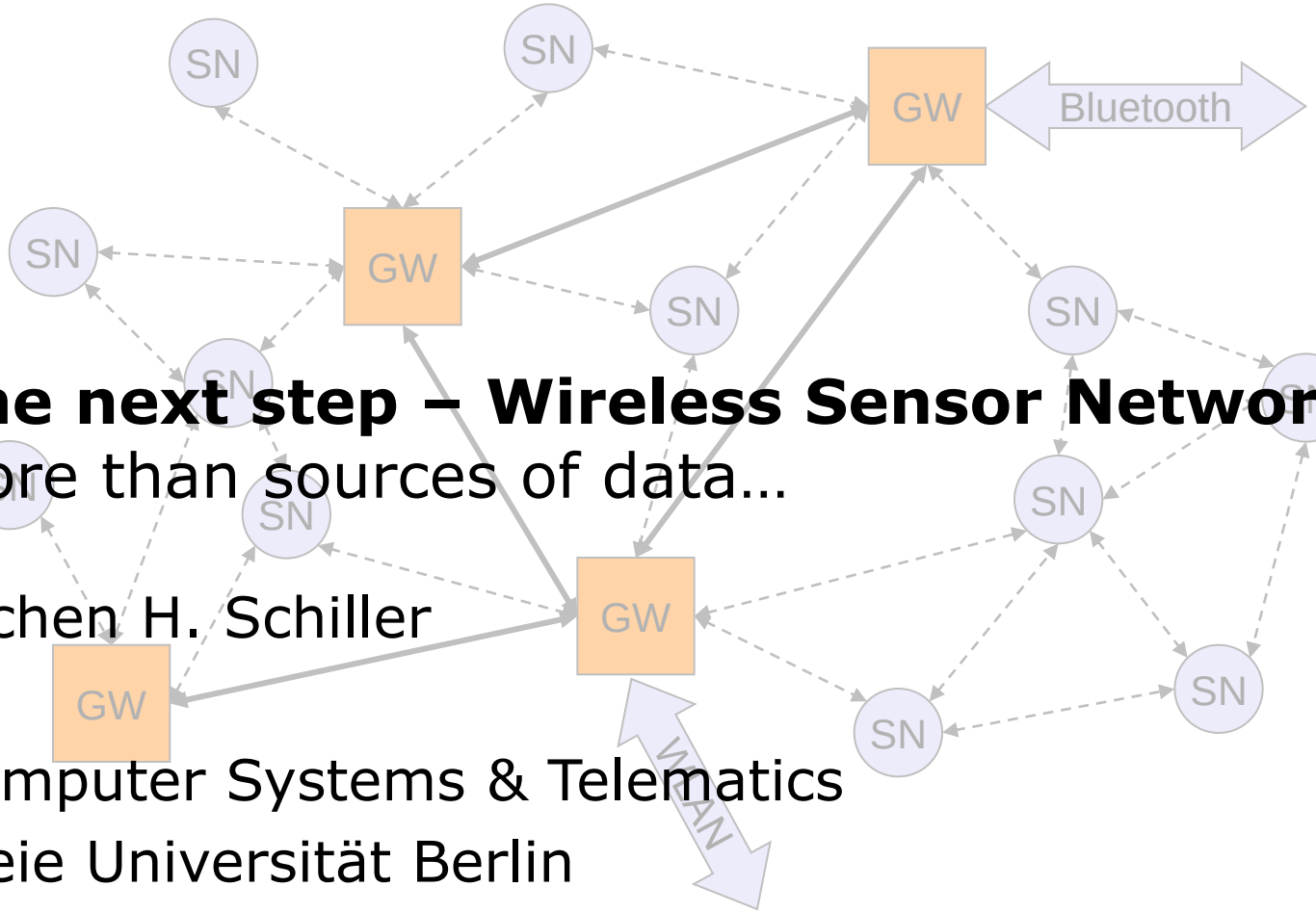

The next step – Wireless Sensor Networks

More than sources of data…

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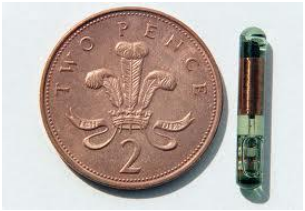
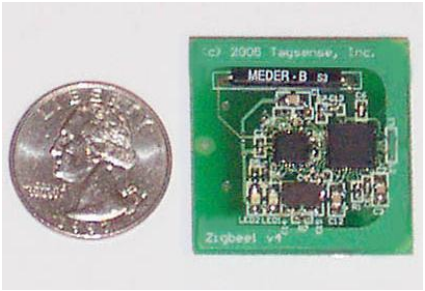
Characteristics of RFID/sensor nodes

- (passive) RFID
  - Transmission of ID as soon as external power available
  - Very simple computations possible
- Active RFID
  - Internal energy source or energy harvesting
  - Longer range, more computing power
- Wireless Sensor Nodes
  - One or more sensors attached
  - Preprocessing of data
  - Simple operating systems
  - But typically used as sources of data, forwarding data to a sink, external computation of events



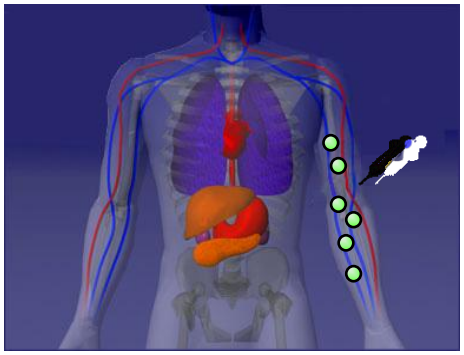


Sensor networks: the "standard" (?) applications (since >10 years)

Gather information about unknown area

Detect structural damage

Inject sensors in the human body ;-)

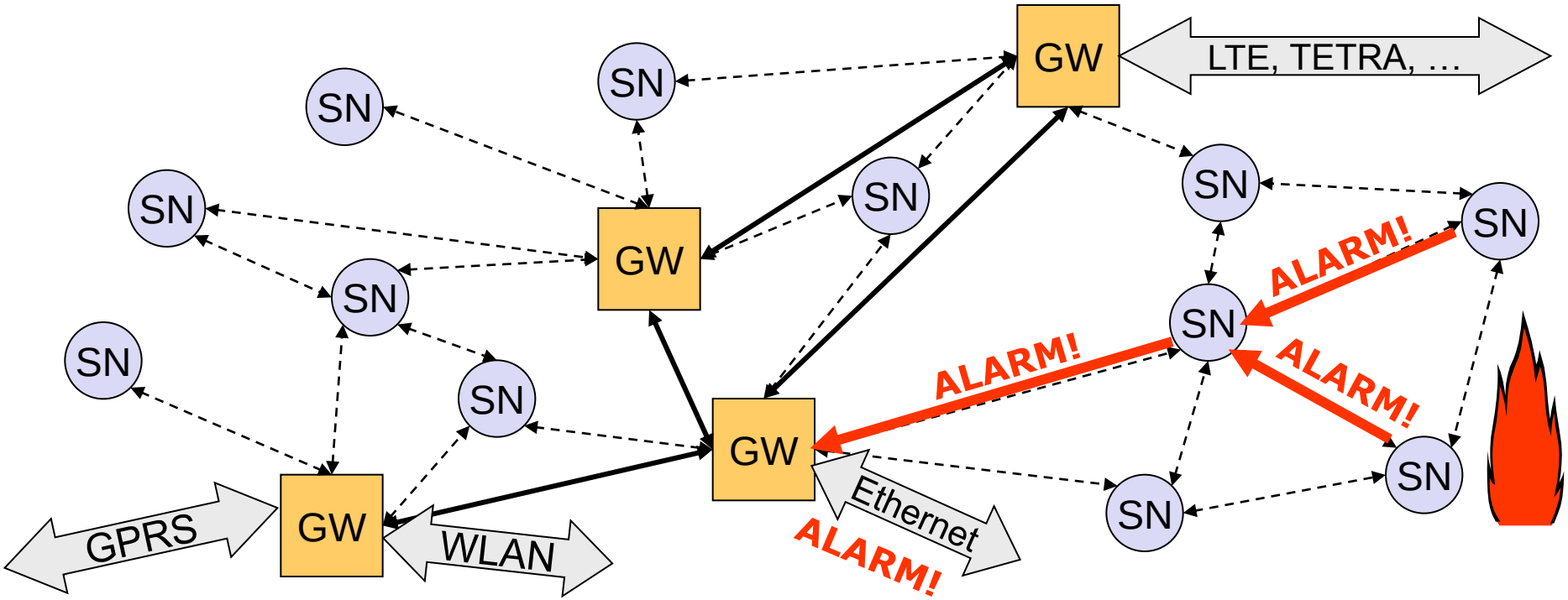


Discover disasters early

Detect leakages

Typical properties of wireless sensor networks

- Sensor nodes (SN) monitor and control the environment
- Nodes process data and forward data via radio
- Integration into the environment, typically attached to other networks over a gateway (GW)
- Network is self-organizing and energy efficient
- Potentially high number of nodes at very low cost per node



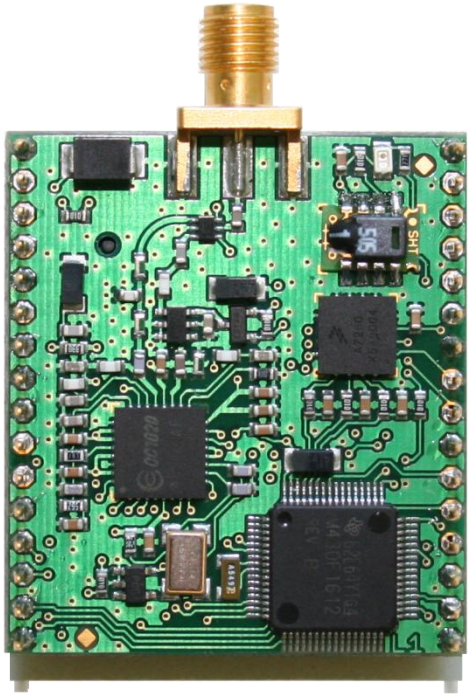
Promising applications for WSNs

- Machine and vehicle monitoring
  - Sensor nodes in moveable parts
  - Monitoring of hub temperatures, fluid levels …
- Intelligent buildings, building monitoring
  - **Intrusion detection, mechanical stress detection**
  - Precision HVAC with individual climate
- **Environmental monitoring**, person tracking
  - **Monitoring of wildlife and national parks**
  - Cheap and (almost) invisible person monitoring
  - Monitoring waste dumps, demilitarized zones

- Health & medicine
  - Long-term monitoring of patients with minimal restrictions
  - Intensive care with relative great freedom of movement
- … and many more: logistics (total asset management, RFID), telematics …
  - WSNs are quite often complimentary to fixed networks!

Robust HW needed - example: ScatterWeb's Modular Sensor Board

- Modular design
  - Core module with controller, transceiver, SD-card slot
  - Charging/programming/GPS/GPRS module
  - Sensor carrier module

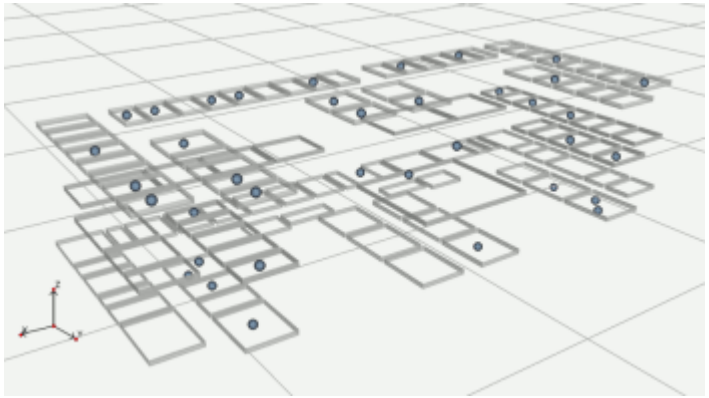


- Software
  - Firmware (C interface)
  - TinyOS, Contiki, µkleos …
  - Routing, management, flashing …
  - ns-2 simulation models
  - Integration into Visual Studio, Eclipse, LabVIEW, Robotics Studio …

- Sensors attached on demand
  - Acceleration, humidity, temperature, luminosity, noise detection, vibration, PIR movement detection…

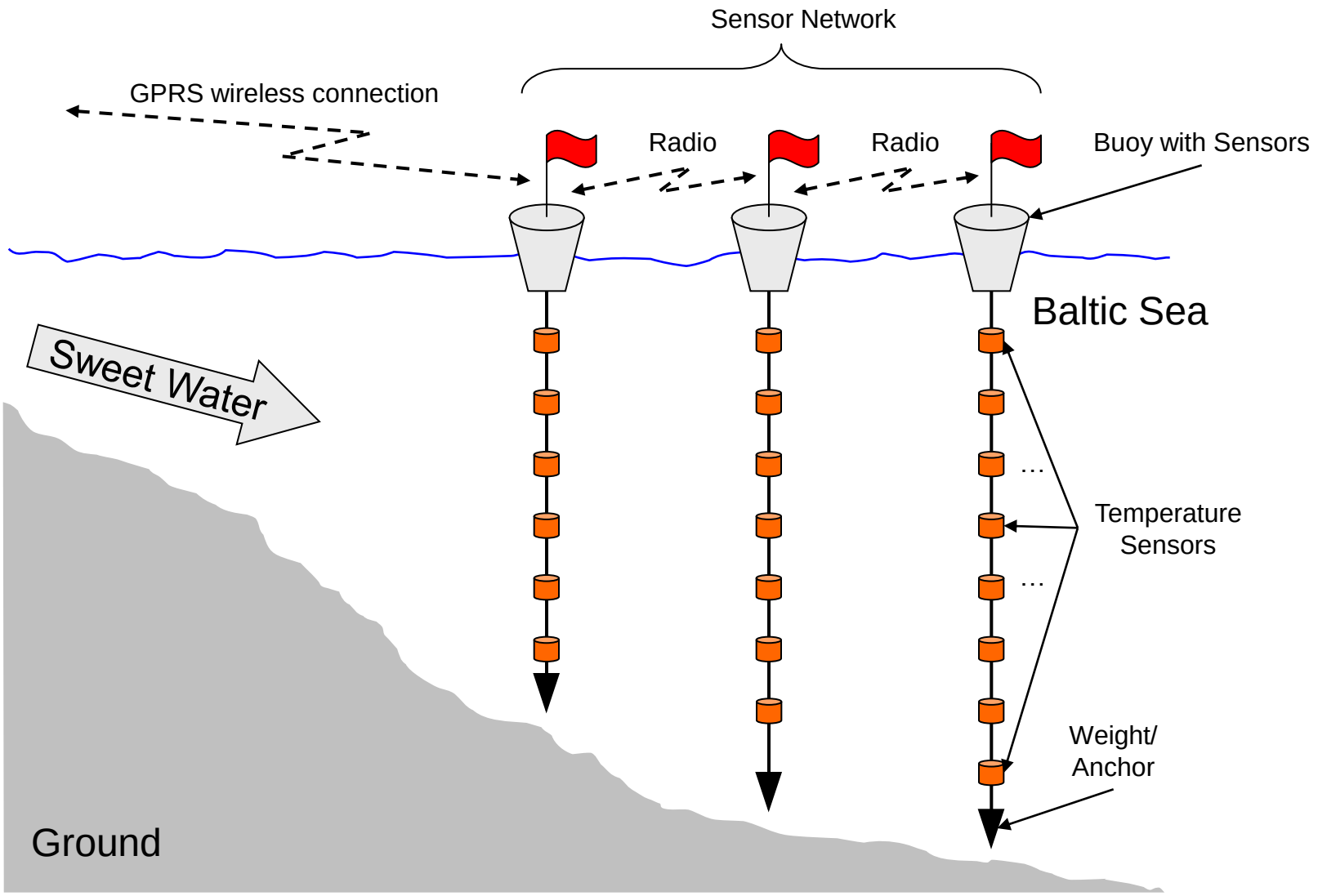
Distributed Embedded System Testbed

- Hybrid wireless multi-transceiver testbed for long-term studies
- Consists of a wireless mesh network (WMN) and a wireless sensor network (WSN)
- Wireless mesh routers equipped with 802.11a/b/g network adapters and wireless sensor nodes



- www.des-testbed.net

Example Application: Temperature Measurement in the Baltic Sea



Making WSNs seawater-proof

Chain of Sensors

Protection of nodes
in oil (incl. antenna)

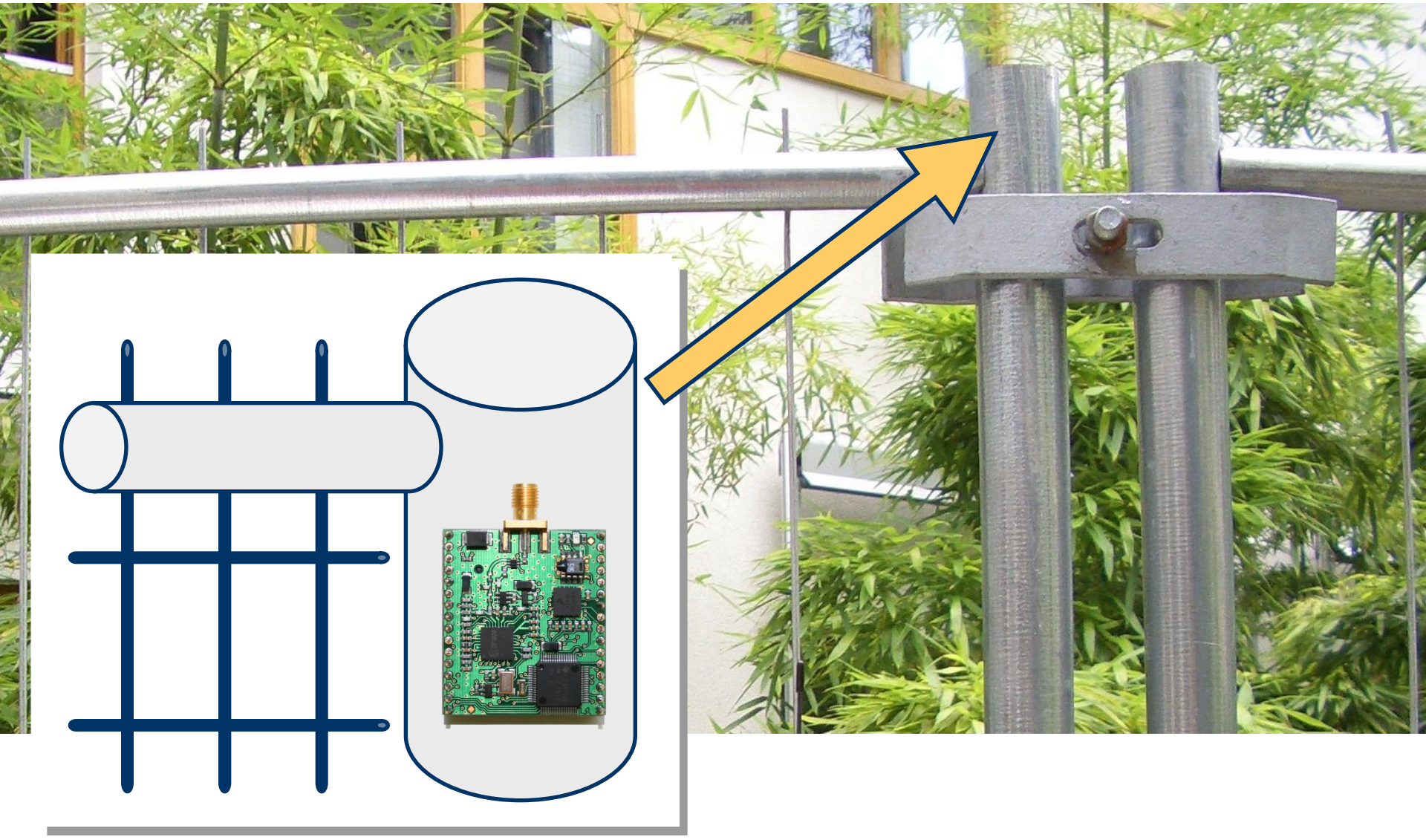
Robustness – the real Challenge of WSNs

- WSNs have to work – as simple as this sound as complicated it is to achieve!
- Example: Alpine WSN
  - ScatterWeb nodes collect temperature data from various sensor
  - GPRS at gateway

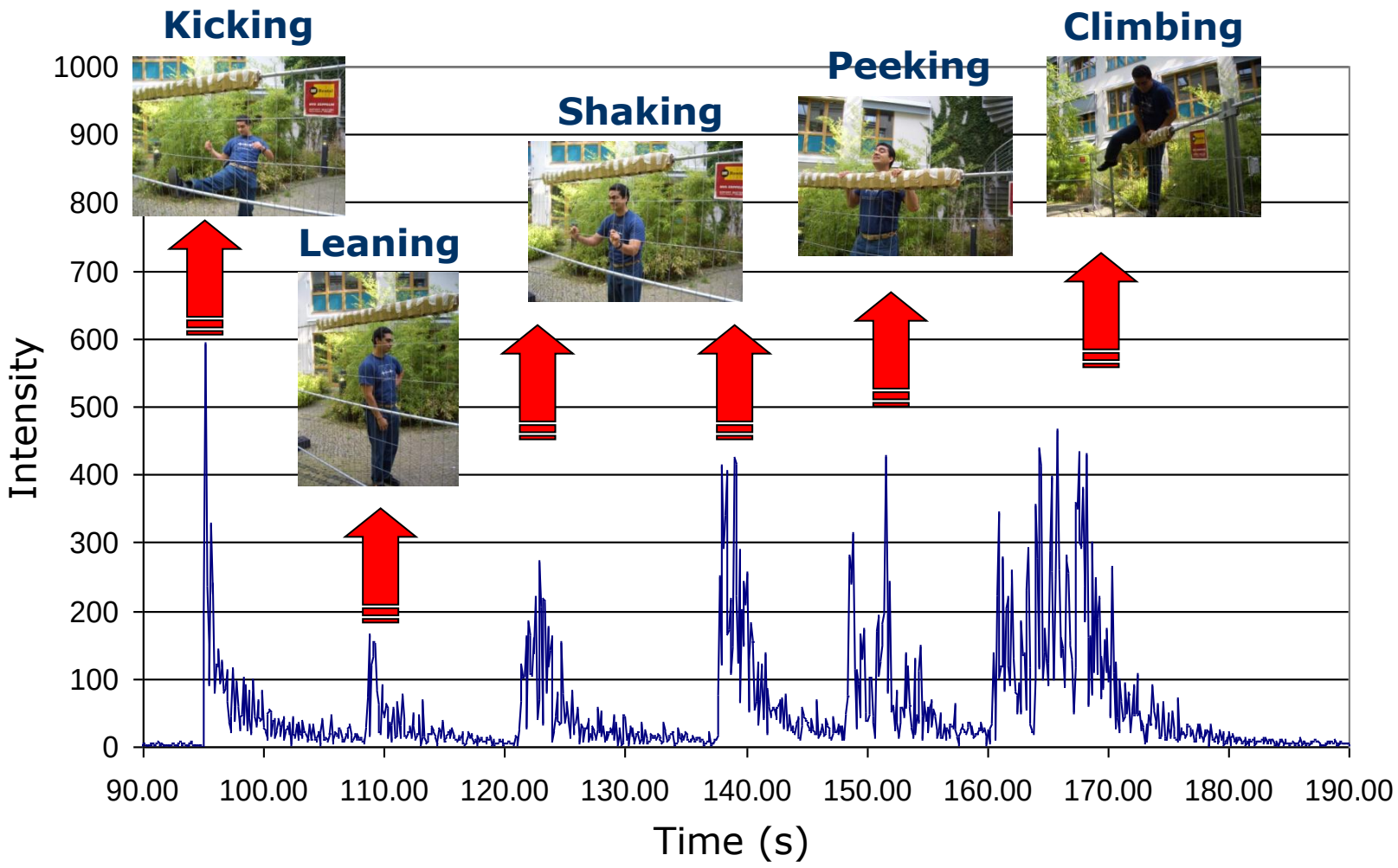
Monitoring Rocks in the Swiss Alps

Experiment: Fence Protections

Sensor Integration



Event Detection



Challenging application: safety for rescue forces

Monitoring of vital parameters

Freie Universität Berlin

MSA AUER
The Safety Company

nanotron TECHNOLOGIES

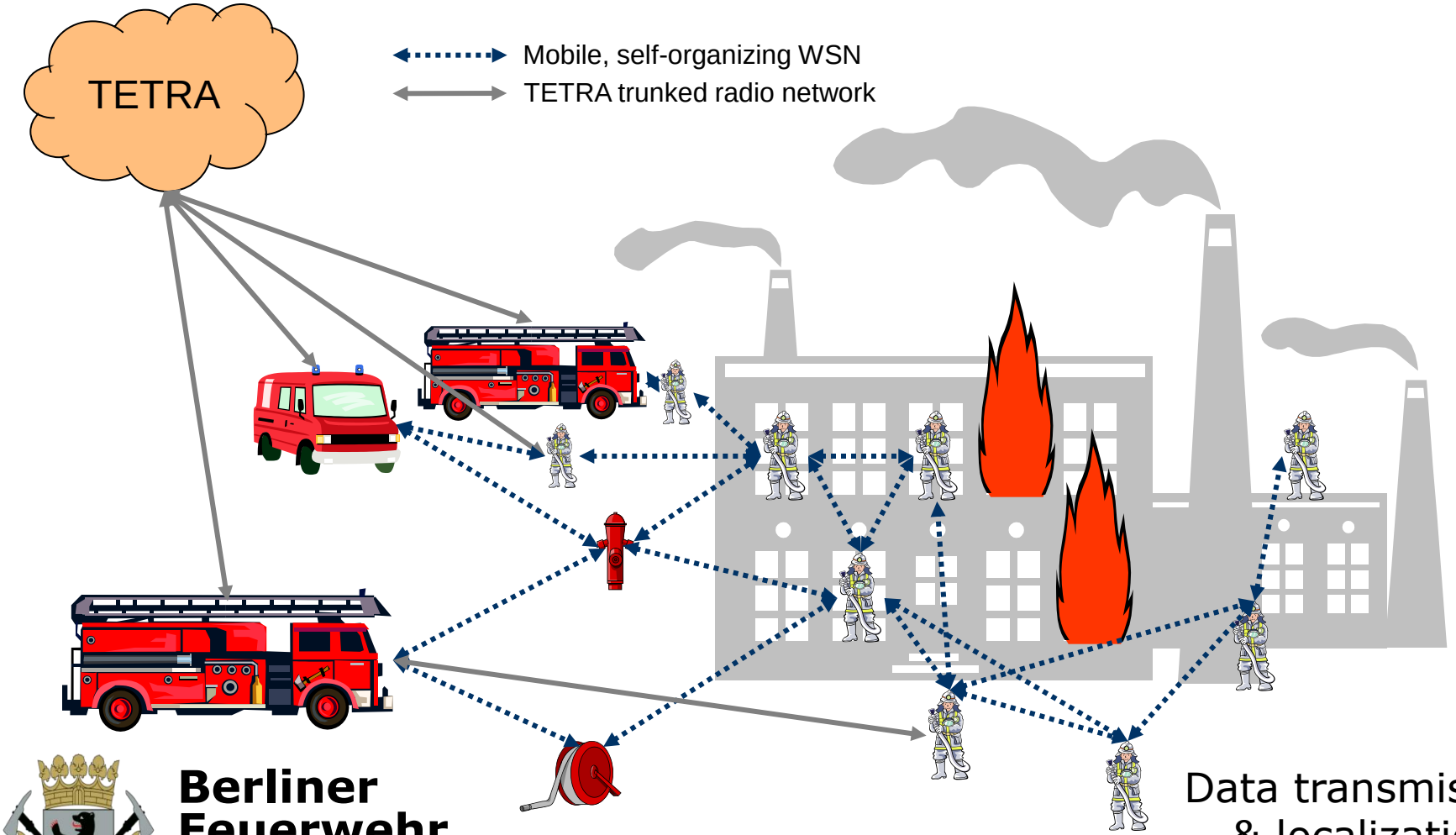
TimeKontor

Berliner Feuerwehr

ihp

Localization on the disaster site

Project FeuerWhere – the extreme challenge



Berliner Feuerwehr
4450 fire fighters
300000 incidents/year (8000 fires)

Data transmission & localization

Example Application: Habitat Monitoring/Skomer Island UK

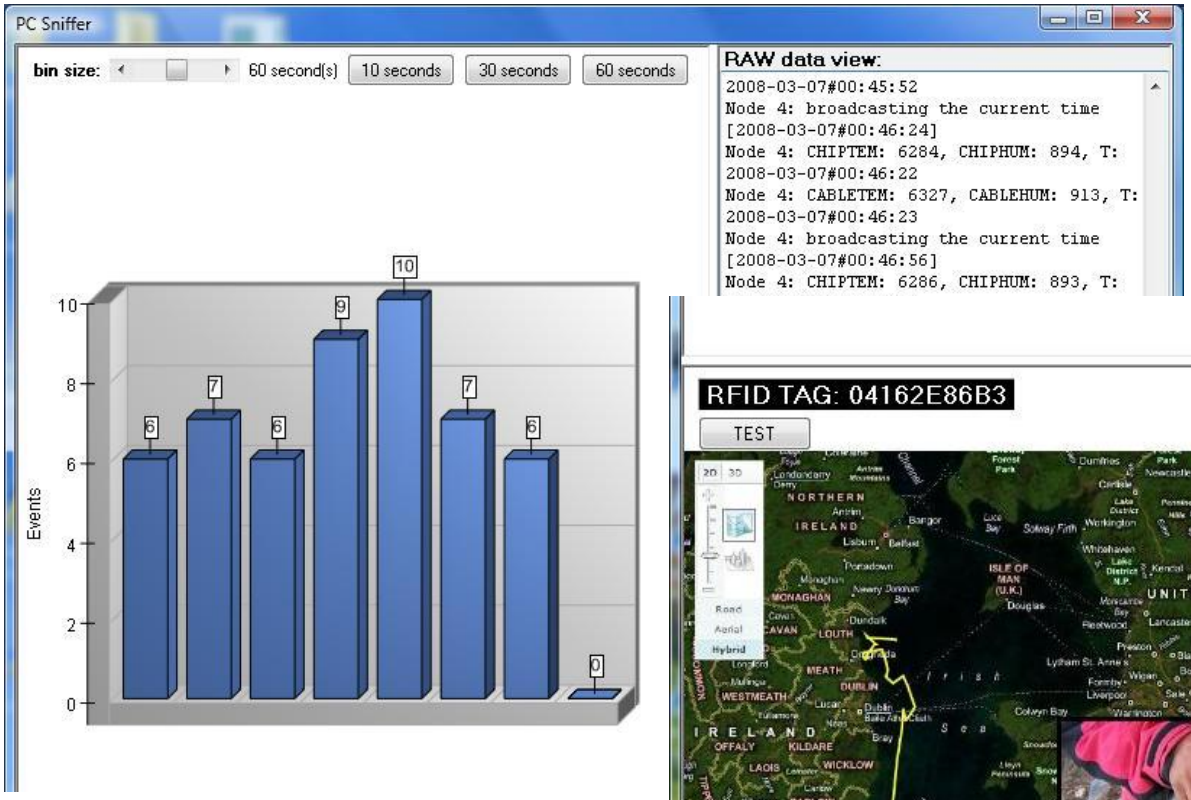
Manx Shearwater

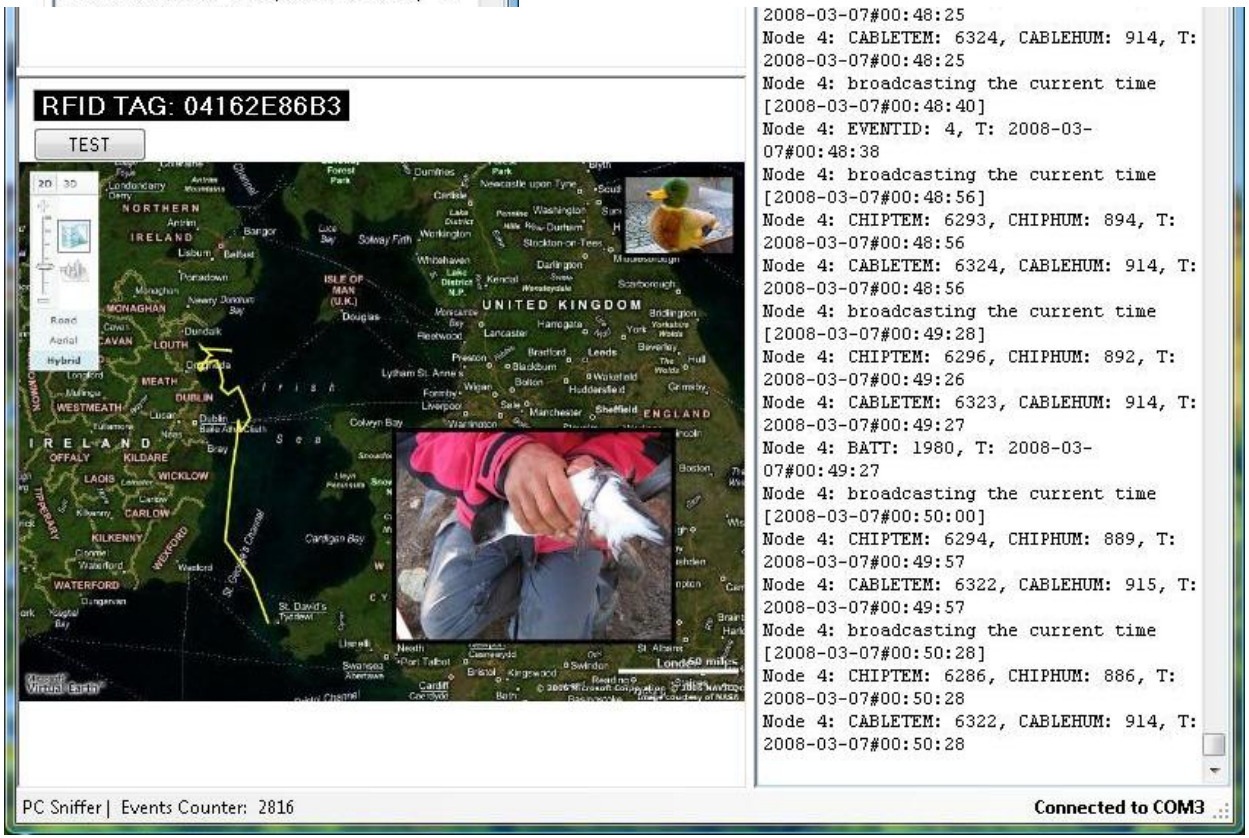
Combination of RFID and ScatterWeb

- Main challenge: robustness, reliability, easy-to-use
- Joint project with Oxford University and MSRC

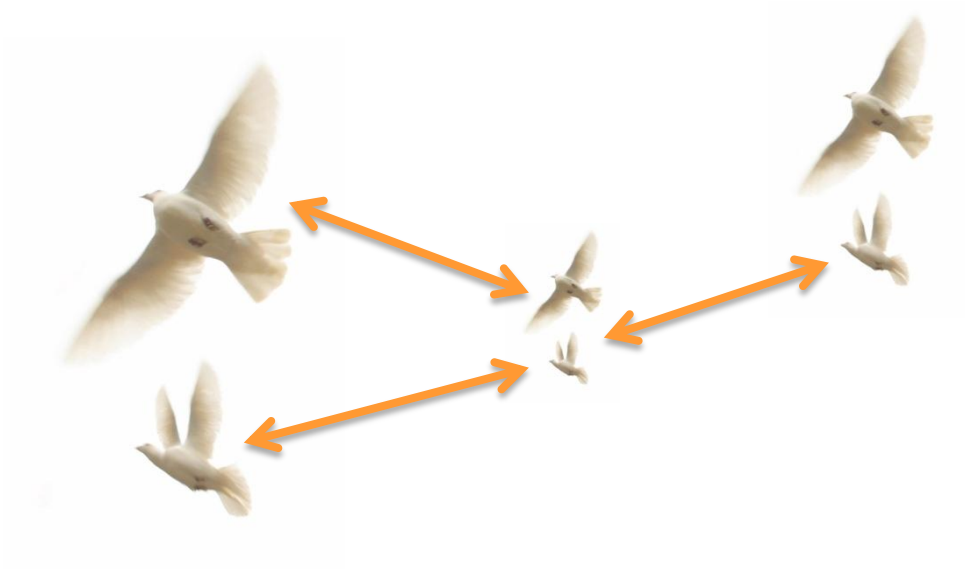
http://skomerisland.codeplex.com/

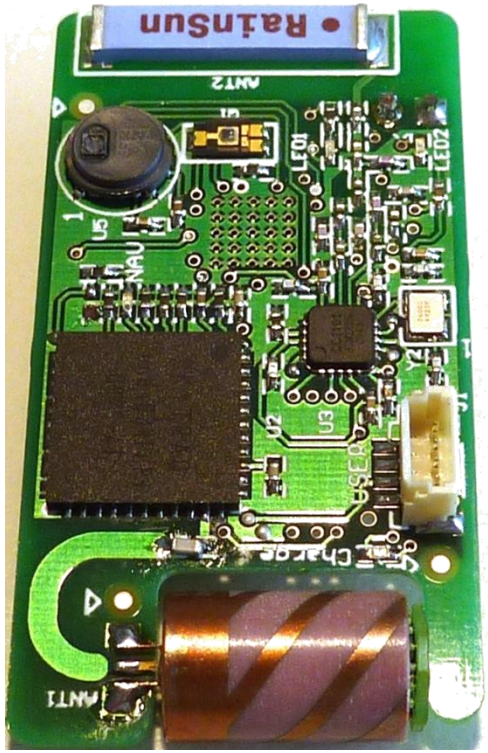
Orwell for birds – total monitoring





Next step: AvianGPS
Cooperative monitoring





- Core: MSP430F1610 + CC1101
- Sensors: GPS, Pressure Sensor, Light Sensor

- Weight: 7 g (without battery)
- Size: 24 mm x 45 mm

- Partners: Freie Universität Berlin, University of Oxford, Microsoft Research Ltd.

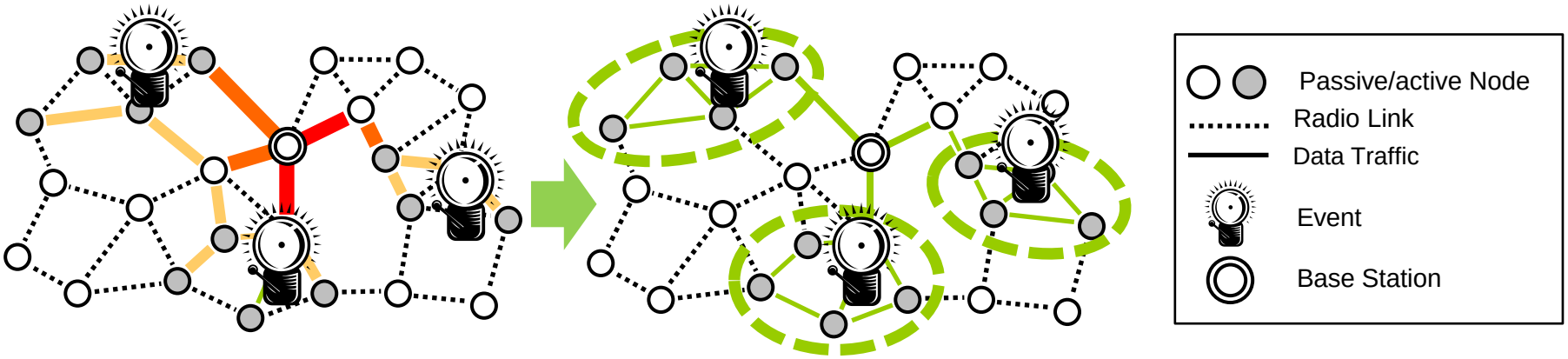
Lightweight sensor module…

…attached to the bird

Tracking the flock of birds

Beyond being simple data sources: Distibuted Event Detection

- In-network data processing is a key feature of Wireless Sensor Networks (WSNs)
  - Reduce communication with base station
  - Extend network lifetime



- Example: Distributed, in-network event detection
  - Decide locally, within the neighborhood, whether an event occurred
  - Send only confirmed events to the base station, not raw data

Applications of distributed event detection

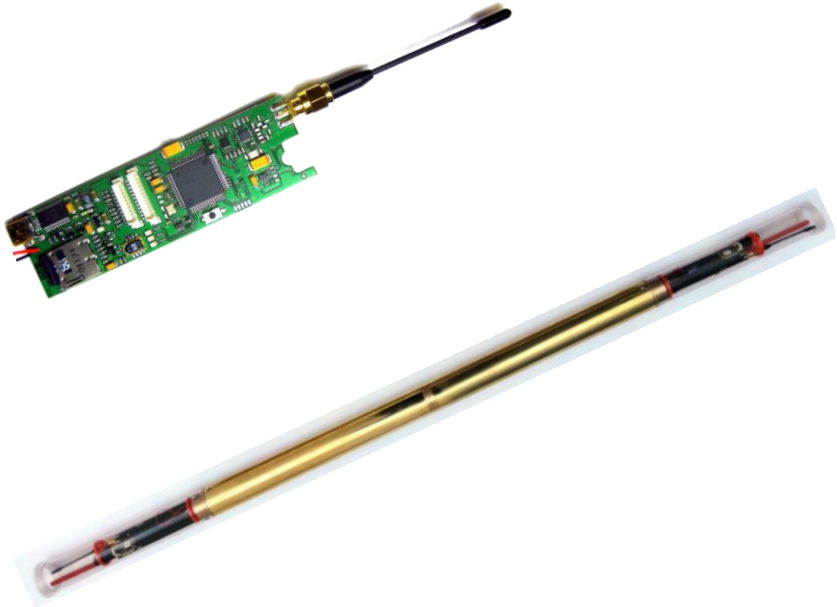
Freie Universität Berlin

1. Fence Monitoring AVS-Extrem

2. Coupled Training Device

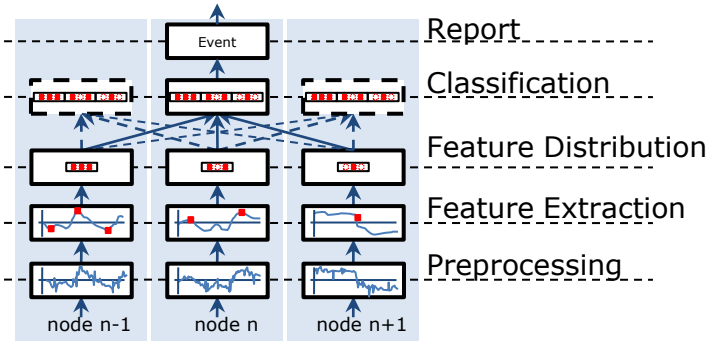
Design Challenges

1. Sensor Node Platform
   - Energy awareness
   - Communication issues
   - Sensor (acceleration)
   - Flexibility

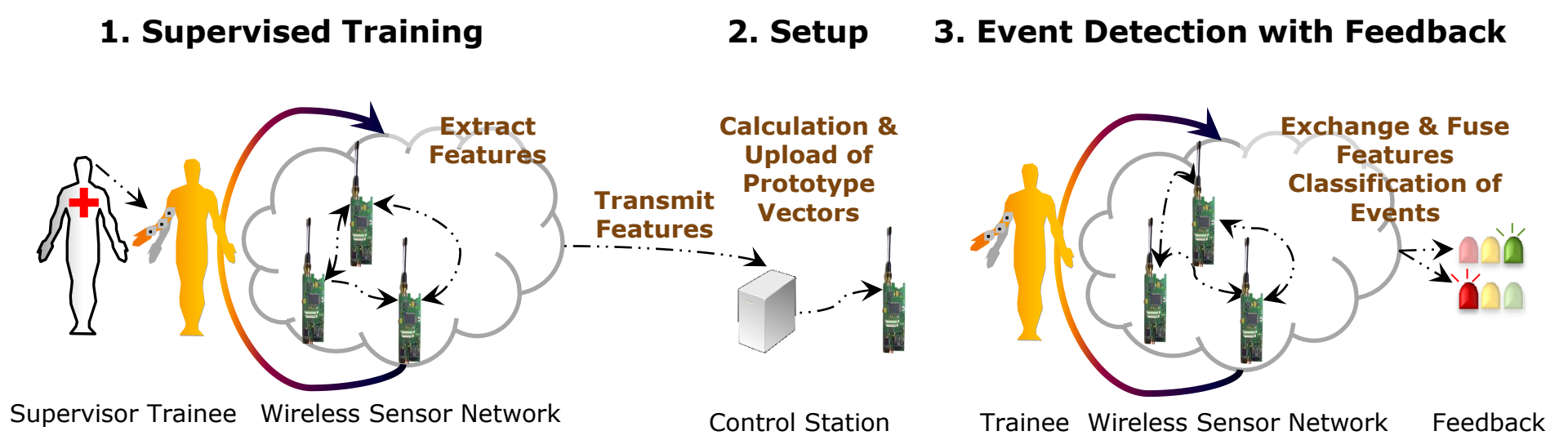


2. Housing
   - Look & feel and usability
   - Thin housing
   - Integration of PCB-Shape & energy supply

3. Event Detection
   - Decentralized pattern recognition
   - No dedicated infrastructure



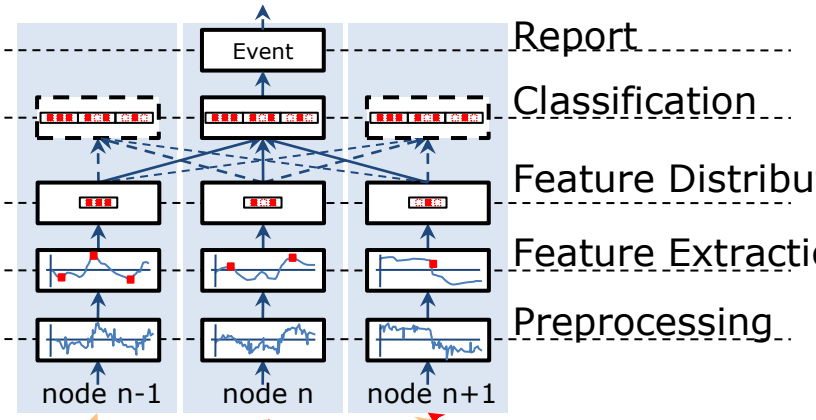
Distributed Event Detection – How it works



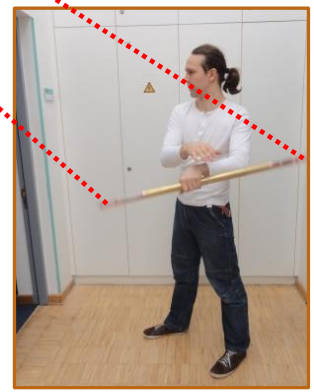
1. Supervised Training
   - Expose sensor network to series of training events
   - Extract ALL features and transmit to control station
2. Setup
   - Select best subset of features, calculate prototype vector for each event
   - Configure nodes to only extract/transmit selected features
3. Event Detection with Feedback
   - Calculate & exchange features to neighbors, fuse own & received vectors to complete fingerprint
   - Evaluate events with Euclidian-distance based prototype classifier

Distributed Event Detection in Detail

1. Preprocessing:
   - Sample raw data
   - Filter and smoothen data
2. Feature Extraction:
   - Extract application-specific set of features from raw data
   - Selection of appropriate features is part of training (cross-validation)
3. Feature Distribution:
   - Send features to neighborhood
   - Retransmit features in case of transmission failures
4. Classification:
   - Fuse received and own features to feature vector
   - Classify feature vector (prototype classifier)
   - Report to base station, if event is configured as relevant
5. Report:
   - Possible alarm or event feedback



Fence Monitoring



Movement Detection

Possible wireless & motion-based applications

Freie Universität Berlin

1. Fence Monitoring AVS-Extrem

Done

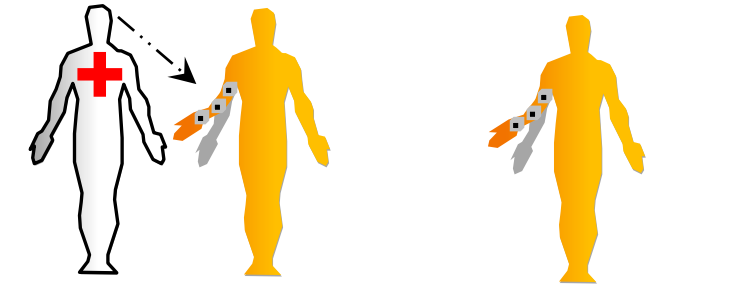
2. Coupled Training Device

Done

3. Decoupled Training Device

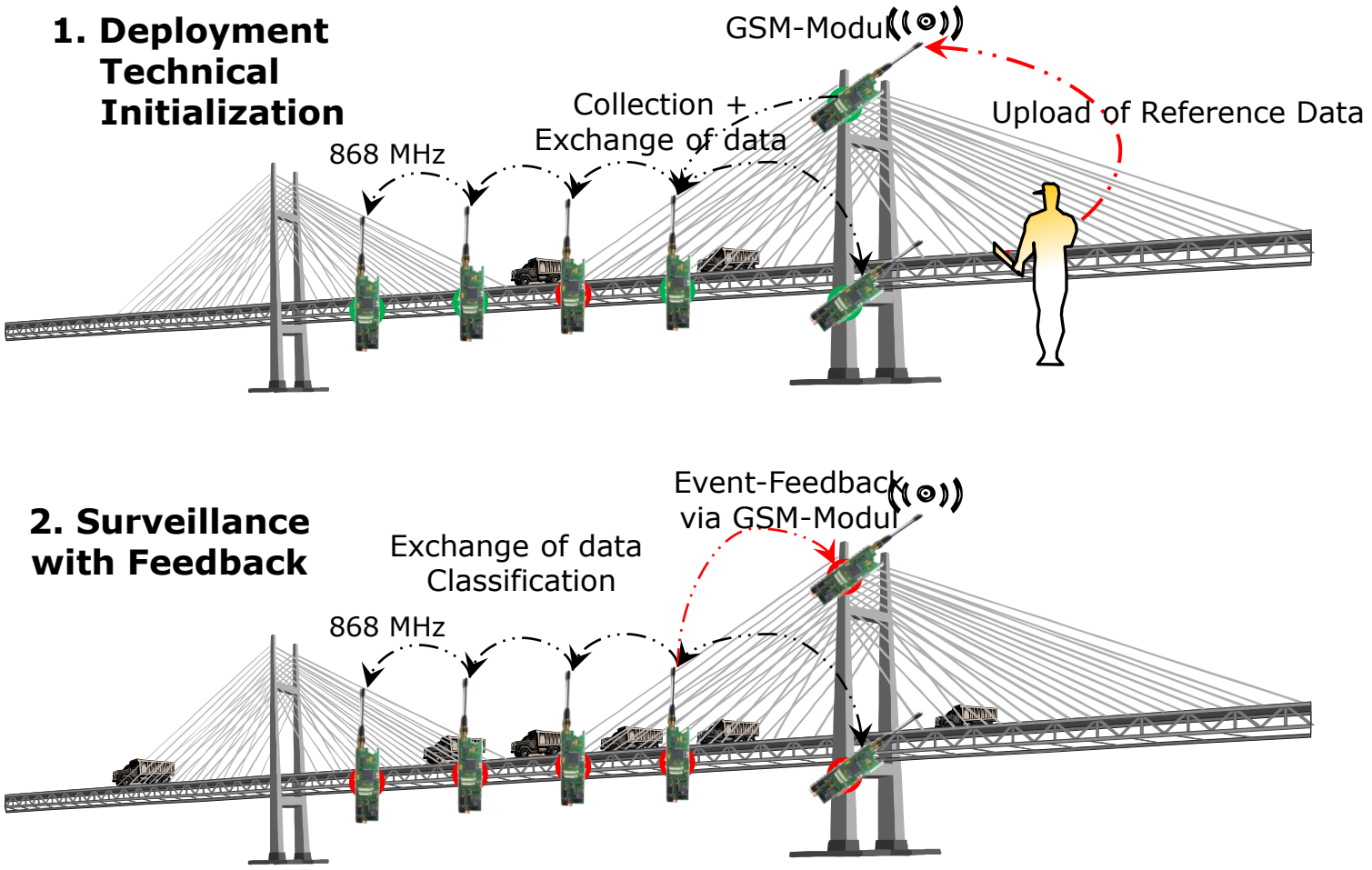
Work in Progress

4. Rehabilitation



Future Work

Bridge monitoring



Conclusion

- WSNs go beyond being simply data sources
  - In-network processing
    - Saves energy
    - Increases reliability of system and results
    - Lowers overall costs
- Robustness of the systems is still a challenge
  - Simple and cheap nodes must survive in rough environments
- Interesting future applications
  - Integration into logistics
    - Did all parts stay together, have the same movement pattern?
  - Integration into construction machines
    - Pay-per-usage, overstress monitoring
  - …