Technische Universität Braunschweig

Institute of Operating Systems and Computer Networks

On the Experiences with Testbeds and Applications in Precision Farming

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Motivation by Research

Research on outdoor (W)SNs

- How to achieve robustness and availability (rough environmental conditions)?
- Deal with constrained energy resources
- How to deal with limited connectivity?

Motivation by Application

Smart Farming – sensor networks in agriculture

- Consequential challenges:
  - Limited maintainability:
    → Robustness and Energy Efficiency
  - Limited connectivity:
    → Limited Infrastructure (Opportunistic Networks)

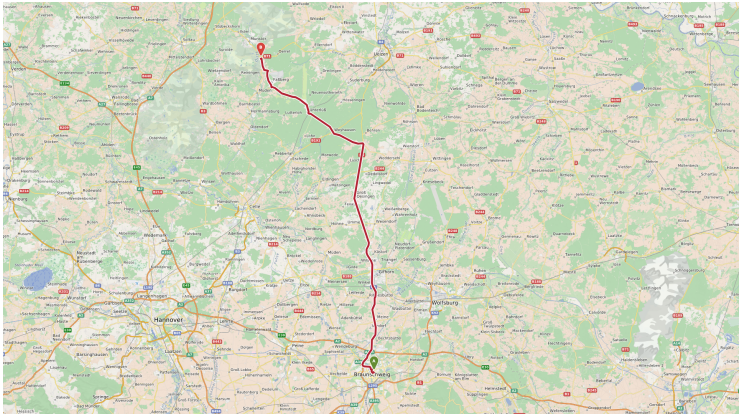
Cooperation with potato research station

Potato research station

- Contact due to begin neighbors
- Possibility for a long-term outdoor testbed
- Additionally sensors for requirements of the research station
  - Temperature, Humidity, Light, ...
- **Constraints**:
  - Limited height of hardware of approx. one meter
  - Cables have to be burrowed >= 20 cm

VSD
VERSUCHSSTATION DETHLINGEN

Challenges (1)



1.5 h by car (single distance)

Challenges (2)

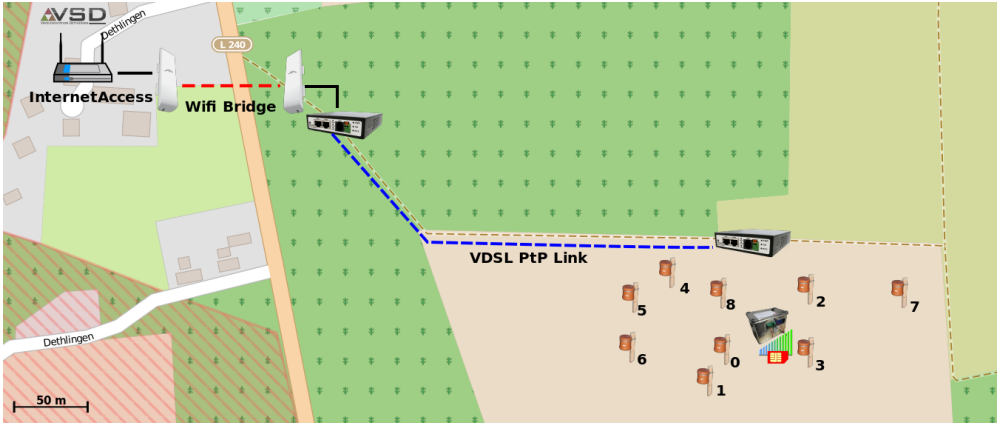
- Regular **farming activities**
  - Tractor
  - Watering
  - Field syringe
- Limited **remote access**
- **Harsh conditions**: Rain, Temperature, Snow
- **Fixed time window** for deploying the network:

J	F	M	A	M	J	J	A	S	O	N	D

PotatoNet – Infrastructure

- Permanent power supply
- WiFi bridge

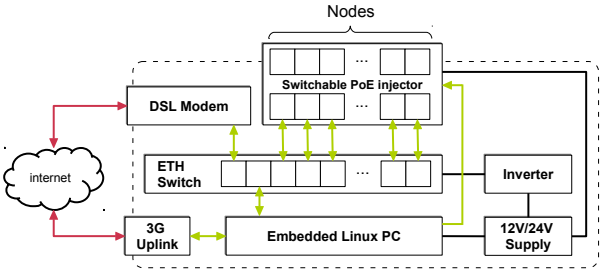
PotatoNet – Setup



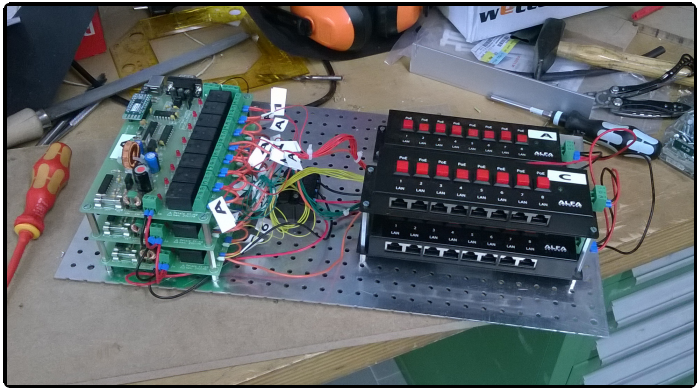
Central Box – Architecture

Components in central box

- Linux IPC (24V powered)
- Ethernet Switch and controllable, passive PoE Injectors
- 24V PSU, Inverter for Ethernet Switch



Central Box – Impressions



Central Box – Impressions

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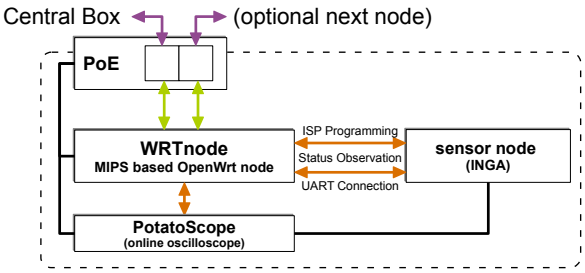
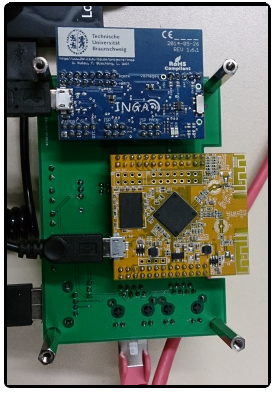
Field Node – Architecture

Components of the field node

- WRTnode (OpenWRT Linux Board)
- INGA (Wireless Sensor Node)
- Powered via PoE → Concatenation of nodes possible



Field Nodes – Impressions



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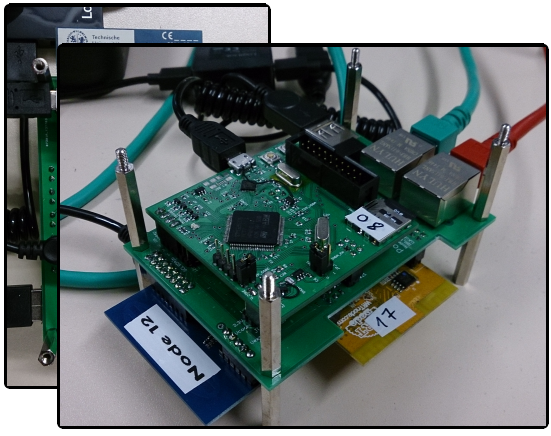

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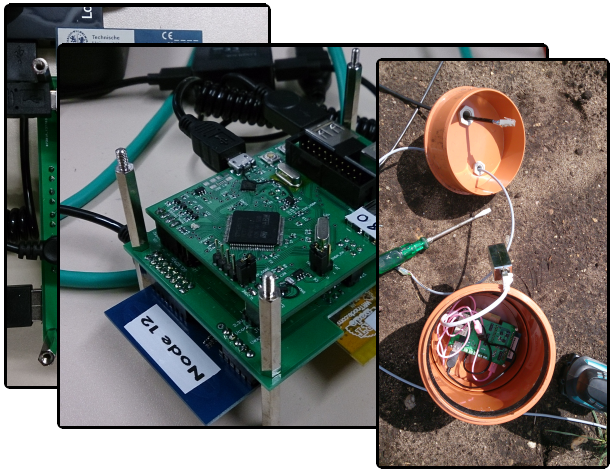

Field Nodes – Impressions

PotatoMesh – Setup

- Deployment on a different field
- No WiFi bridge, but LTE
- Area of interested for the research station far away

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Network setup

Lesson #1: Farming Activities (1)

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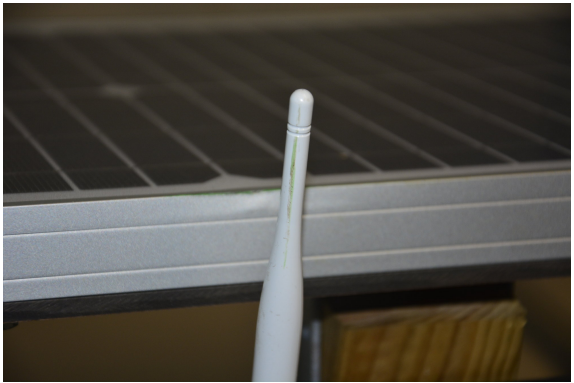
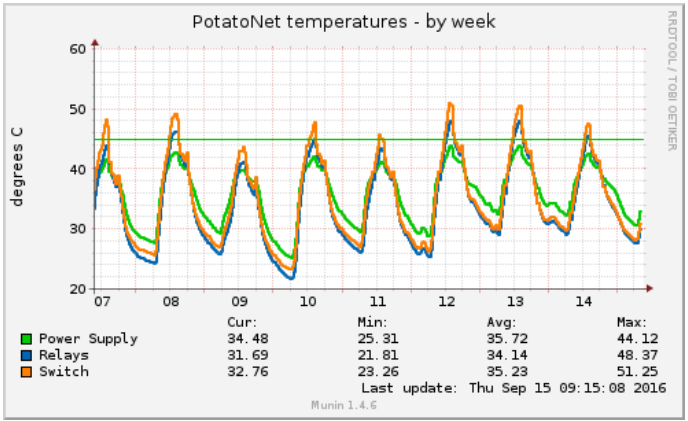
Lesson #1: Farming Activities (2)

- Field Syringe was too low
- Scratch on one of our PotatoMesh nodes



Lesson #2: Temperature

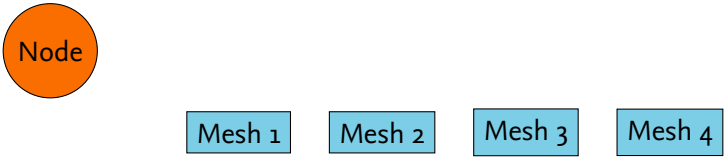
- High temperatures in summer: fan was damaged



Lesson #2: Temperature

- Umbrella on top of the central box to reduce heat

Lesson #3: Clock drift



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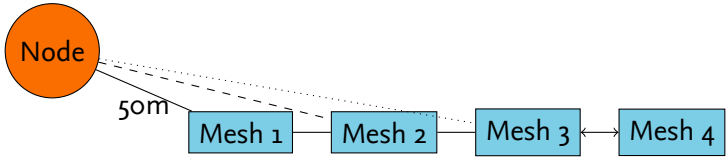
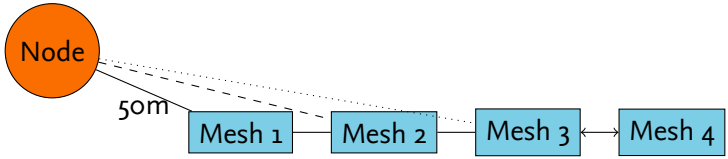


- PotatoMesh is a WiFi-based mesh network

Lesson #3: Clock drift



- PotatoMesh is a WiFi-based mesh network
- Duty cycling of high-power node to reduce energy consumption

Usable time slot

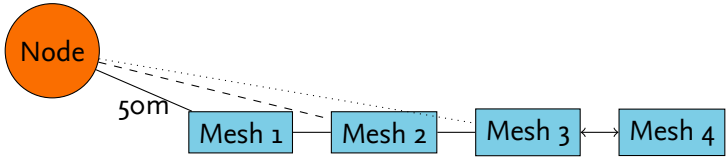
Mesh 1

Mesh 2

Mesh 3

Mesh 4

Lesson #3: Clock drift



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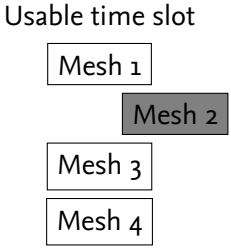

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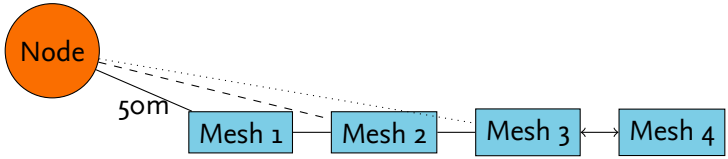

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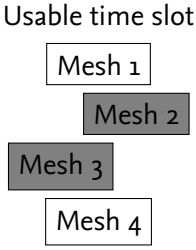

Lesson #3: Animals

- Use infrared sensor to measure surface temperature
- Requires direct line-of-sight

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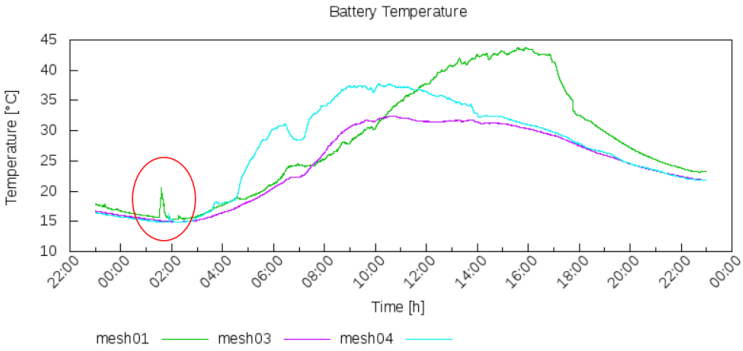
- Use infrared sensor to measure surface temperature
- Requires direct line-of-sight
- Spider in one of the housings

Lesson #3: Animals (2)

- Bucket used to cover battery

Lesson #3: Animals (2)

- Temperature increase during night time



Lesson #3: Animals (2)

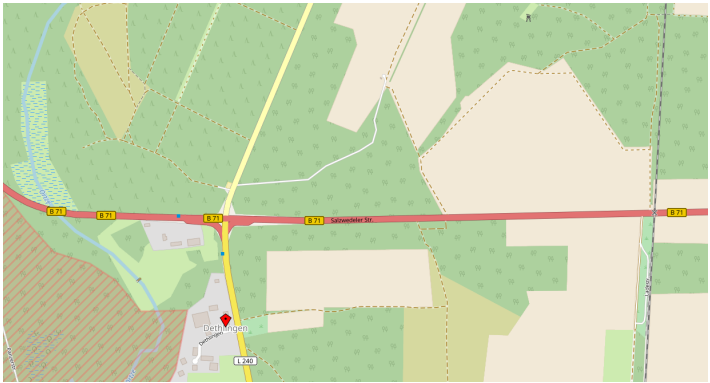
- Nibbled cable

Lesson #3: Animals (2)

- Additional slab below the battery

Lesson #4: Vandalism

- PotatoMesh node was stolen



Lesson #4: Vandalism

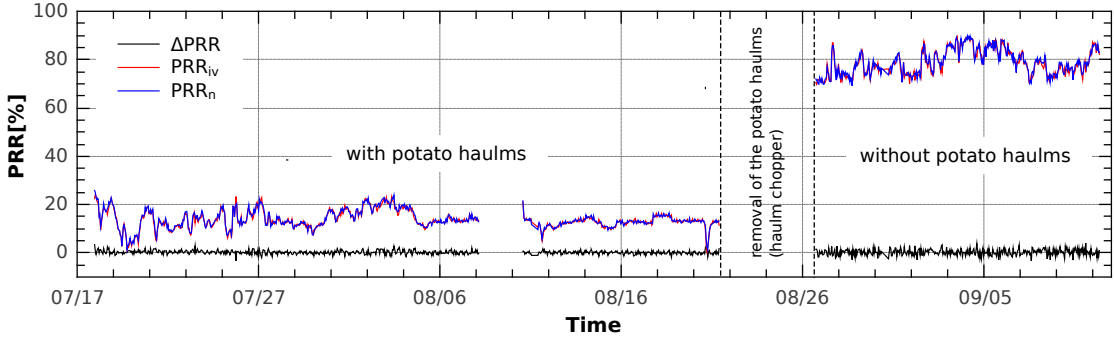
- Cable was cut

Lesson #4: Vandalism

- Cable moved by a human or an animal?

Lesson #5: RF Shadowing

- Good for research, bad for maintenance

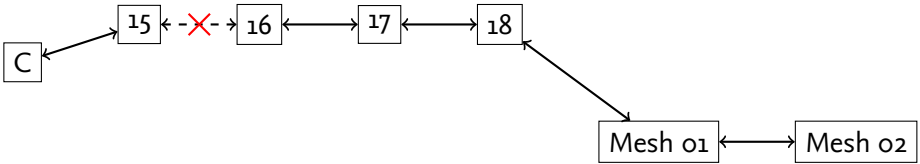


Lesson #5: RF Shadowing

- Problem: Potato plants grew larger than we were told

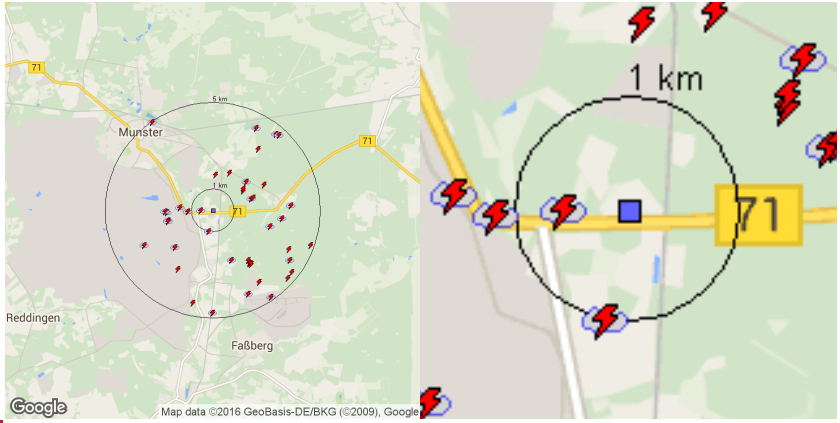
Lesson #6: Weather

- unreachable nodes (including mesh network)



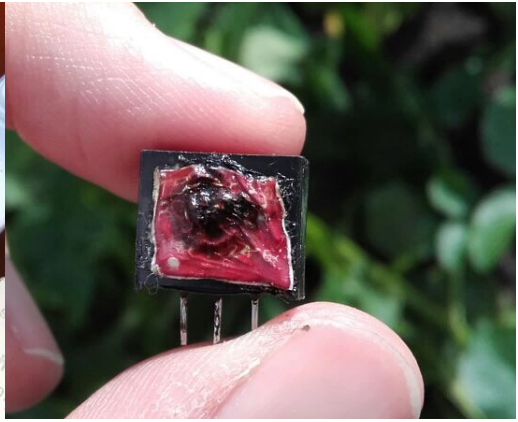
Lesson #6: Weather

- Heavy thunderstorm the day before, data provided by Siemens BLIDS service



Lesson #6: Weather

- Electromagnetic field couplying in ethernet cable's shield



Concepts

Initial Requirements

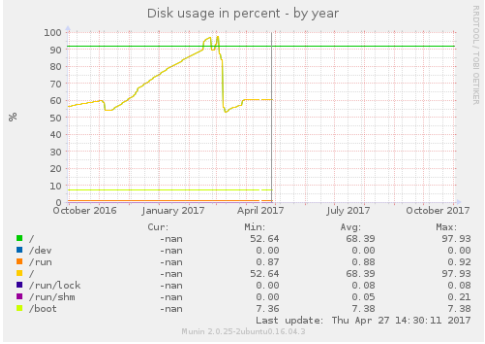
- well known (from own and other related work)
- awareness of long distance and remote access
- this heavily influenced the system design

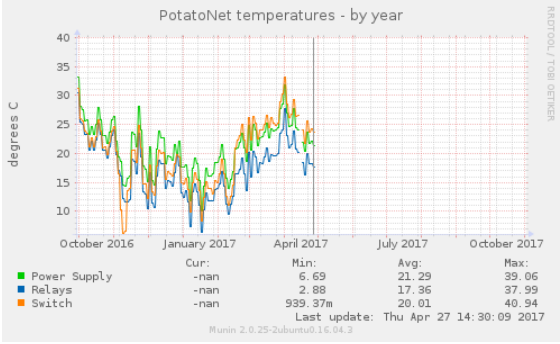
Unexpected Causes

- Many ”fails” were unexpected and could not have been prevented easily
- But: We learned from them!

Concept #1: Monitoring

System and process monitoring (e.g. munin, supervisord, ...)





Concept #1: Monitoring

Installation of a webcam

Time lapse Video

Concept #2: Take everything with you!

Conclusion

Despite all provisions we experienced a few fails

- Animals
- Plowing
- Lightning Strike

Many Success Stories

- So far 18 significant publications
  - e.g. at DCoSS, SECON, Senseapp, Chants, ...
- More than 14 student thesis
- Cooperation with other research groups

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