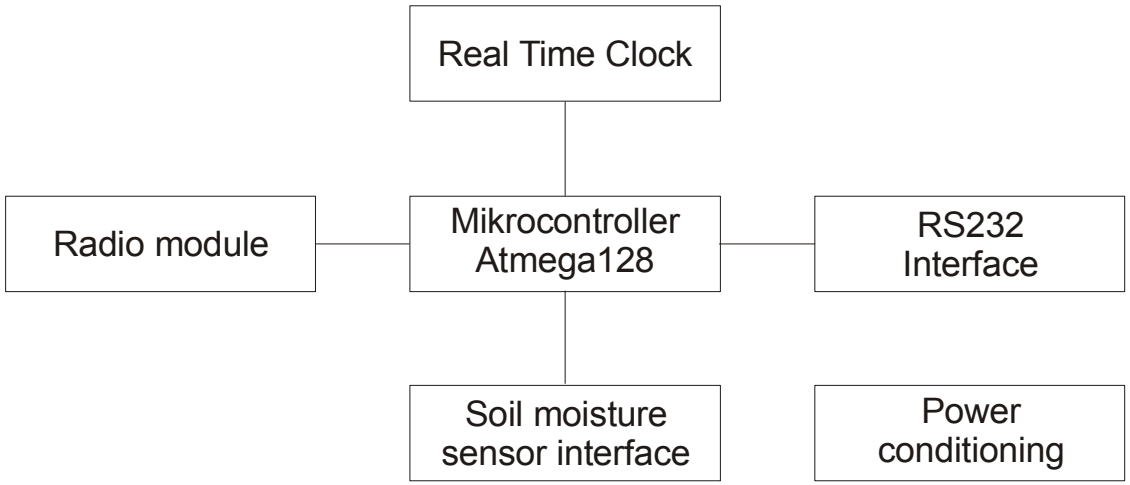
Network coordinator

Router

End device

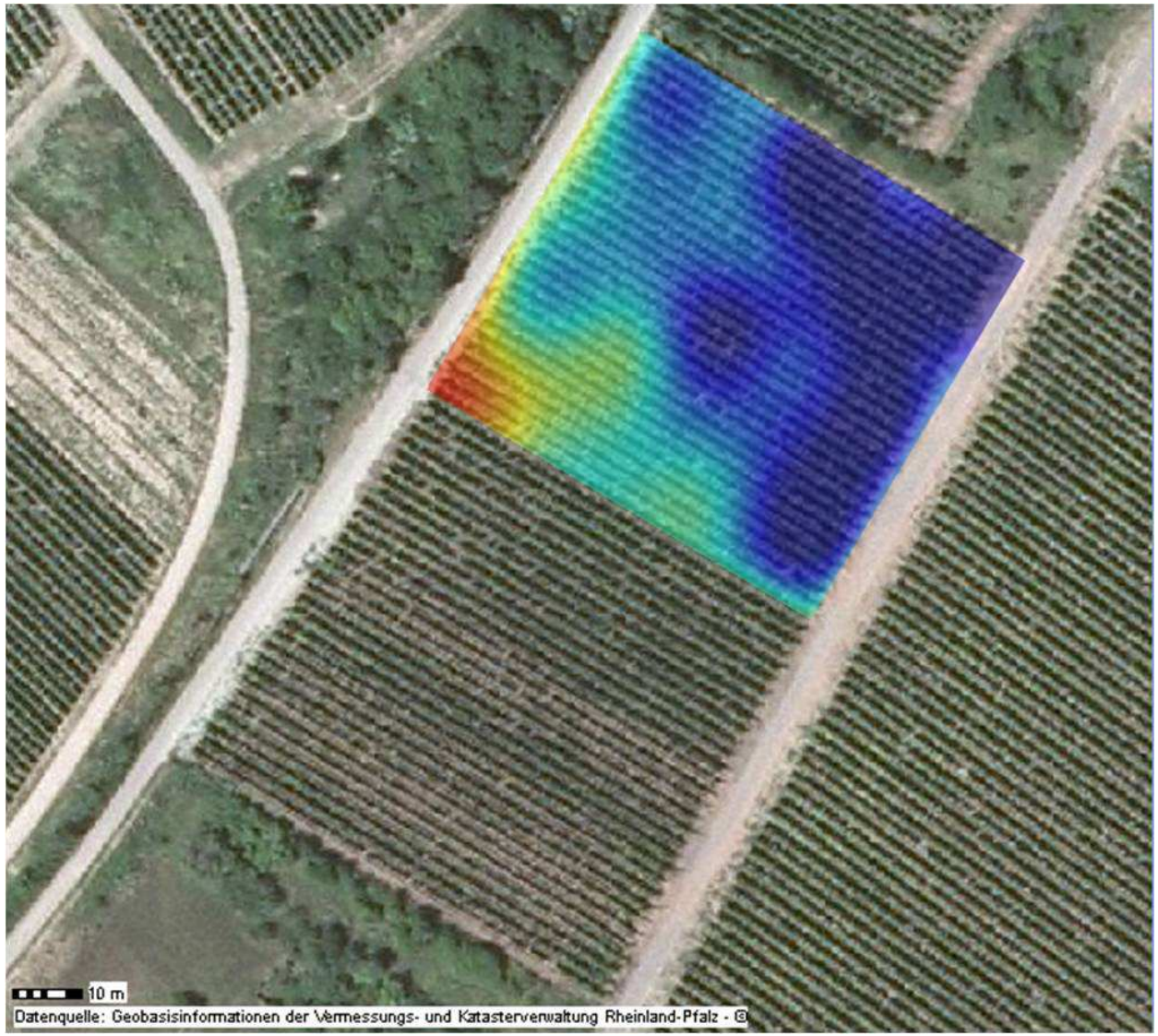
Star or mesh topology also possible
(problem: routers are non-sleeping)

Wireless node for outdoor applications

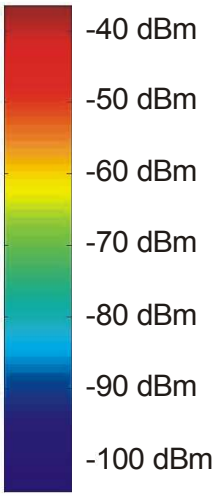


Radio propagation experiment (2.4 GHz)

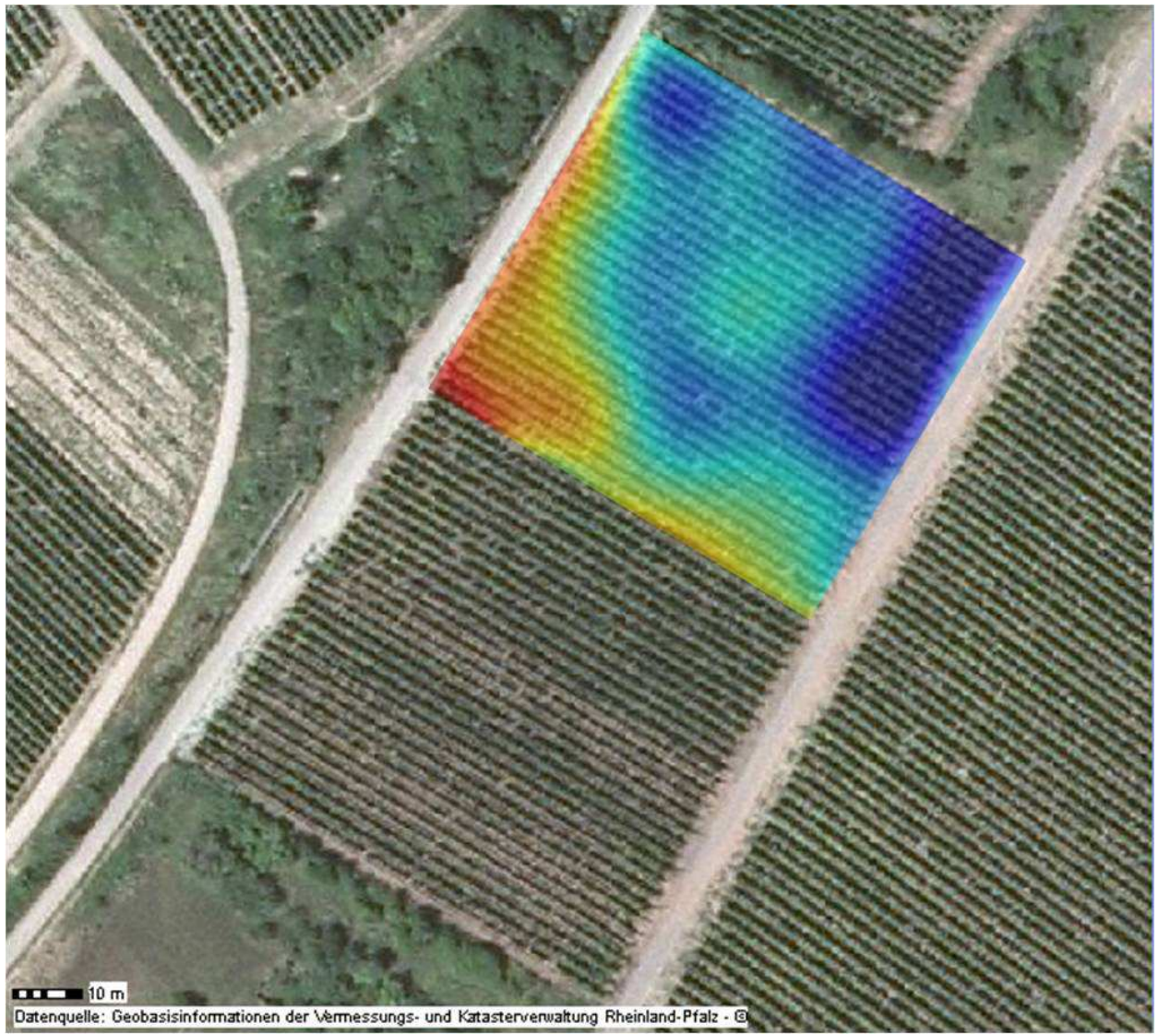
Wireless modules at 5 different heights



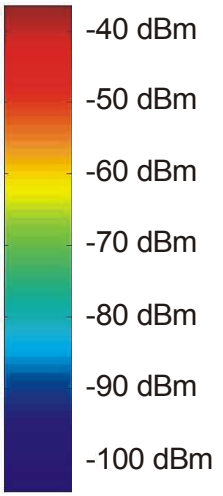
Node height above ground: 10 cm



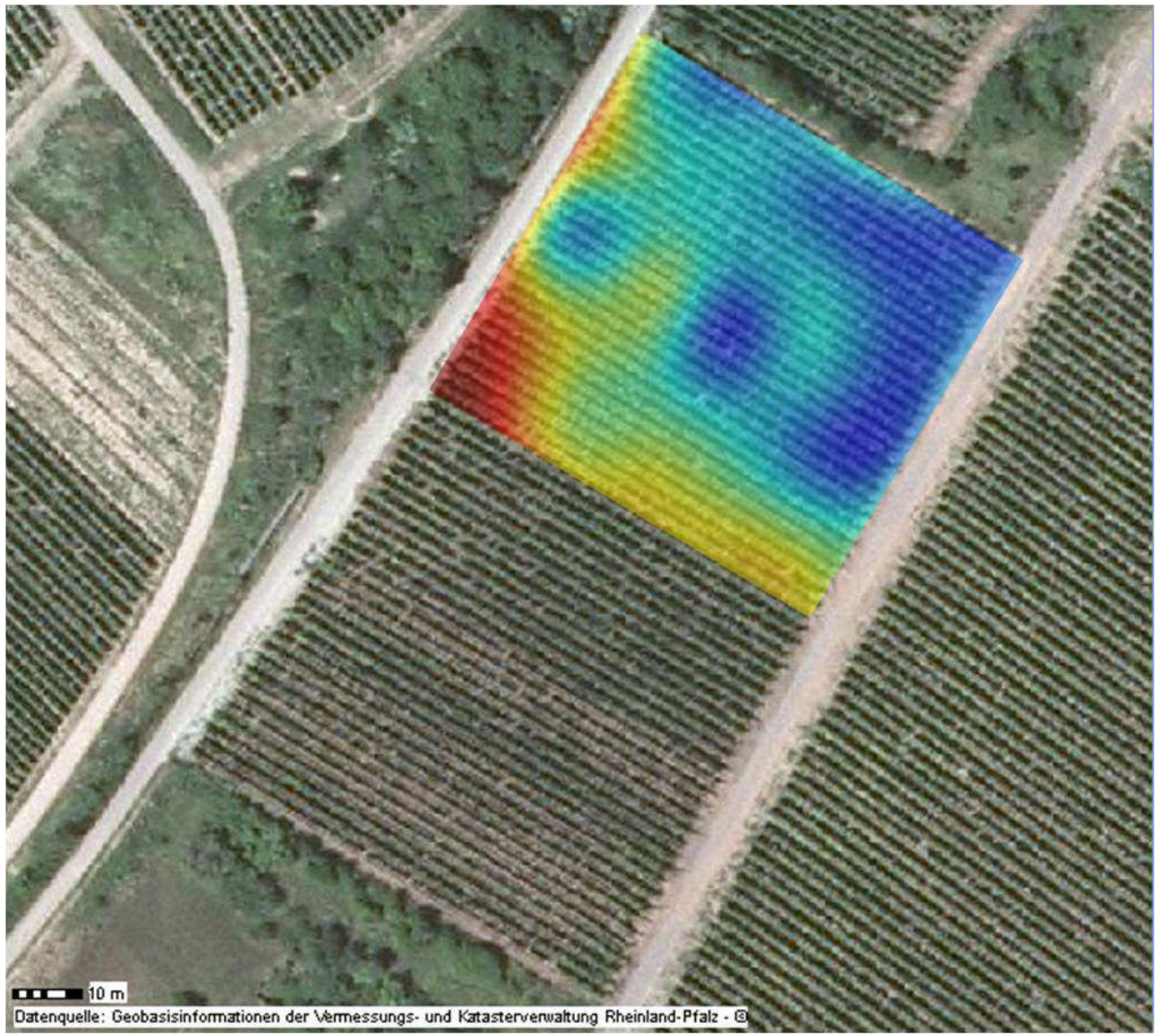
Signal level



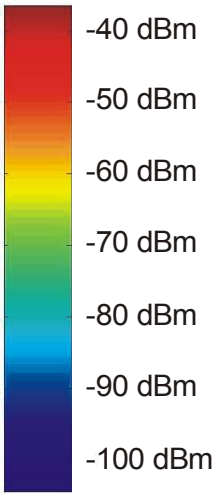
Node height above ground: 60 cm



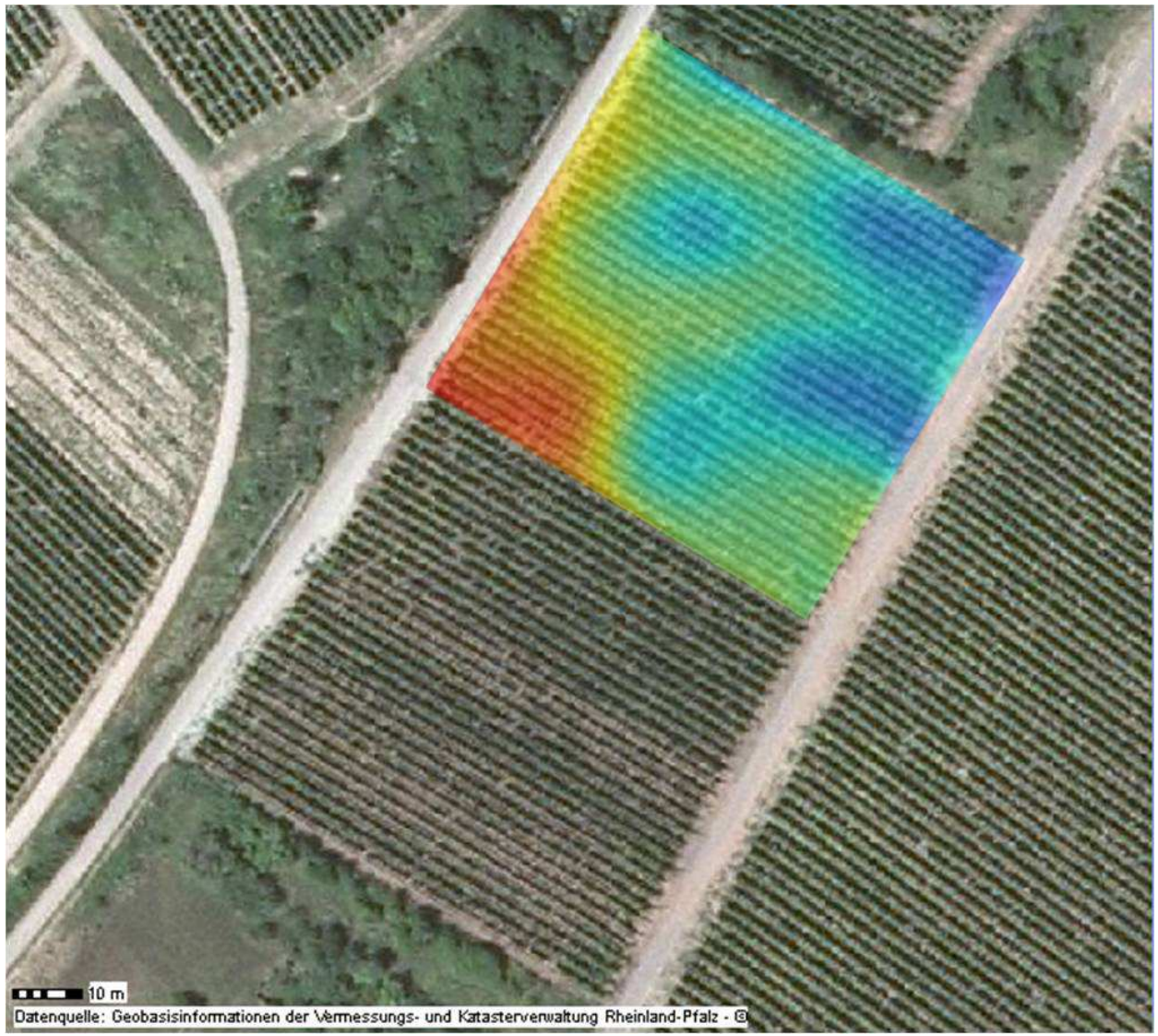
Signal level



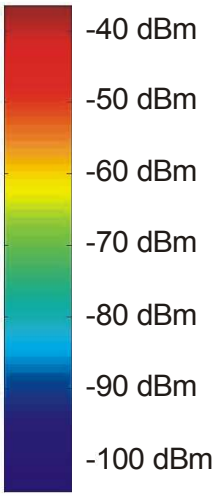
Node height above ground: 110 cm



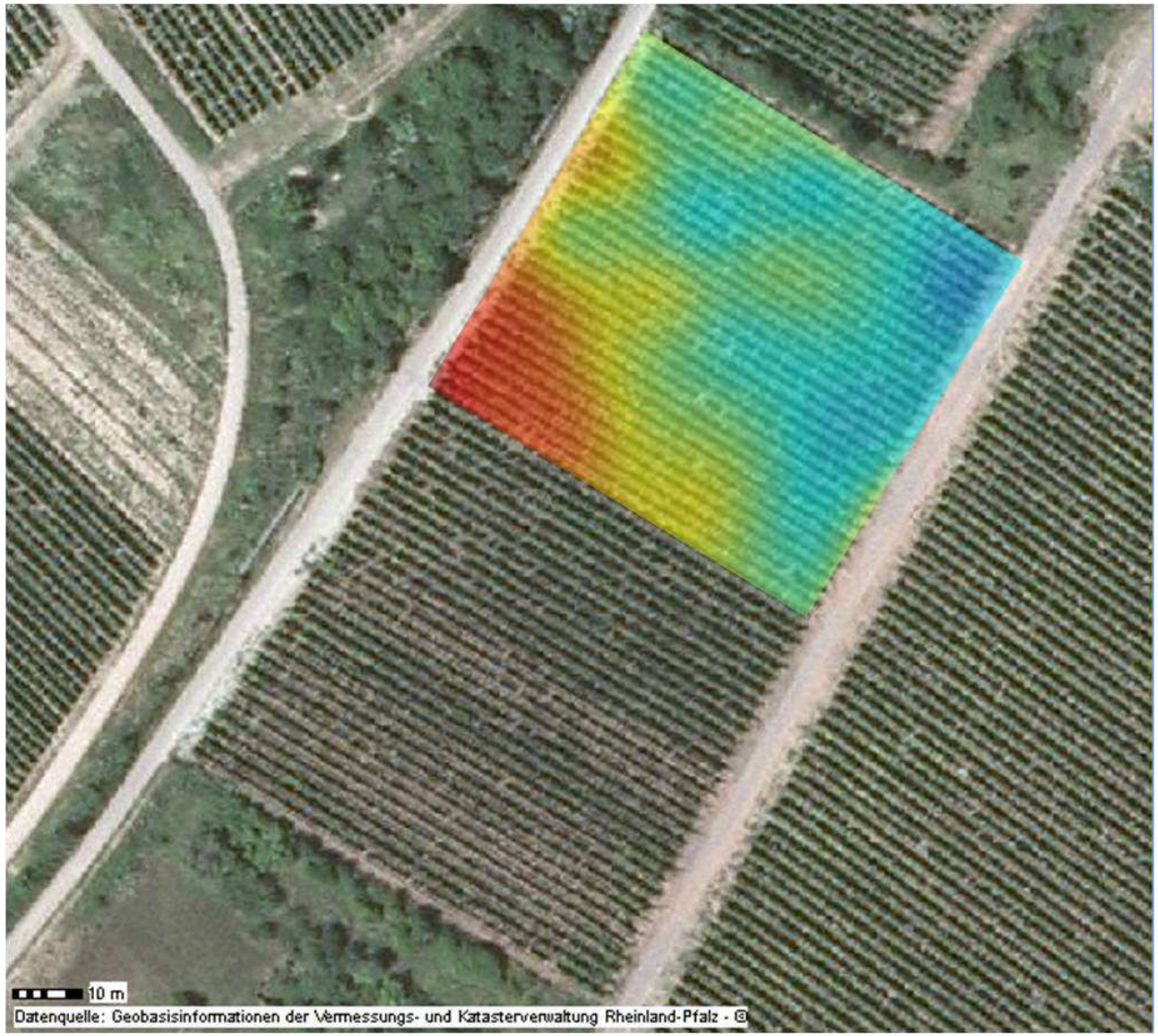
Signal level



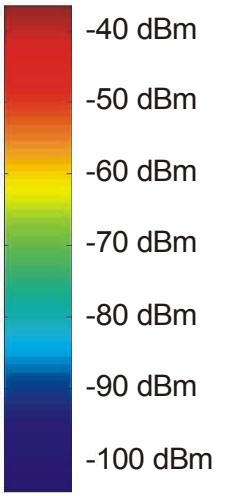
Node height above ground: 160 cm



Signal level

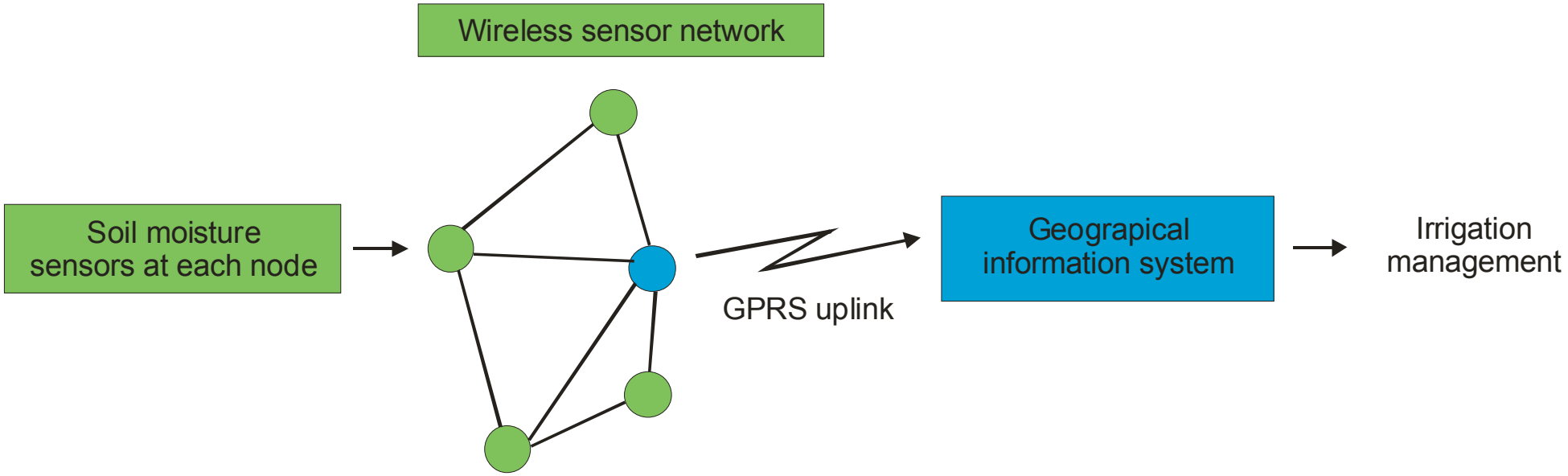


Node height above ground: 210 cm



Signal level

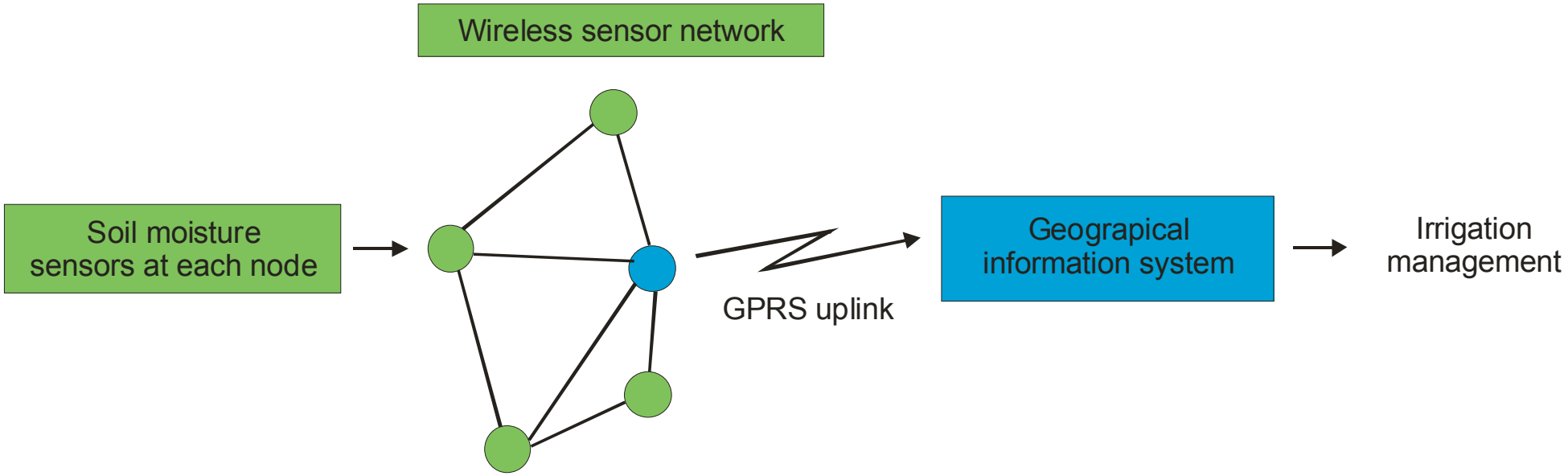
System overview



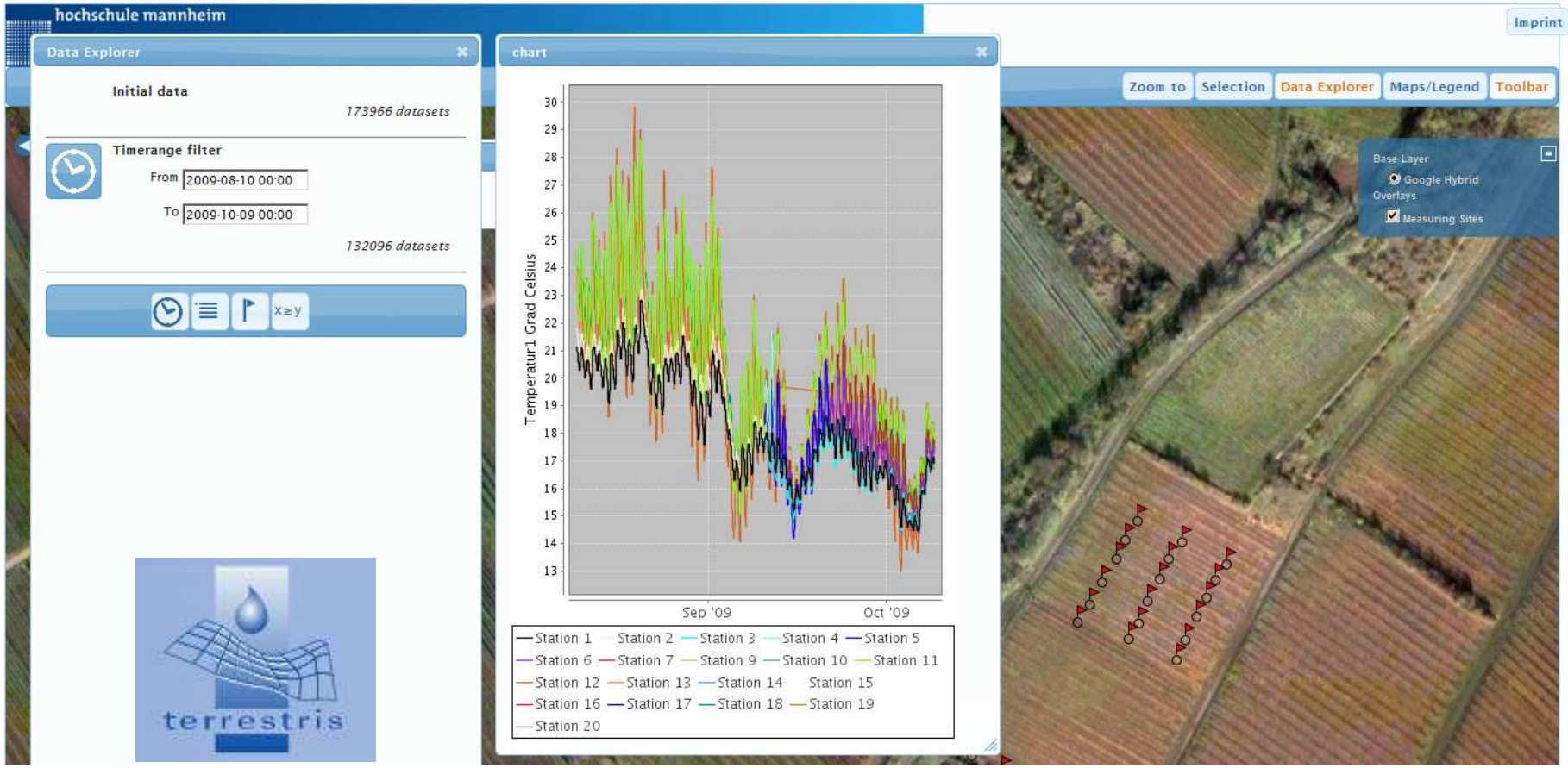
Gateway solution

- Embedded PC (500 MHz, 256 MB RAM, 4 W power consumption)
- GPRS modem
- Standard Debian distribution, Compact Flash card (/ ro, /data rw)
- Autossh for tunneling

System overview

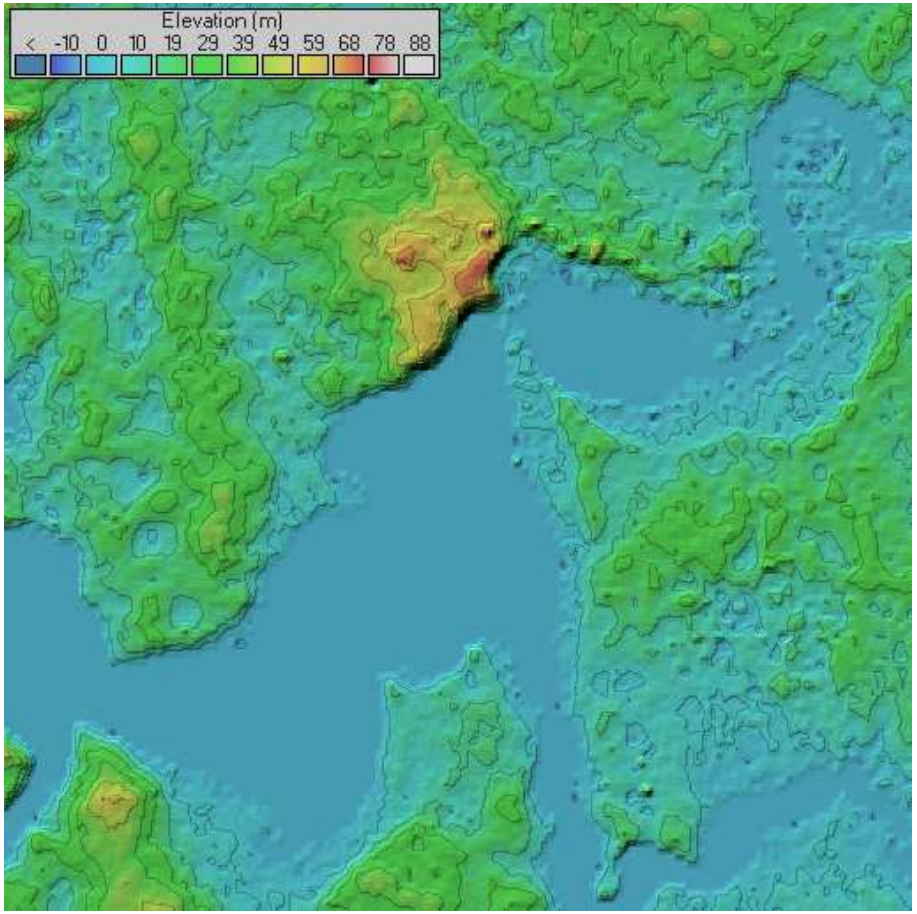


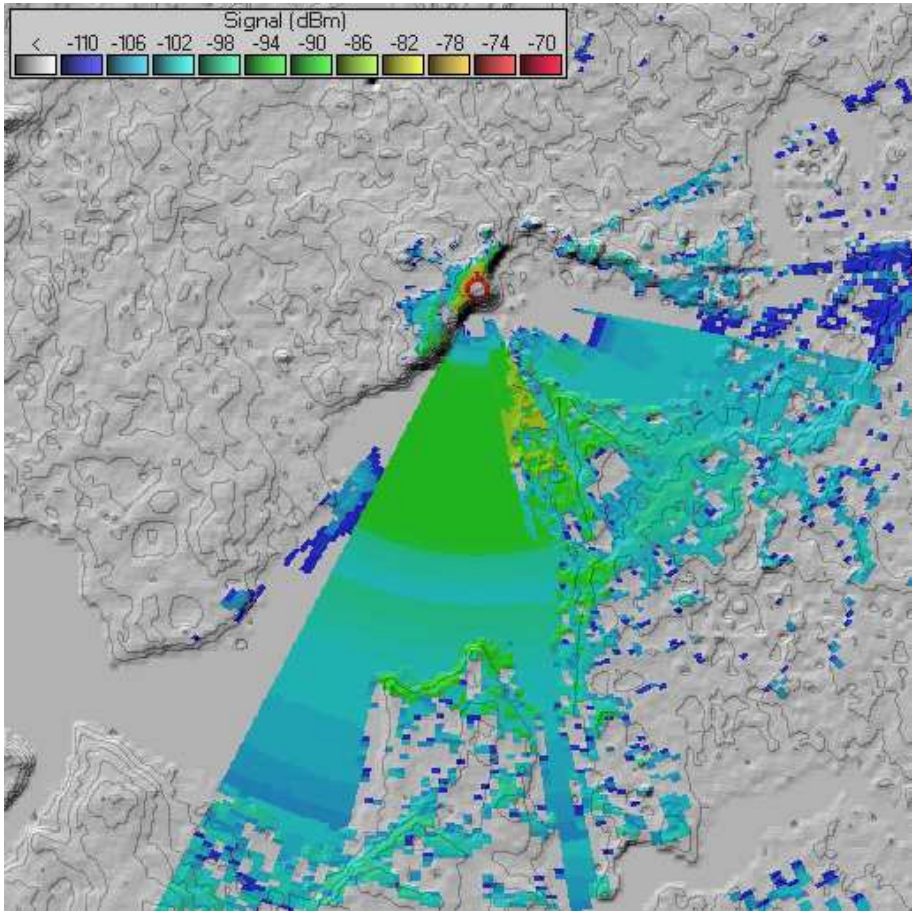
Geograpical information system



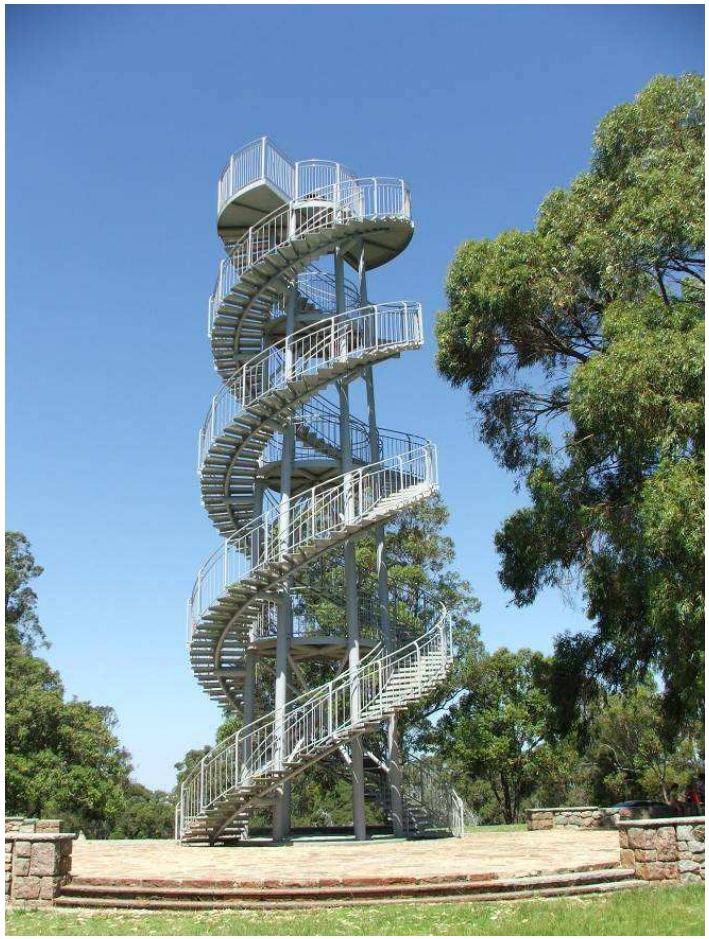
Range measurement (900 MHz) , Kings Park

Topography and radio range calculation

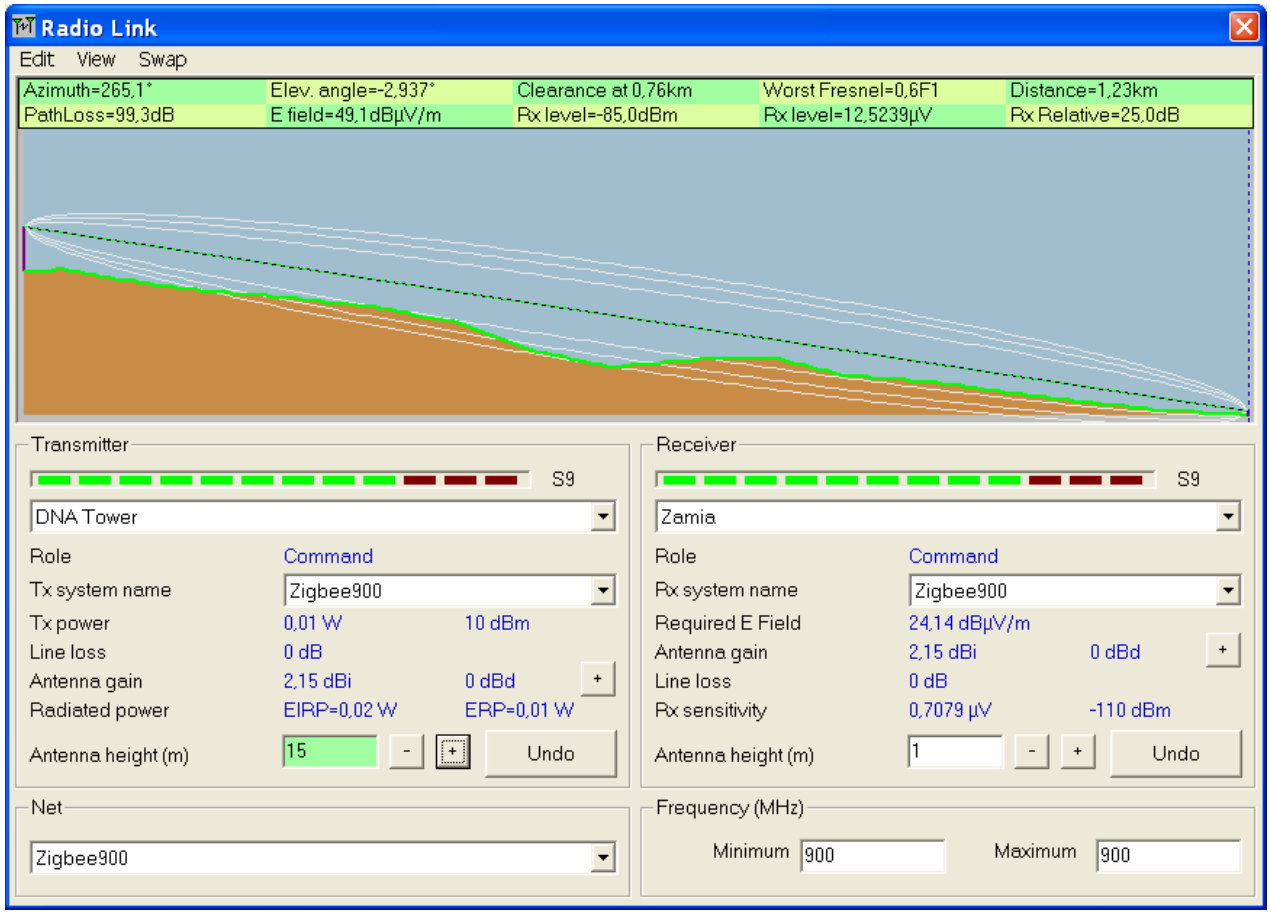




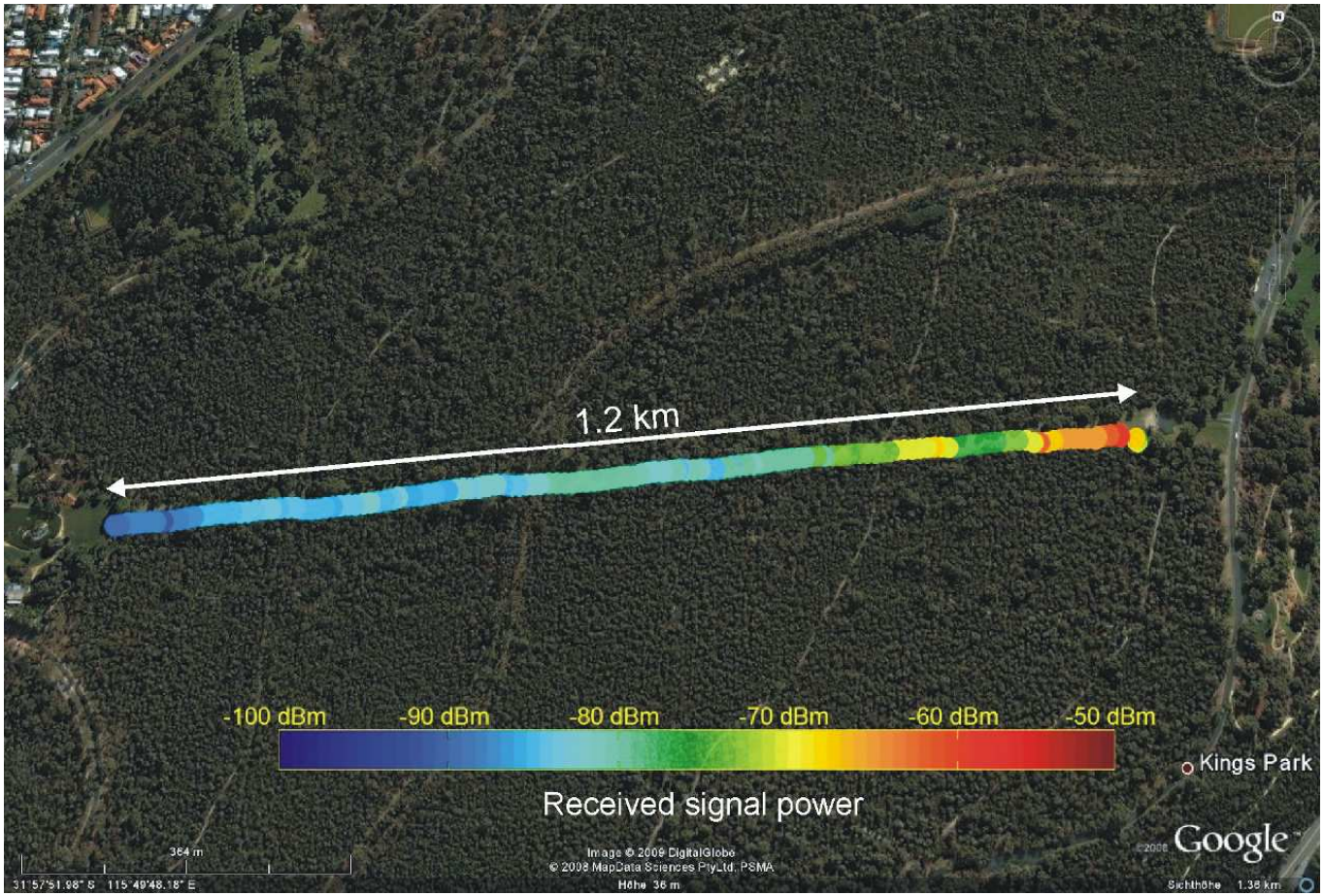
Range measurement (900 MHz), DNA Tower I



Topography Broadway, Kings Park

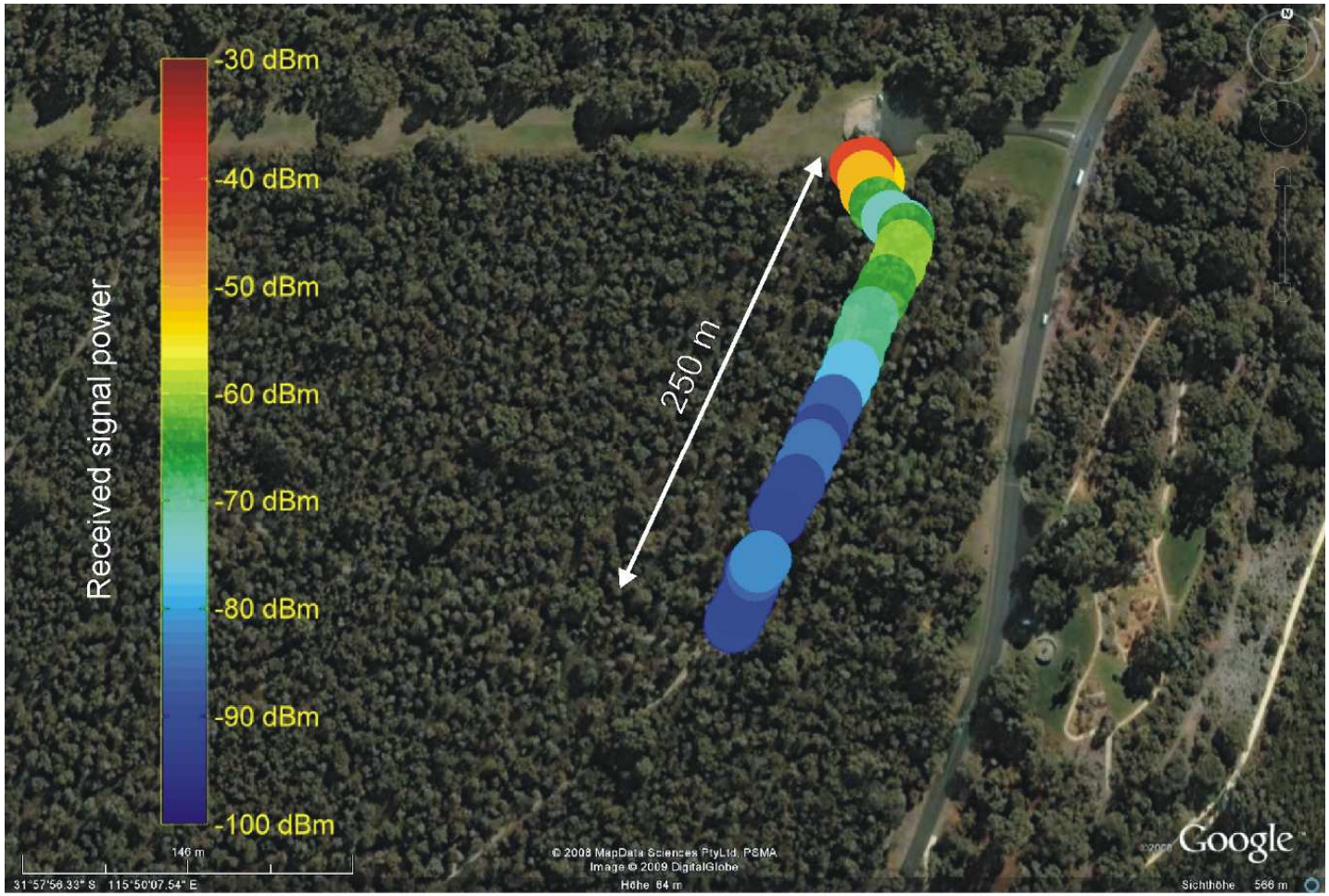


Range measurement (900 MHz), DNA Tower II

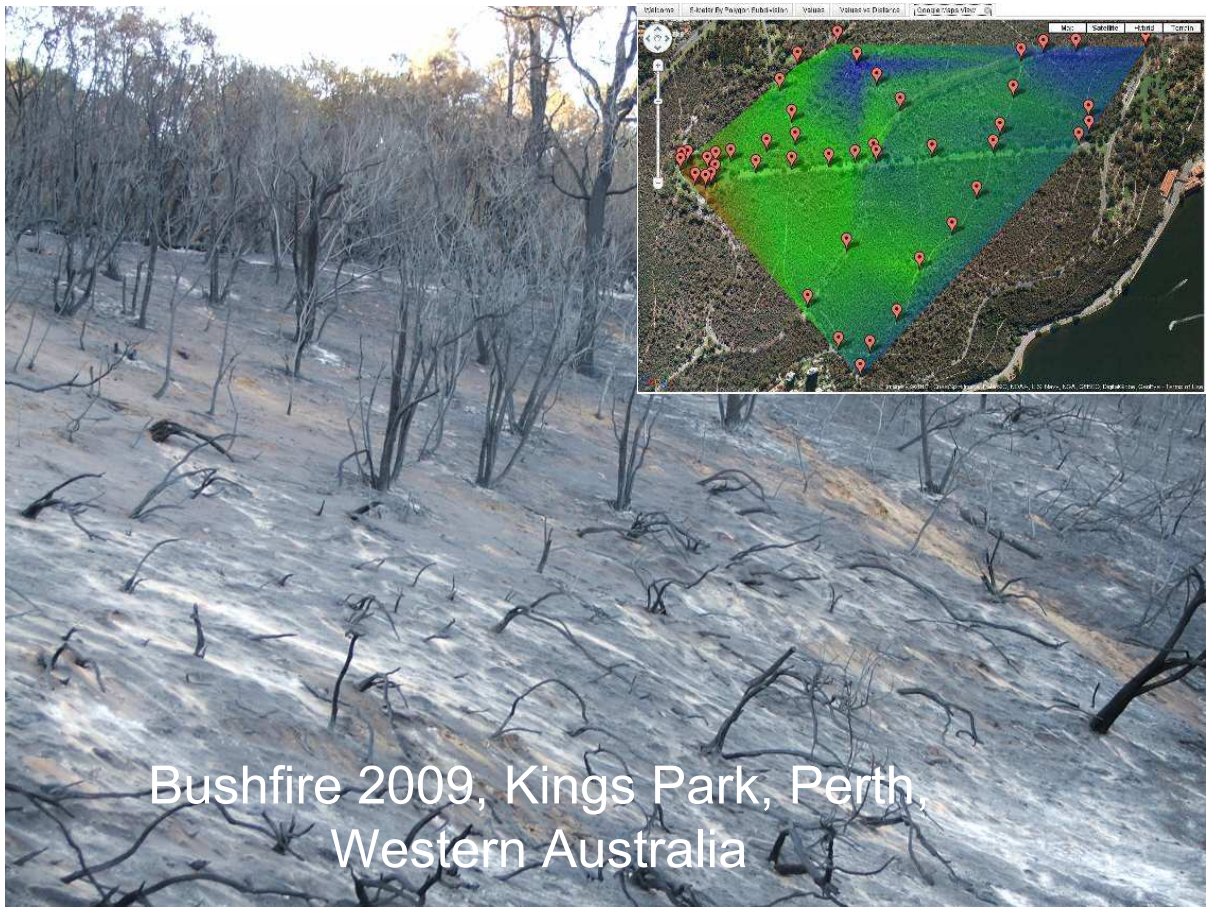


Range measurement (900 MHz), Kings Park

Range measurement (900 MHz), Kings Park

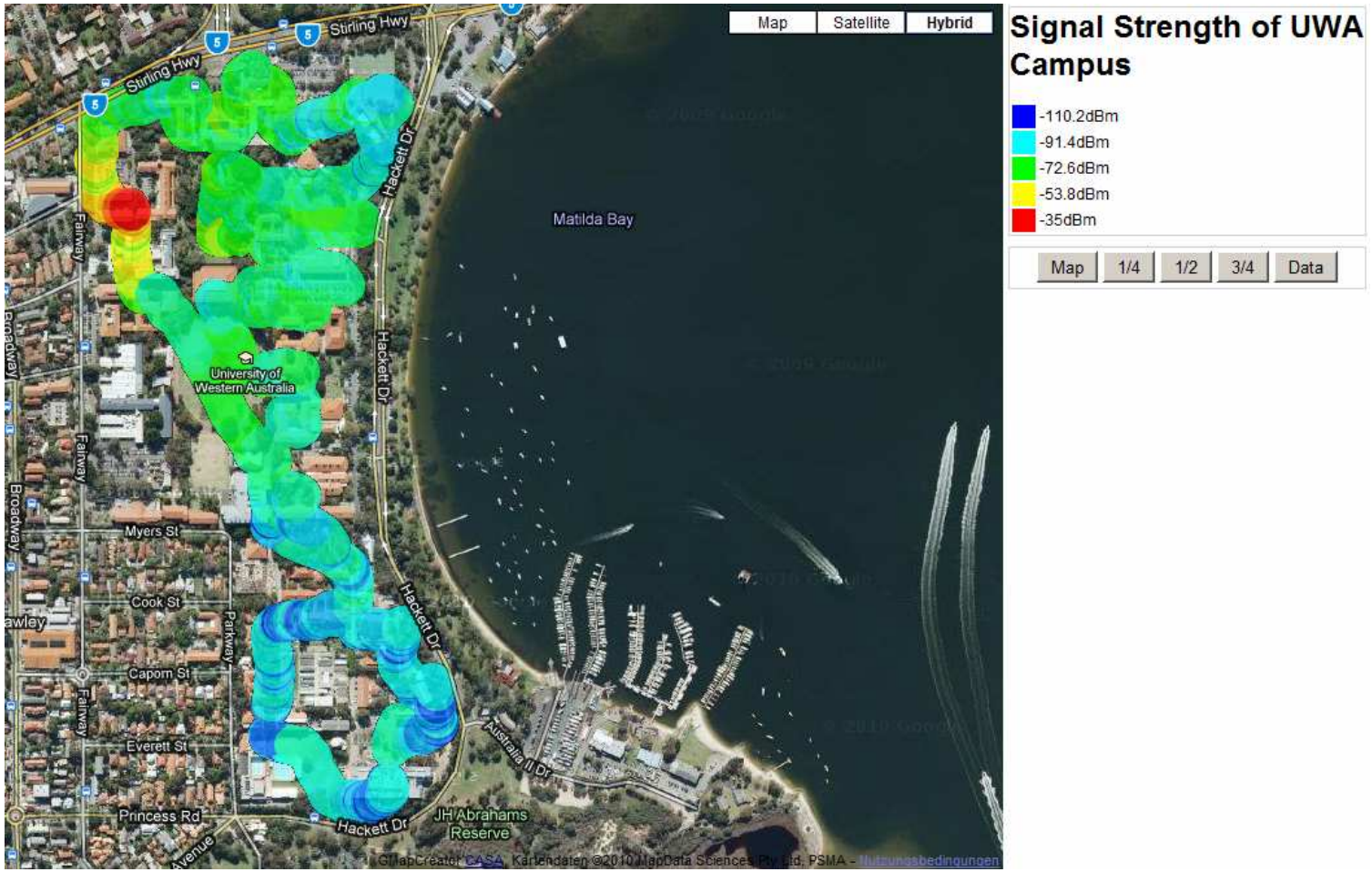


Bushfire warning system



- 20 mW transmitter
- temperature sensor
- software defined radio
- up to 5 km range

Asset tracking



Wireless intelligent seating system

LAE Engineering Systemintegration

mauser SitzKultur

ZIM impulse für wachstum Zentrales Innovationsprogramm Mittelstand

Conclusions

- Soil moisture sensor networks for precision agriculture
- Wireless nodes, gateways and geographical information systems
- Radio propagation models for range prediction and deployment
- Request for complete and reliable systems