Performance Control in Wireless Sensor Networks

WSN Evaluation in Industrial Environments

First results and lessons learned

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Project Motivation

Petrogal Oil Refinery

- 35 000 cabled sensors and actuators installed
- monitoring of pressure, flow, valve states, etc.
- monitoring, semi-automatic actuation and fully-automatic closed-loop control

Wired systems are

- Inflexible, installation is time consuming
- complicated and costly to adapt and to extend

Project Goals

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Create a Wireless Sensor Network, that

- honours application requirements
- ensures network and software performance
- embraces the planned deployment approach
- performs debugging and reconfiguration of nodes
- integrates with industry IT systems (e.g. ERP, ERM)
- is proven in a real-world industrial plant

Application Requirements

- low transport **delay**
  - 1 second for actuation and sensing
- high transport **reliability**
  - Up to 99.99% for some scenarios
- high **sampling rates**
  - Up to 1 Hz for certain sensors
- small **sample sizes**
  - 32 bit sufficient for most sensors and actuators

Petrogal Oil Refinery Testbed

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Current state

- 2500 m^2 covered area
- 14 sensors (flow / pressure)
- 1 flow sensor with actuator
- 1 sink inside portable office container (incl. backend PCs)

Planned in the near future

- 3500 m^2 covered area
- 14 additional nodes / sensors

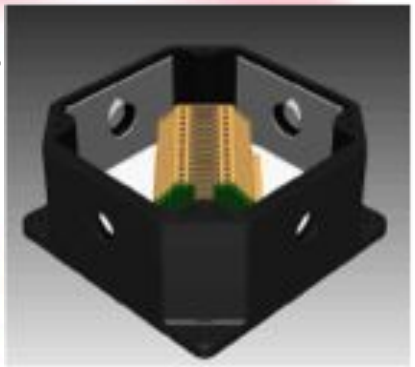
Refinery Safety Regulations

Personal Safety Requirements

- full day training
- personal Equipment
  - fire-proof overall
  - boots, safety glasses, helmet

Electronic Equipment Safety Requirements

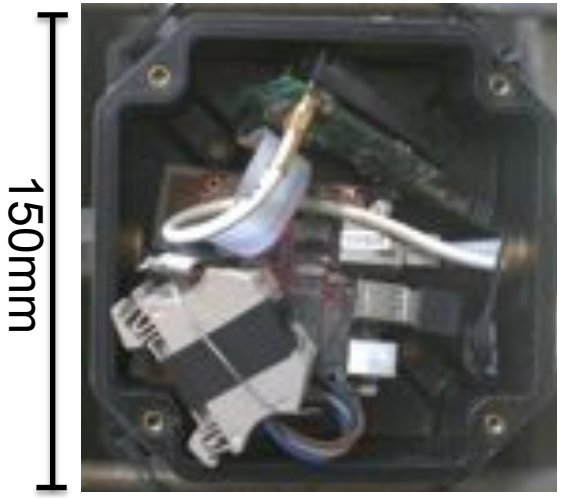
- ATEX certification necessary
- no uncertified devices in the open
- sensor nodes installed indoors or inside certified ATEX boxes with external antennas

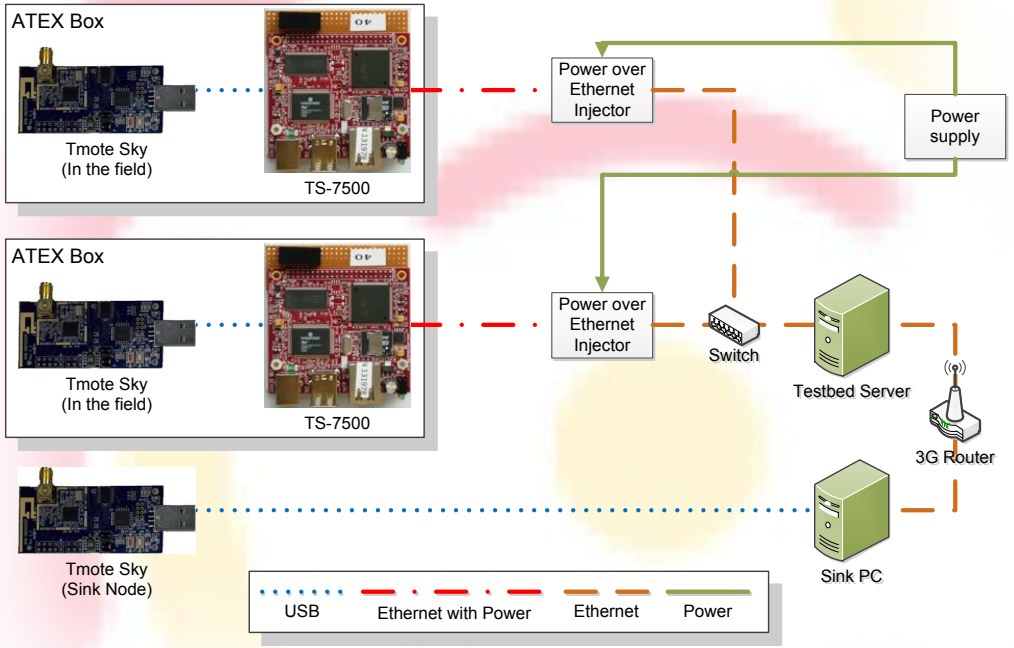


Source: ehawke.com

Remote Access to Testbed

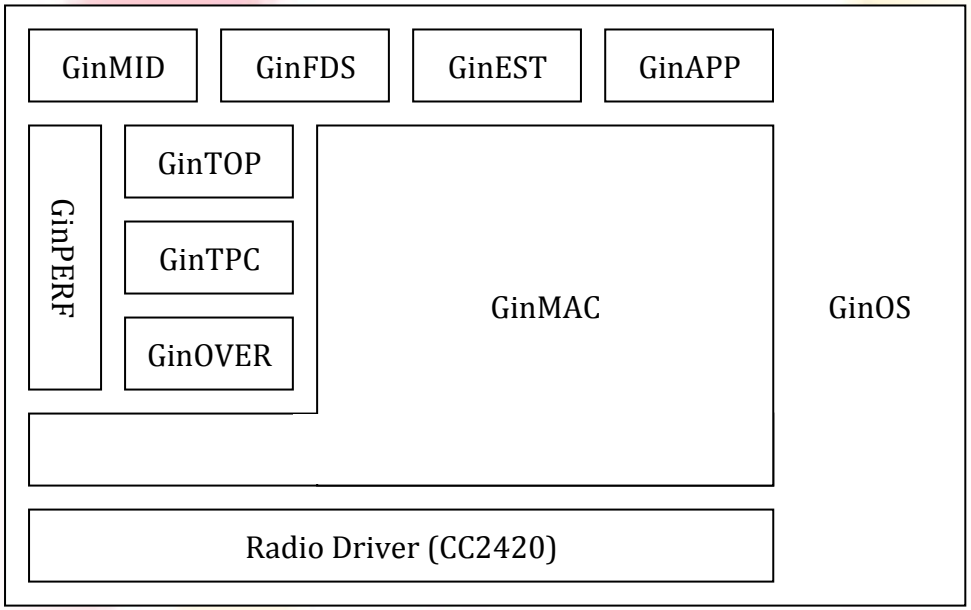
- tiny embedded PCs connected to Tmote Skys
- powered and networked over Ethernet
- flash images and logs from/to central testbed server
- remote access to test-bed via 3G uplink





GINSENG Components

- Target platform is Tmote Sky: MSP430 + CC2420
- **GinOS**: Contiki + real time support + ring file system
- **GinMAC**: exclusive TDMA multi-hop MAC
- **GinTOP**: dynamic topology forming
- **GinMID**: distributed middleware
- **GinAPP**: GINSENG Application



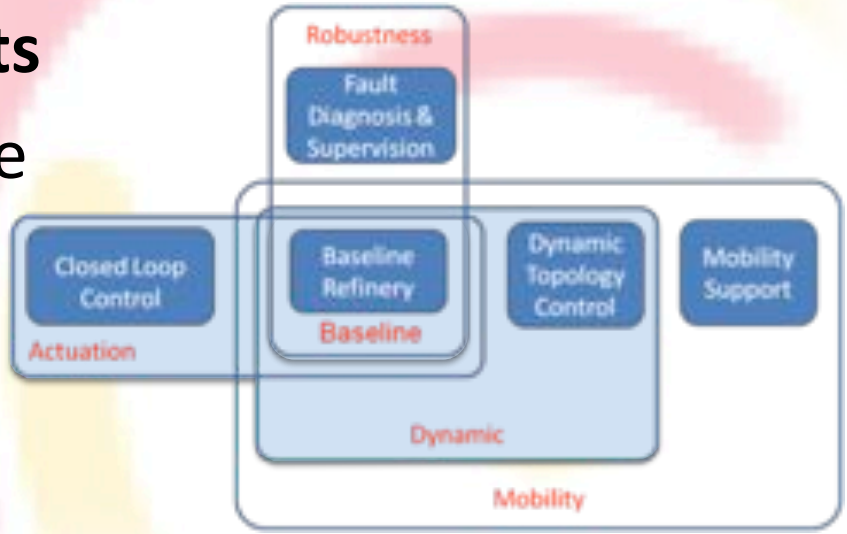
Evaluation Methodology

In-Lab experiments

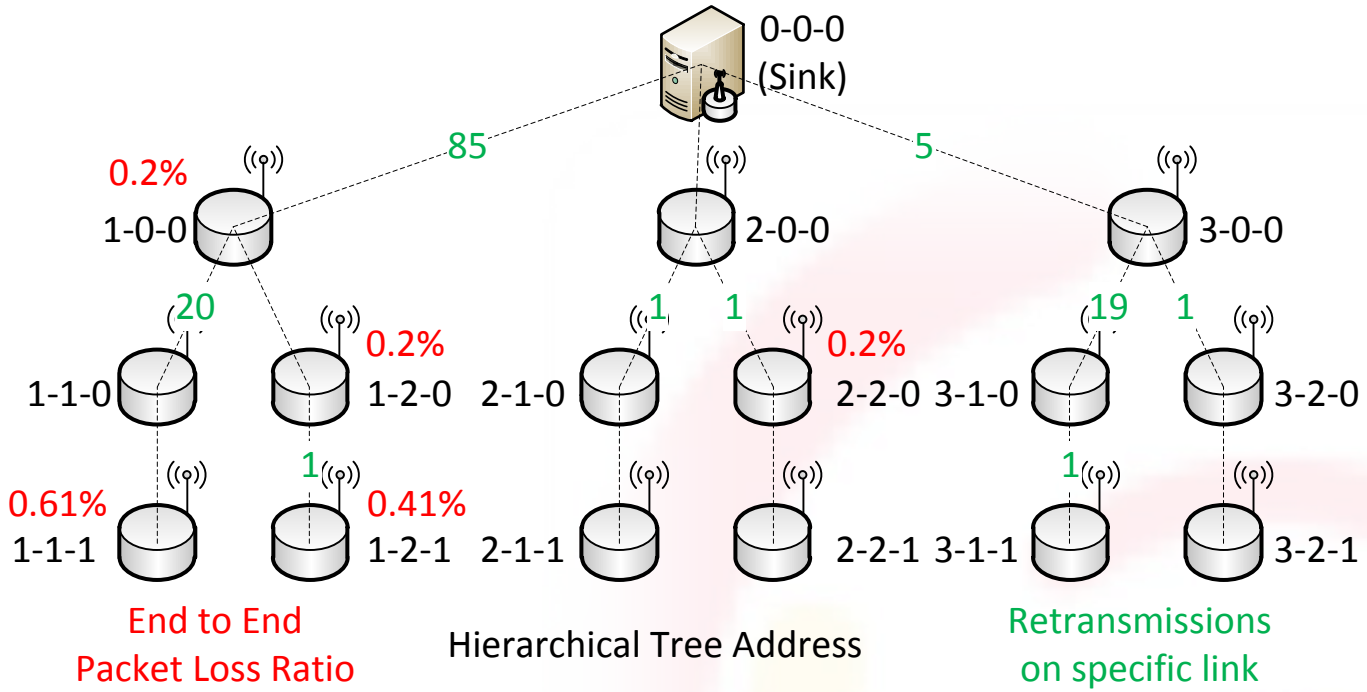
- due to large number of possible configurations, extensive per-component experiments in labs
- provide base line numbers and create expectations

Refinery Testbed experiments

- modify one option at a time
- verify in-lab results
- prove system in real industrial setting



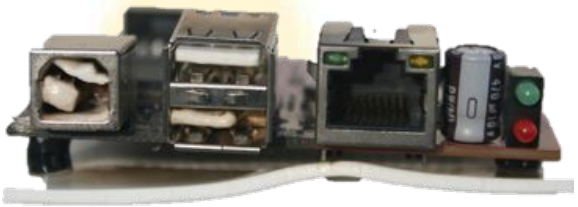
Exemplary Baseline Results



- maximum delay of 900 ms, mostly below 500 ms
- power Consumption 0.1 – 0.9 mW (in 30 minutes)
- losses can be pinned down onto specific links

Lessons Learned

- overhead of personal and equipment safety procedures should not to be underestimated
- remote access significantly increases usability and usage efficiency of testbed
- huge distances in testbed are problematic for backend cabling (e.g. Ethernet)
- Tmotes are occasionally unresponsive and require a power cycle
- data sheets cannot be trusted, things will go wrong at some point



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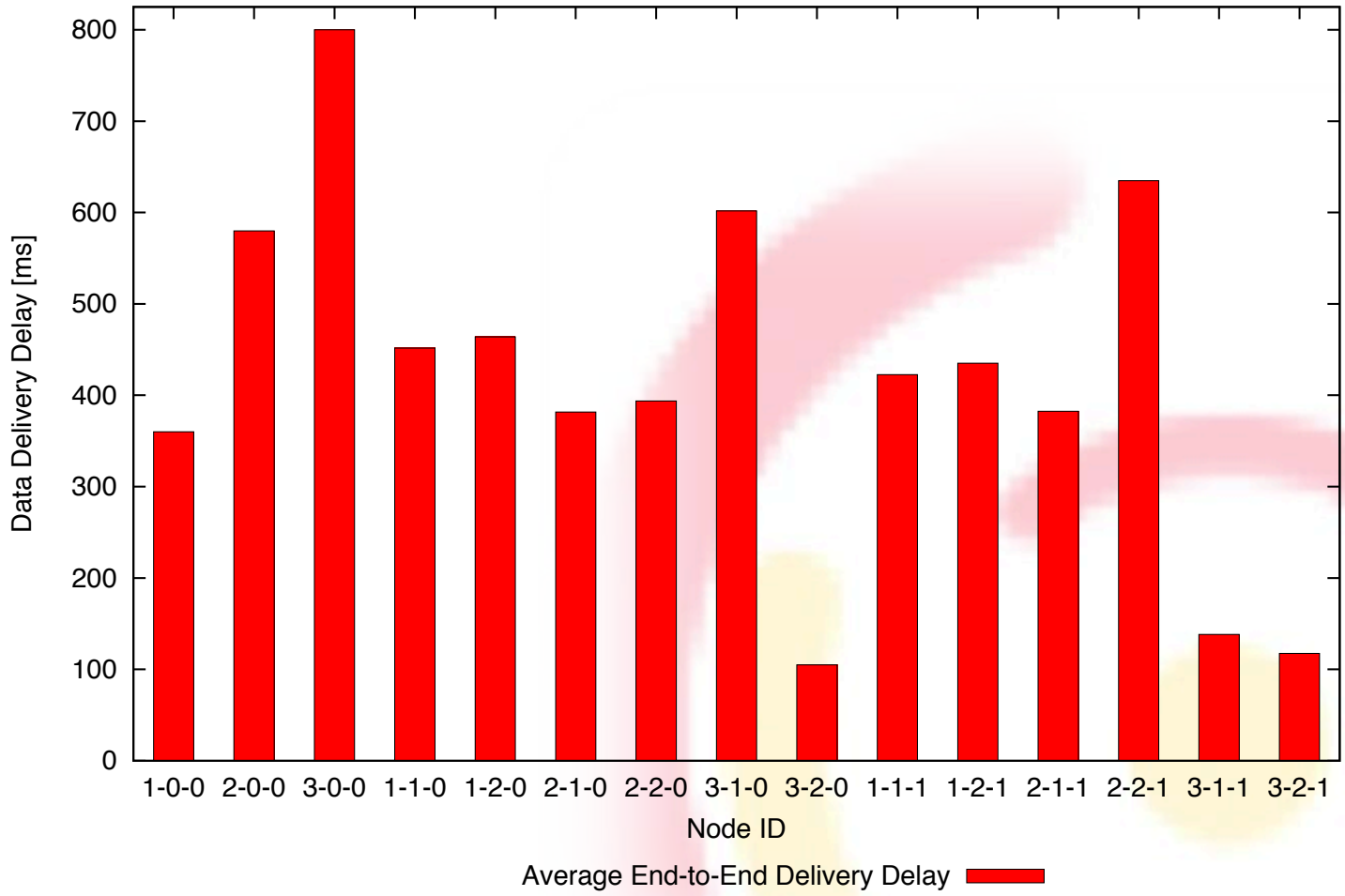
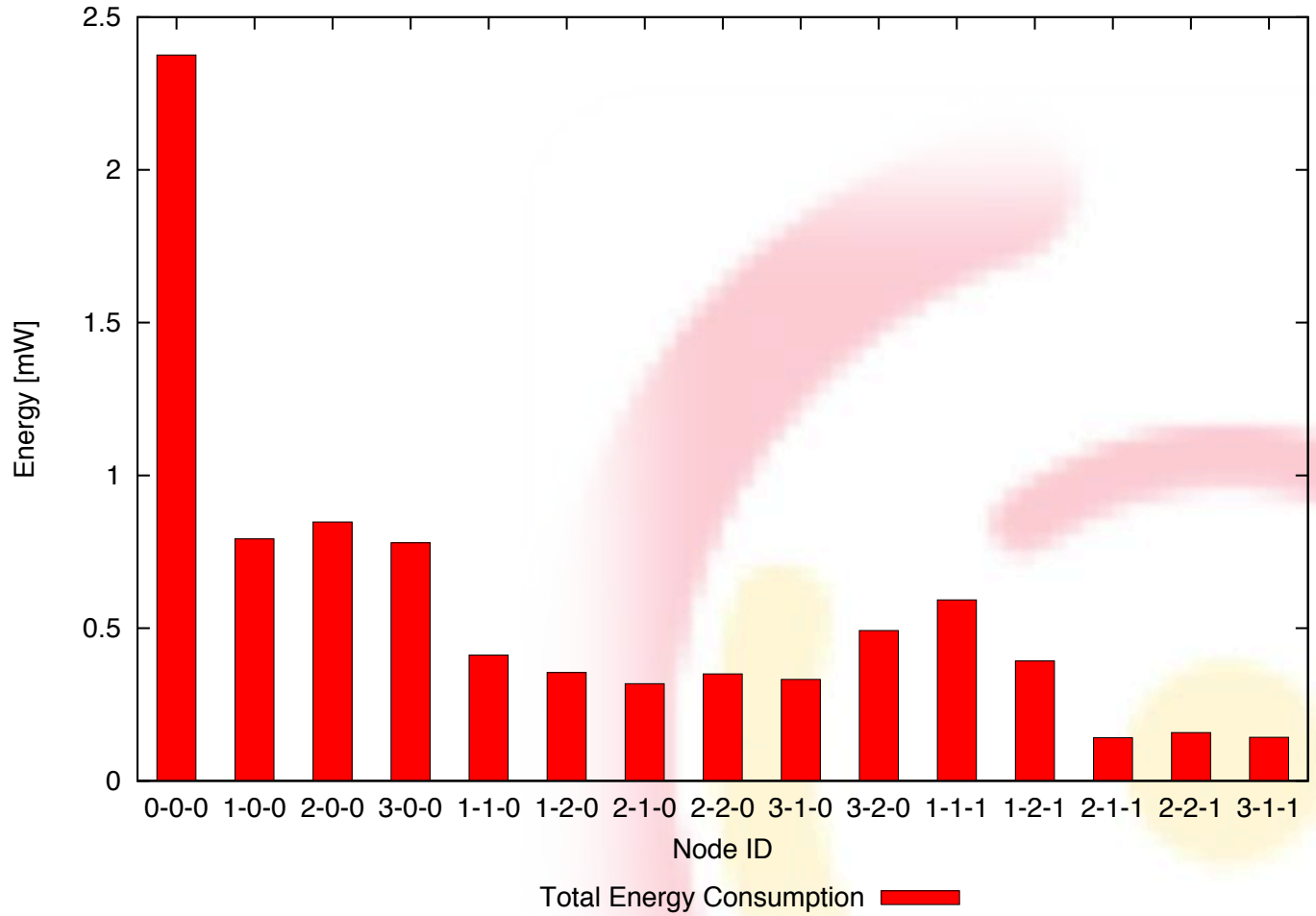
BACKUP SLIDES

End to End Delivery Delay



Per Node Energy Consumption



End to End Packet Loss