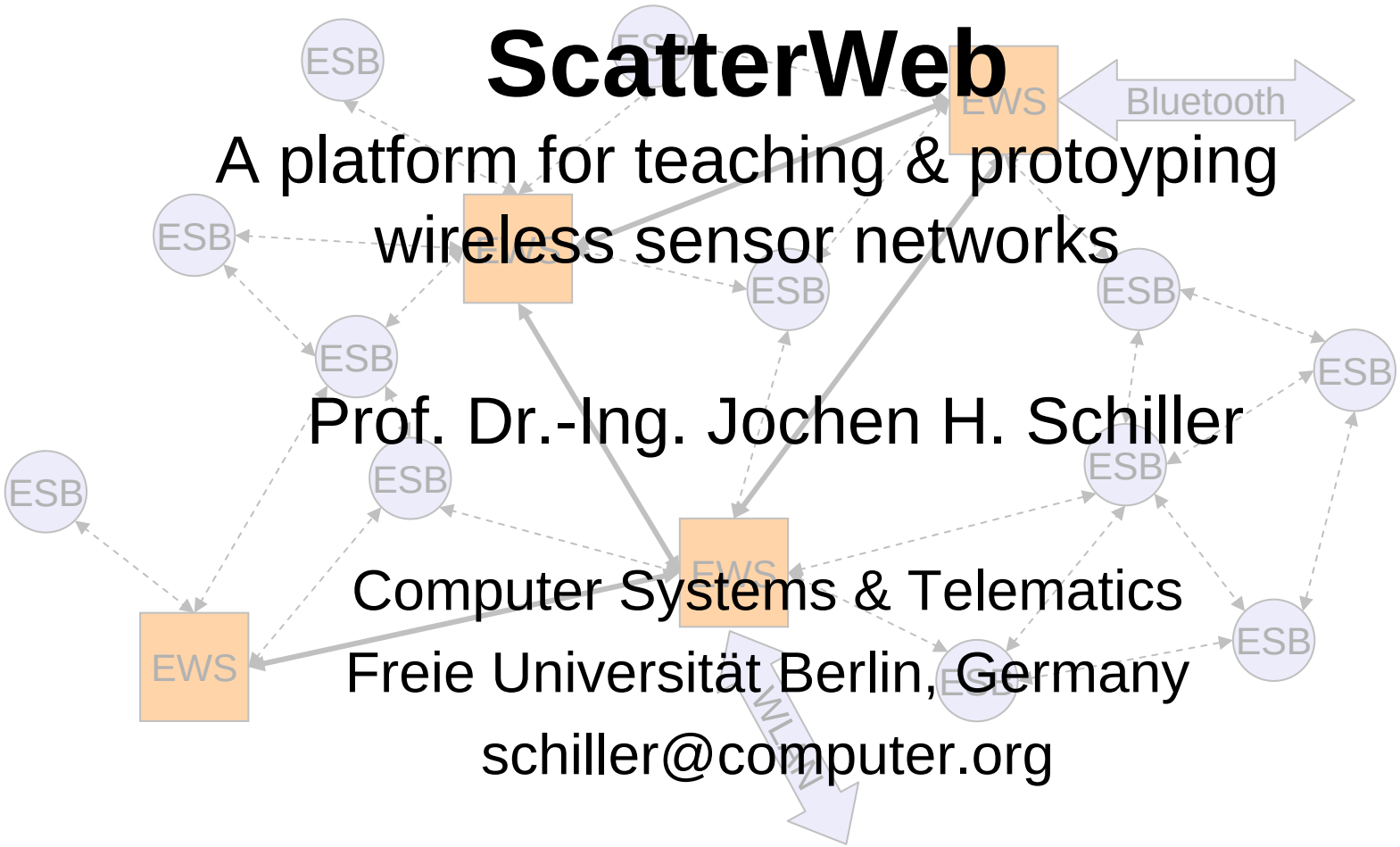
ScatterWeb

A platform for teaching & protoyping wireless sensor networks



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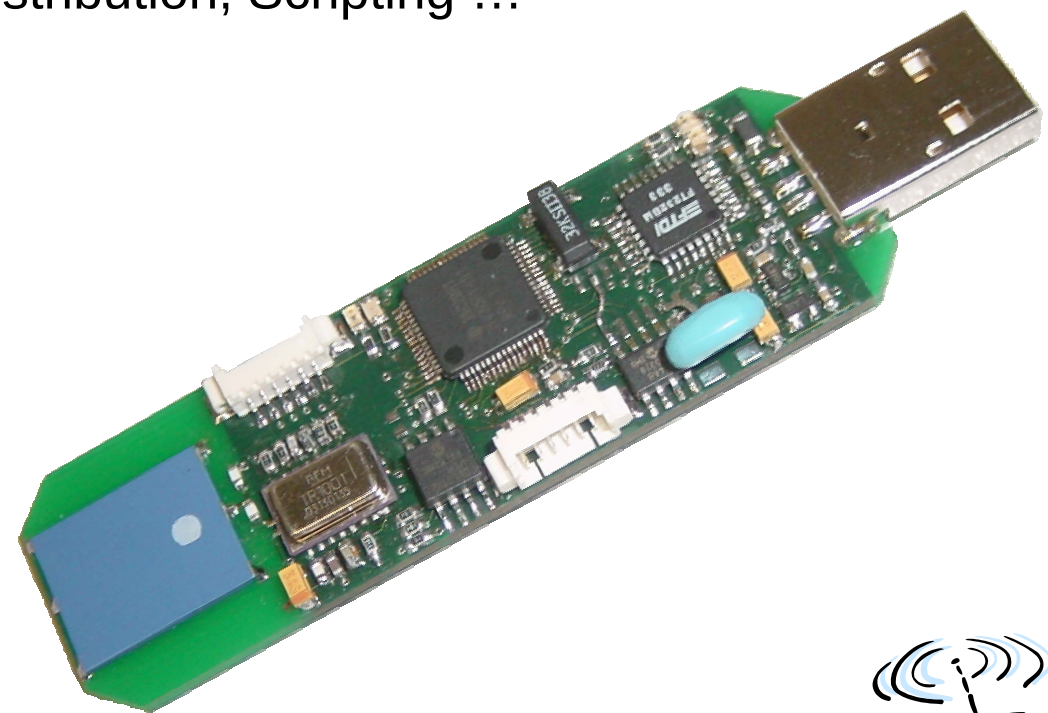
Overview

Applications for Sensor Networks

ScatterWeb components

Energy, Management, Code distribution, Scripting …

Current and Future Activities



Goals for ScatterWeb @ FU Berlin

Students

- should be able to derive system parameters from high-level requirements for certain technologies, e.g., QoS in Web Service – QoS in Network – QoS in wireless transmission.
- should understand the impact of transmission technology, network topology, hardware parameters etc. onto application layer services.

The system should serve as a test-bed for ad-hoc networking, peer-to-peer networks, power and resource constrained communication devices, and sensor networks.

Courses

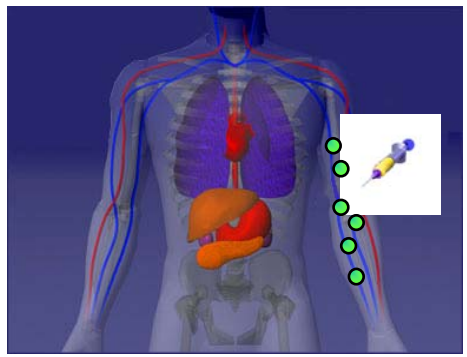
- Telematics, Embedded Internet, Mobile Communications, Embedded Web Server Lab, Mobile Communications Lab, Next Generation Internet, Hardware Lab, Microprocessor Lab

Sensor Networks: The “Standard” Applications

Gather information about unknown area

Detect structural damage

Inject sensors in the human body



Discover disasters early

Detect leakages

Sensor Networks: Research Areas

Long-lived, autonomous networks

- Use environmental energy sources
- Embed and forget

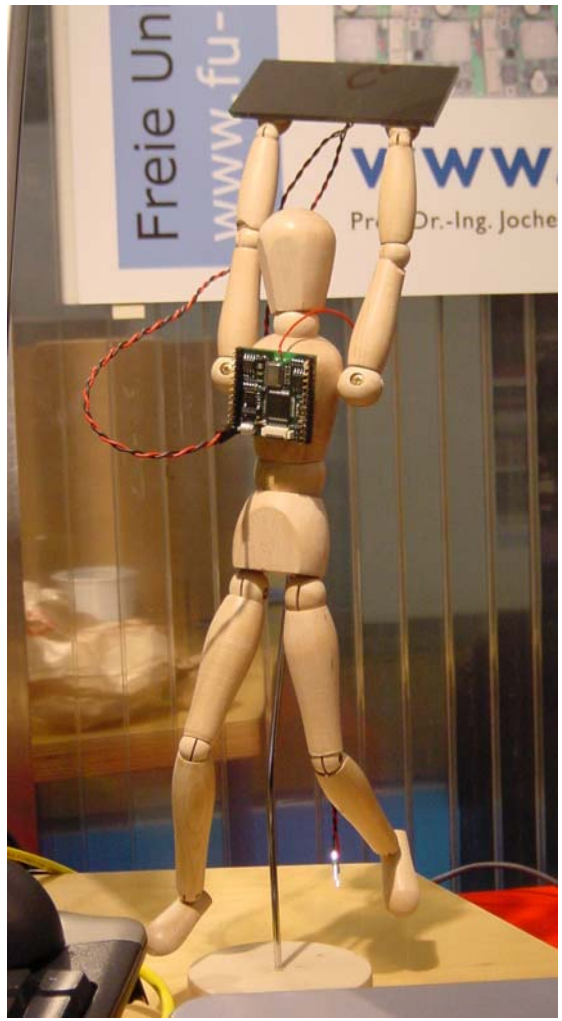
Self-configuring networks

- Routing
- Data aggregation
- Localization

Managing wireless sensor networks

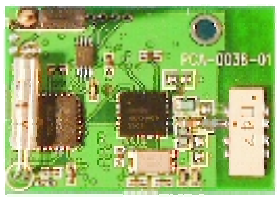
- Tools for access and programming
- Update distribution

…



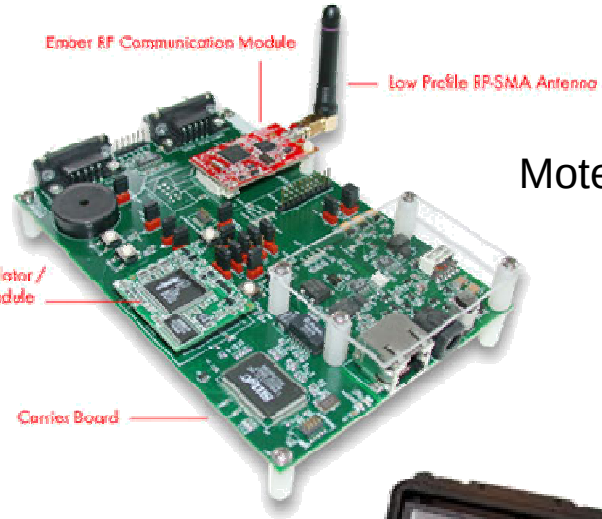
Several Systems Available

EnOcean

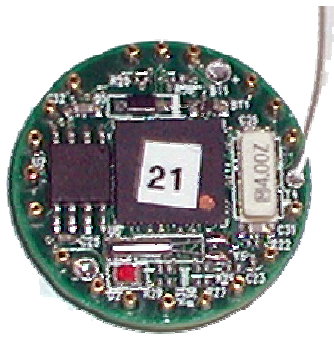


Sensicast

Motes

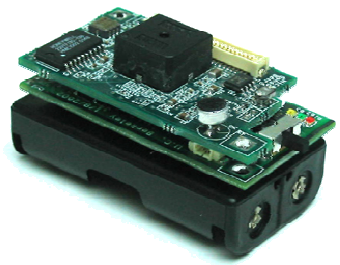


Millenial

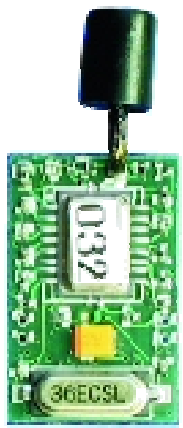


BTnode

Ember

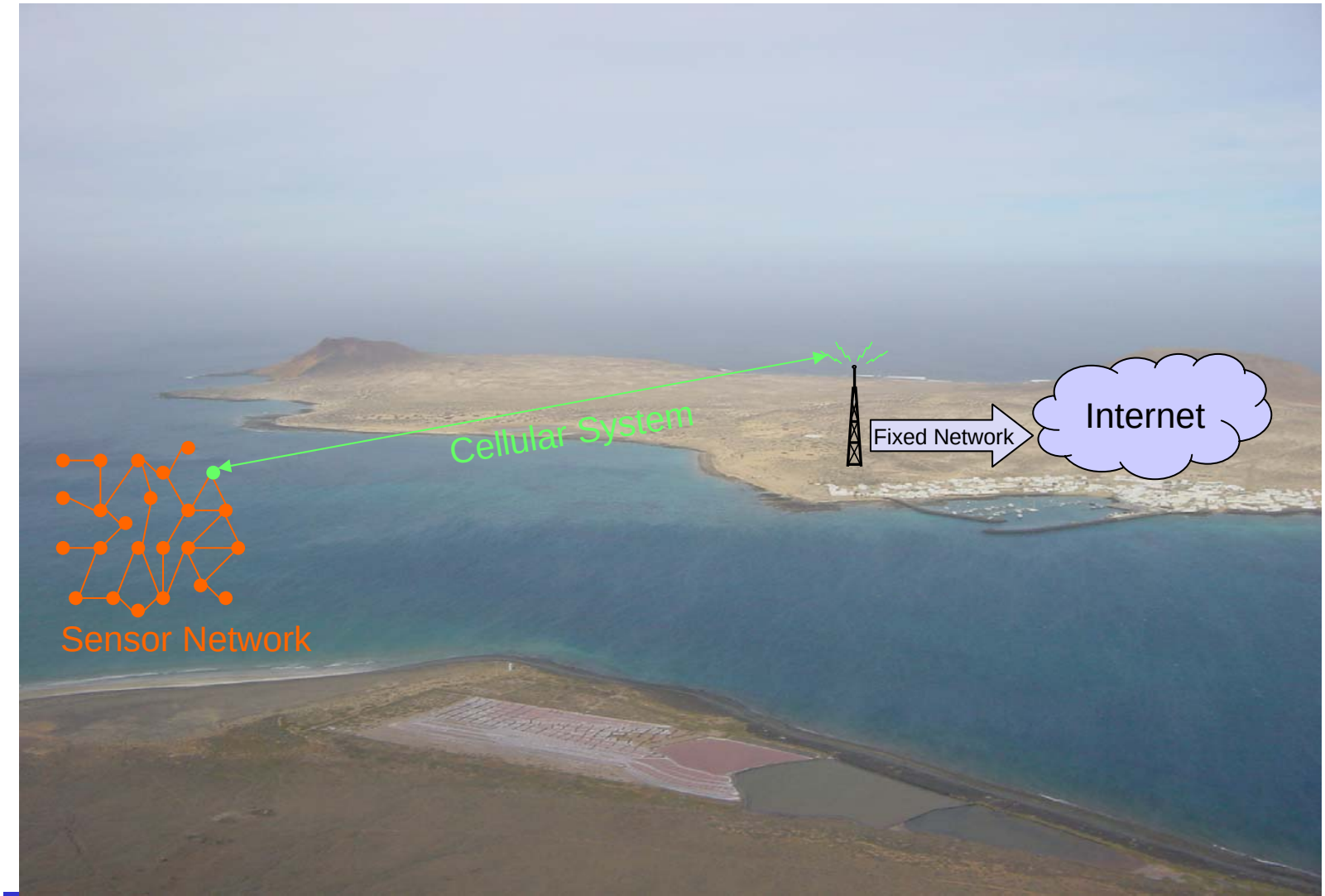


Helicomm

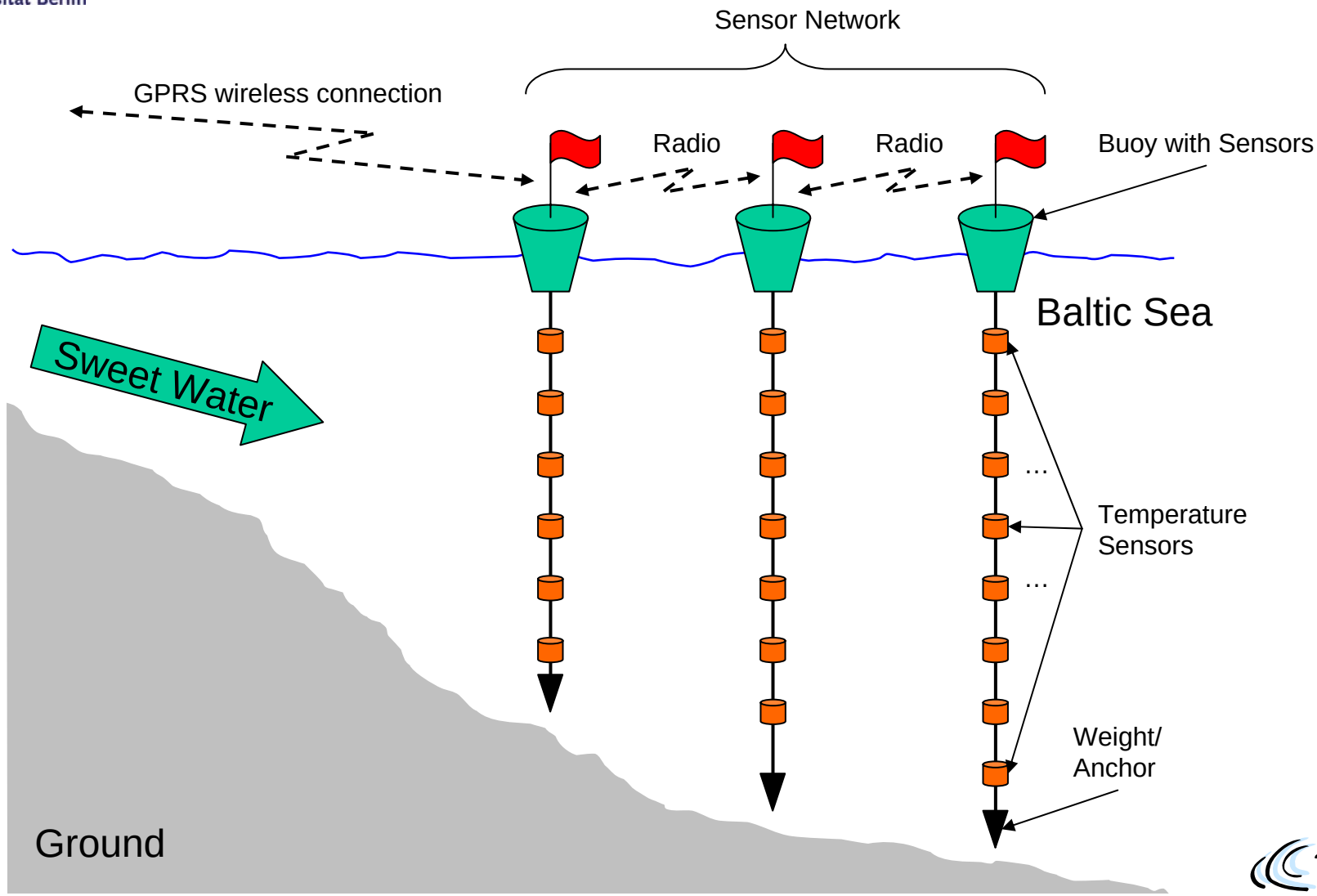


Crossbow

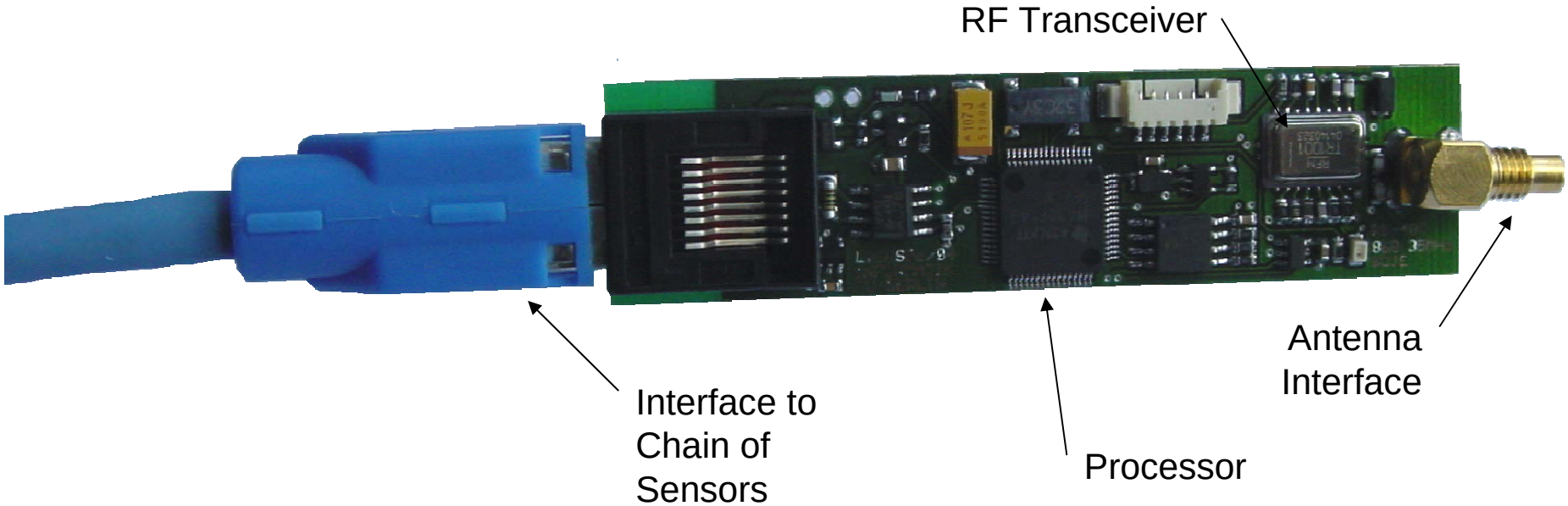
ScatterWeb Application Example



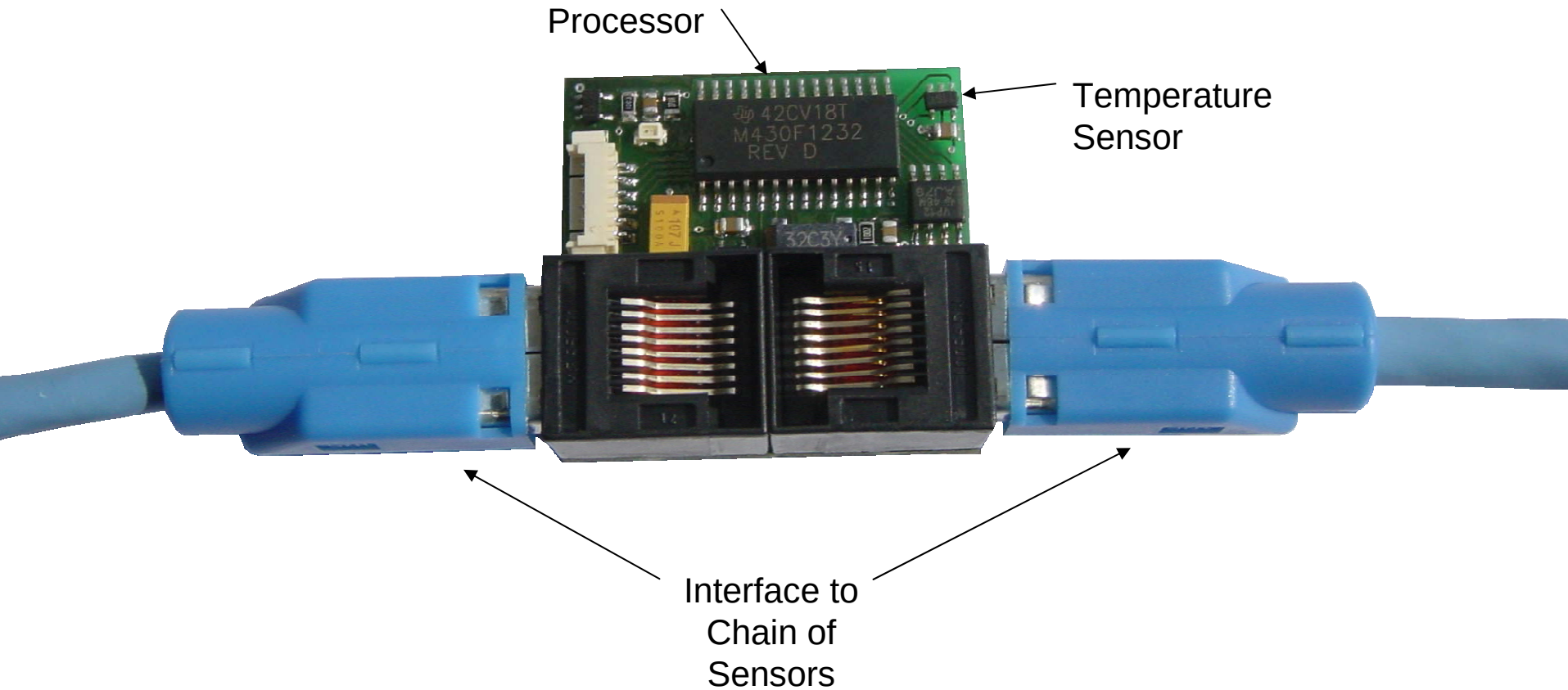
Application: Temperature Measurement in the Baltic Sea



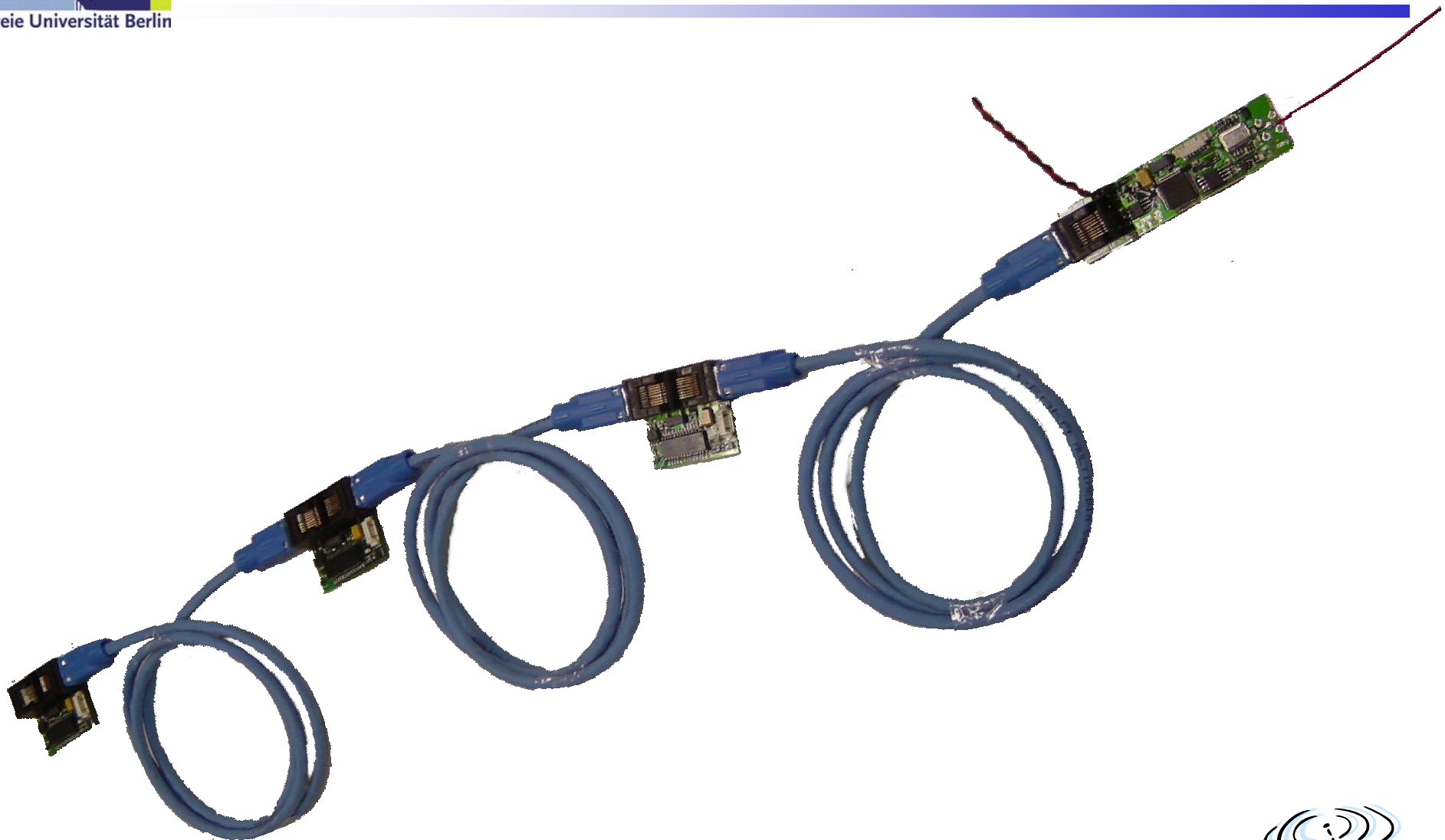
Sensor Node with Processor, RF, Sensor I/F



Sensor Node with Processor and Sensor I/F



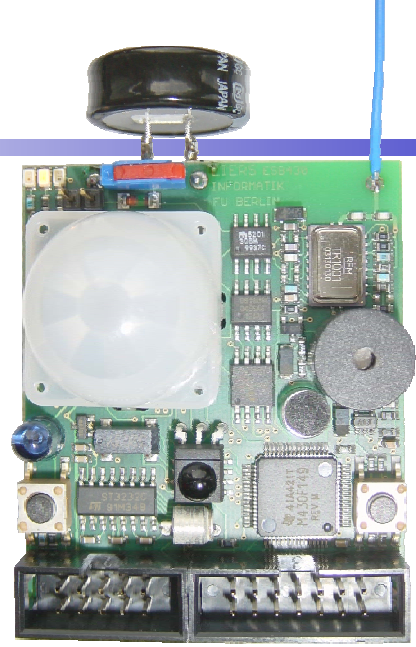
Configured Chains of Sensors



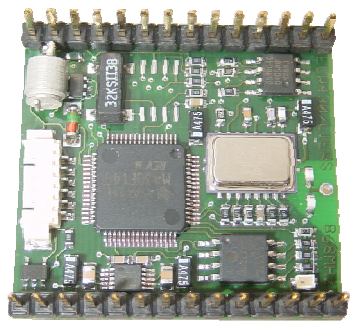
ScatterWeb Nodes

Embedded Sensor Board

- Luminosity sensor
- Noise detection
- Vibration sensor
- PIR movement detection
- Microphone/speaker
- IR sender/receiver
- Precise timing
- Communication using 868 MHz radio transceiver
- Simple programming (C interface)



Embedded Sensor Board



Modular Sensor Node

Further information:
www.scatterweb.net

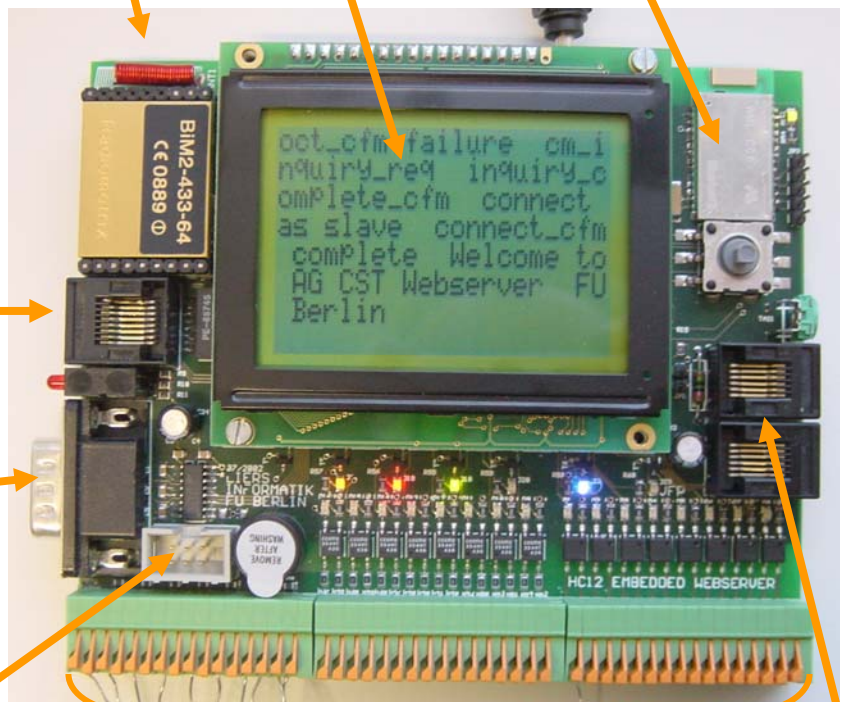
ScatterWeb Web Server

Embedded Web Server

RF

Display

Bluetooth



Ethernet

Serial I/O

WLAN
GPRS
WPAN
…

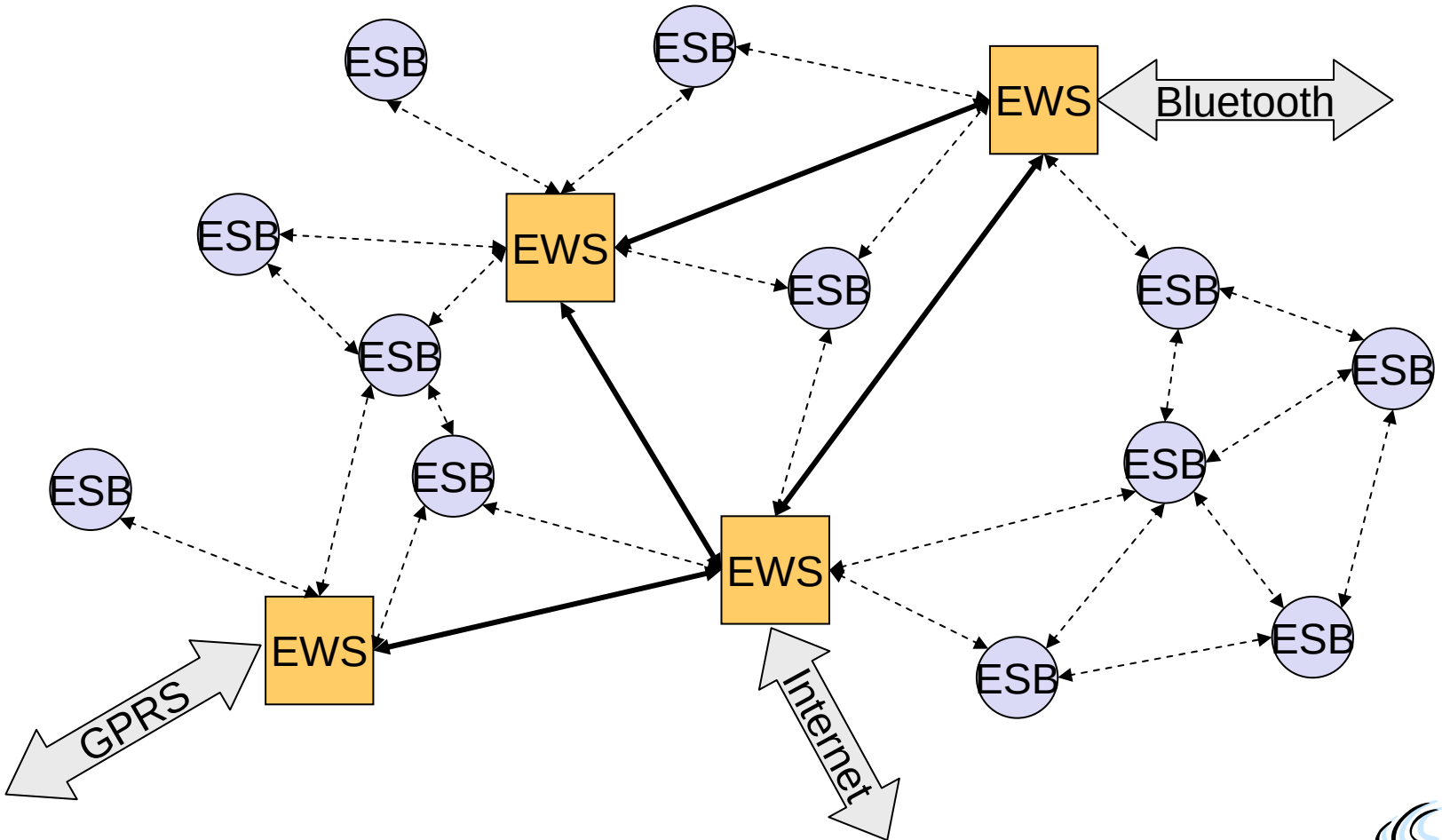
Debug interface

Digital & analog I/O

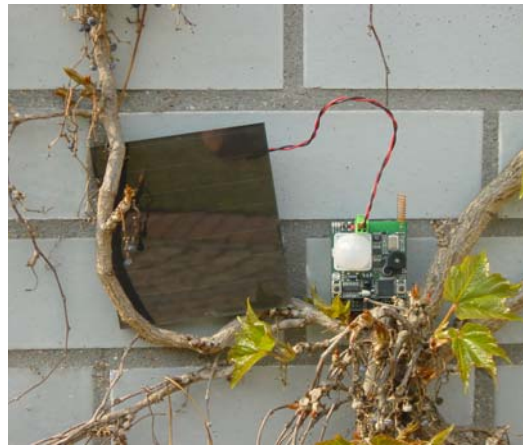
CAN

ScatterWeb

Interoperation between sensor network and web server



Energy Considerations



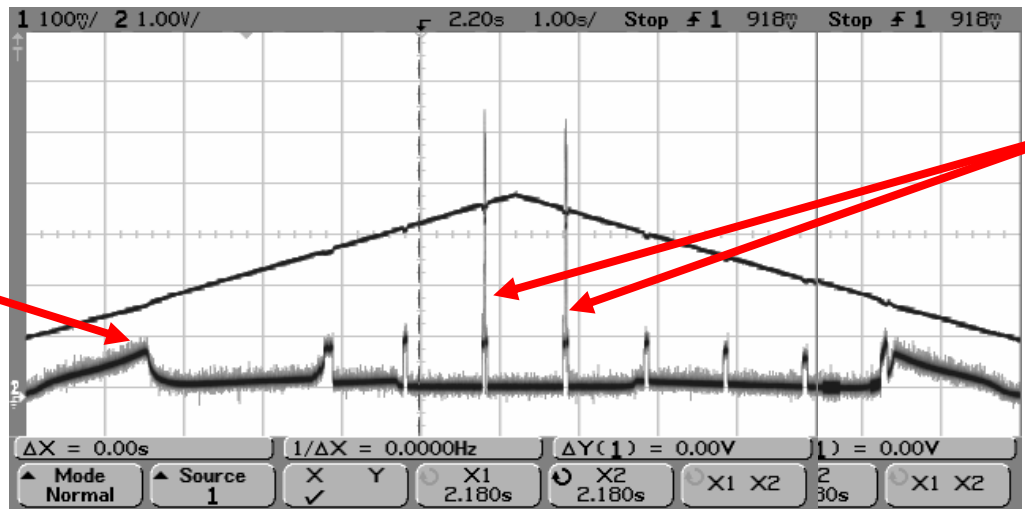
Solar-cell only deployment possible
⇒ routing across these nodes “for free”

Charging of a GoldCap
190 s full power run-time

Active energy management:
Switching to low power mode **before** running out of energy

power-on reset

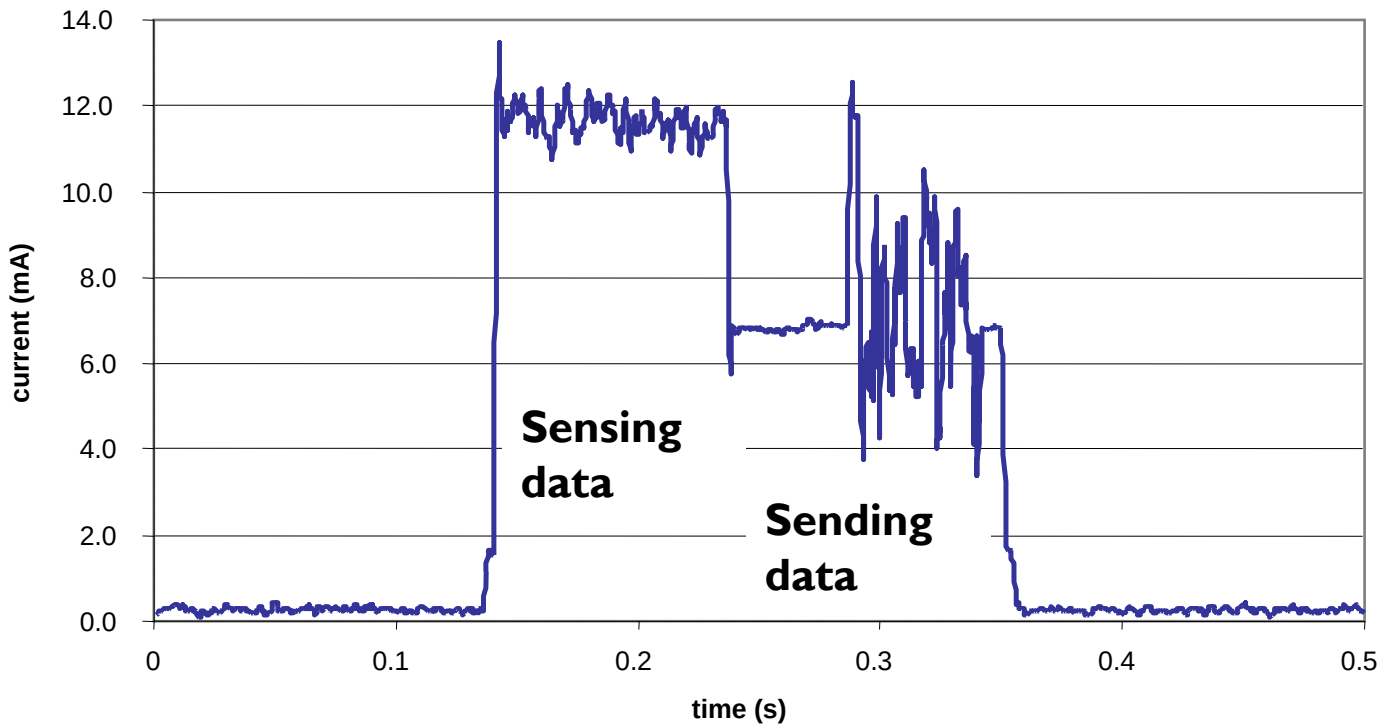
sending data



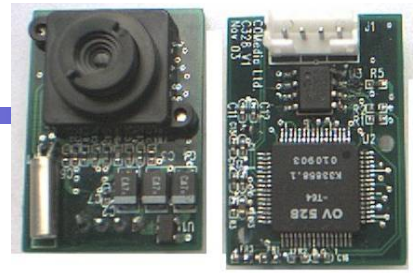
Typical Cycle: Measurement and Transmission

Current Sensors (ESB/2) – Stand-by: 7.6µA

- 5 years life-time with AA battery and 1% duty-cycle
- 17 years life-time with AA battery and sending 25 byte every 20 s
- Unlimited life-time with solar cell and gold cap capacitor

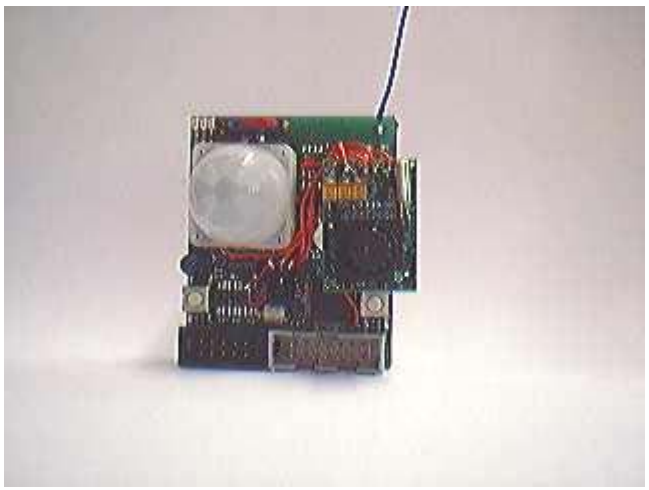


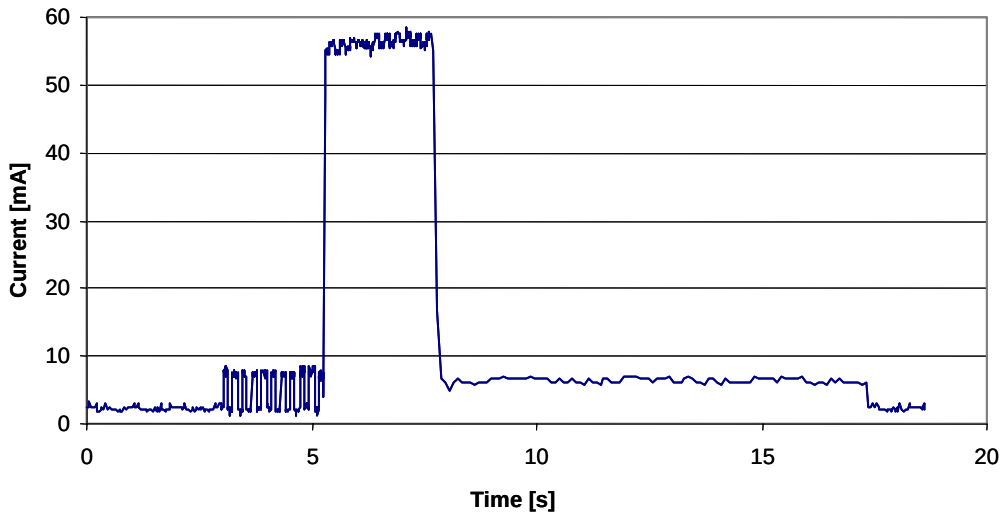
Low-Power Image Transmission



Low-power camera module with integrated JPEG engine

- 100 µA stand-by, 55 mA capture/transfer
- Serial interface, different modes (greyscale, 12/16 bit color, up to 640x480)

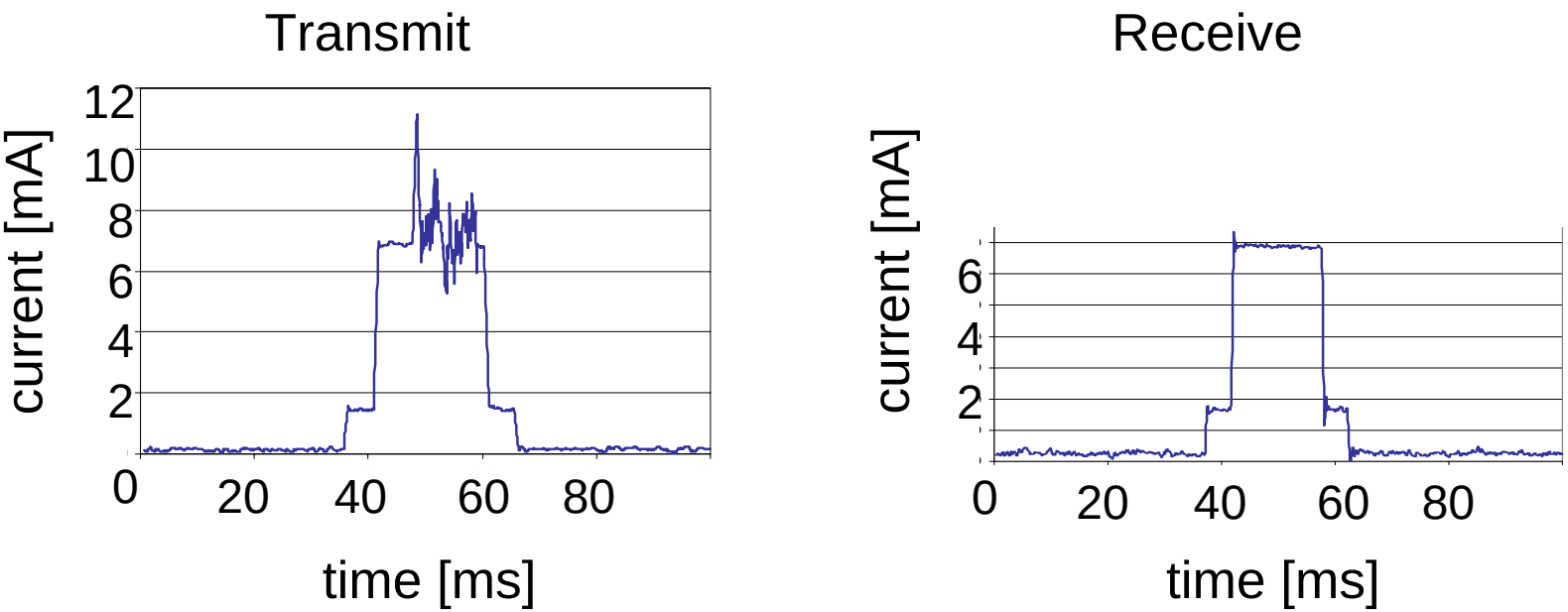




Power consumption of 0.058 mAh per transmitted picture

- Assuming 640x480, 20 kbyte and a 2000 mAh AA battery/80% usable as power supply - a sensor can now transmit about 27500 pictures!

Further Strategies



Receiving nearly as “expensive” as transmitting

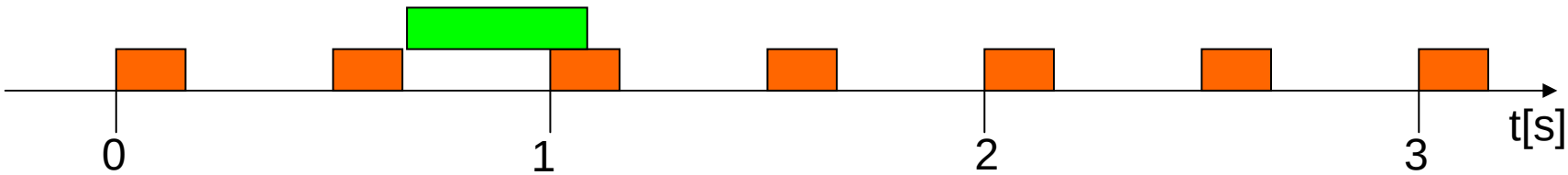
Small wake-up times

⇒ Always-on (listening all the time) too expensive

Outlook: Tradeoff of different MACs

Short listening times?

- Nodes listening into the medium at short intervals
- Nodes intending to transmit send longer request-to-send packet



150 ms listening, every 500 ms

400 ms request to send of a sending node

Slotted communication (synchronization)?

- Listen exactly at the assigned slot
- 1 s per day time shift with on-board real-time clock
- Synchronization overhead; flooding once a day?

Simple Aloha enough? ATIMs? SMAC? NAV like 802.11?

Data Aggregation

Content-dependent distribution

- Sensors send only packets if a critical value is reached
- User/application define critical value
- Publish/subscribe paradigm

Specification of critical value **and** time-dependency

- Pure rate-based wastes energy (e.g., transmitting every 10ms)
- Pure value-based unreliable (nothing changed or packet lost?)

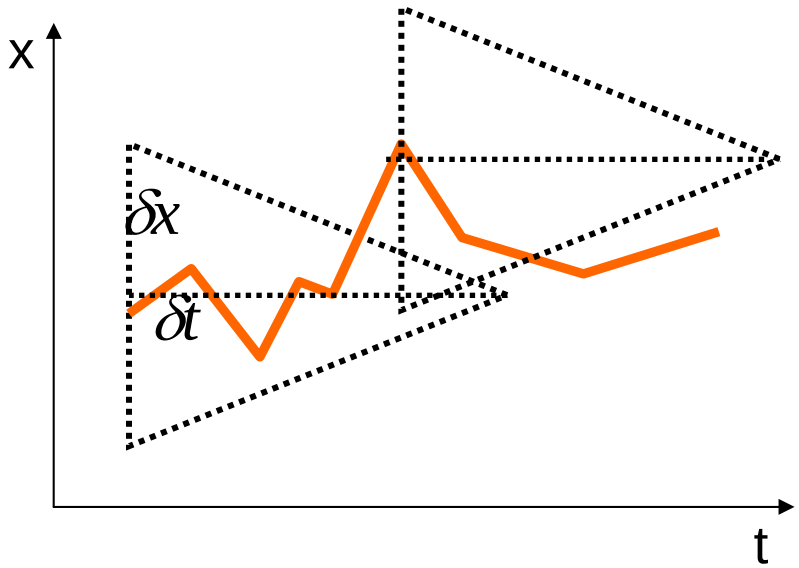
Proposition of *funnel functions*:

- Immediate notification of massive changes
- Iterative notification (heartbeat)

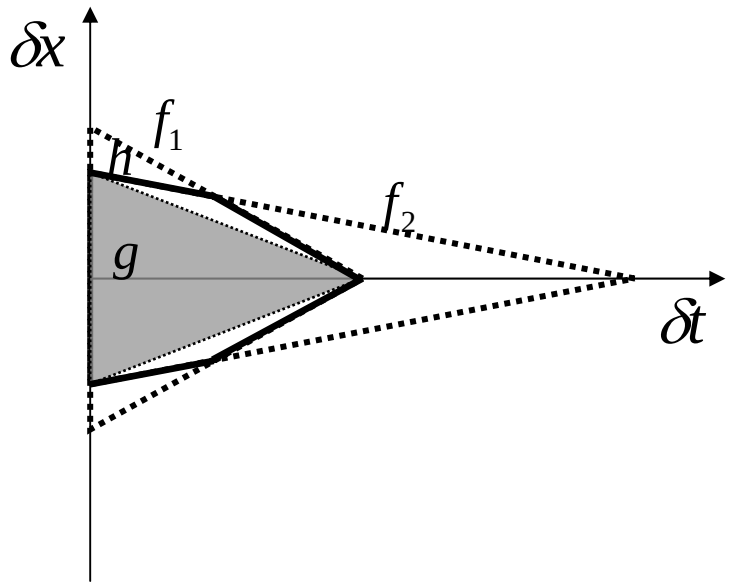
- Ongoing work together with Technical University of Berlin (Prof. Geihs)

Funnel Functions

Example: transmit if $|\delta x| > 1° \times (1 - \delta t/10s)$



sequential application of funnel functions

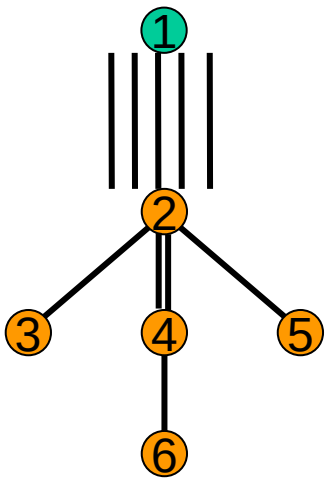


perfect (h) and imperfect (g) merging of funnel functions

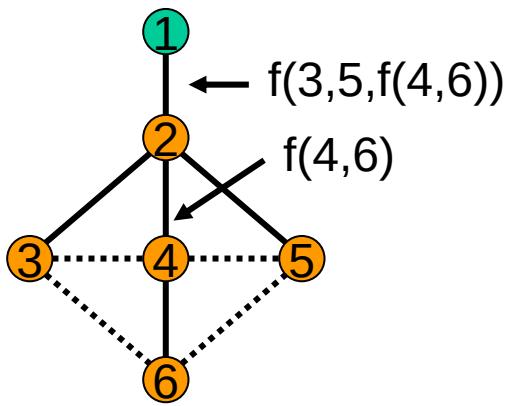
Outlook: Nested Queries

Nested queries

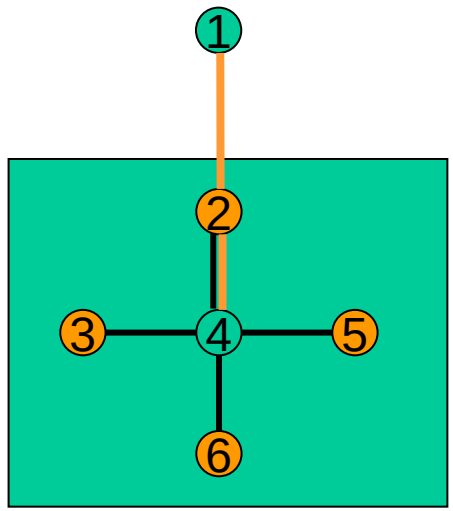
- One event triggers sensing activity in an area (**conditional sensing**)
- Example:
  Start of noise level sampling when at least four nodes detect movement
  ($\Rightarrow$ intrusion detection in buildings)



straight forward



aggregated



aggregated and conditional

Managing WSNs with 100+ Nodes

How to debug 100+ nodes?

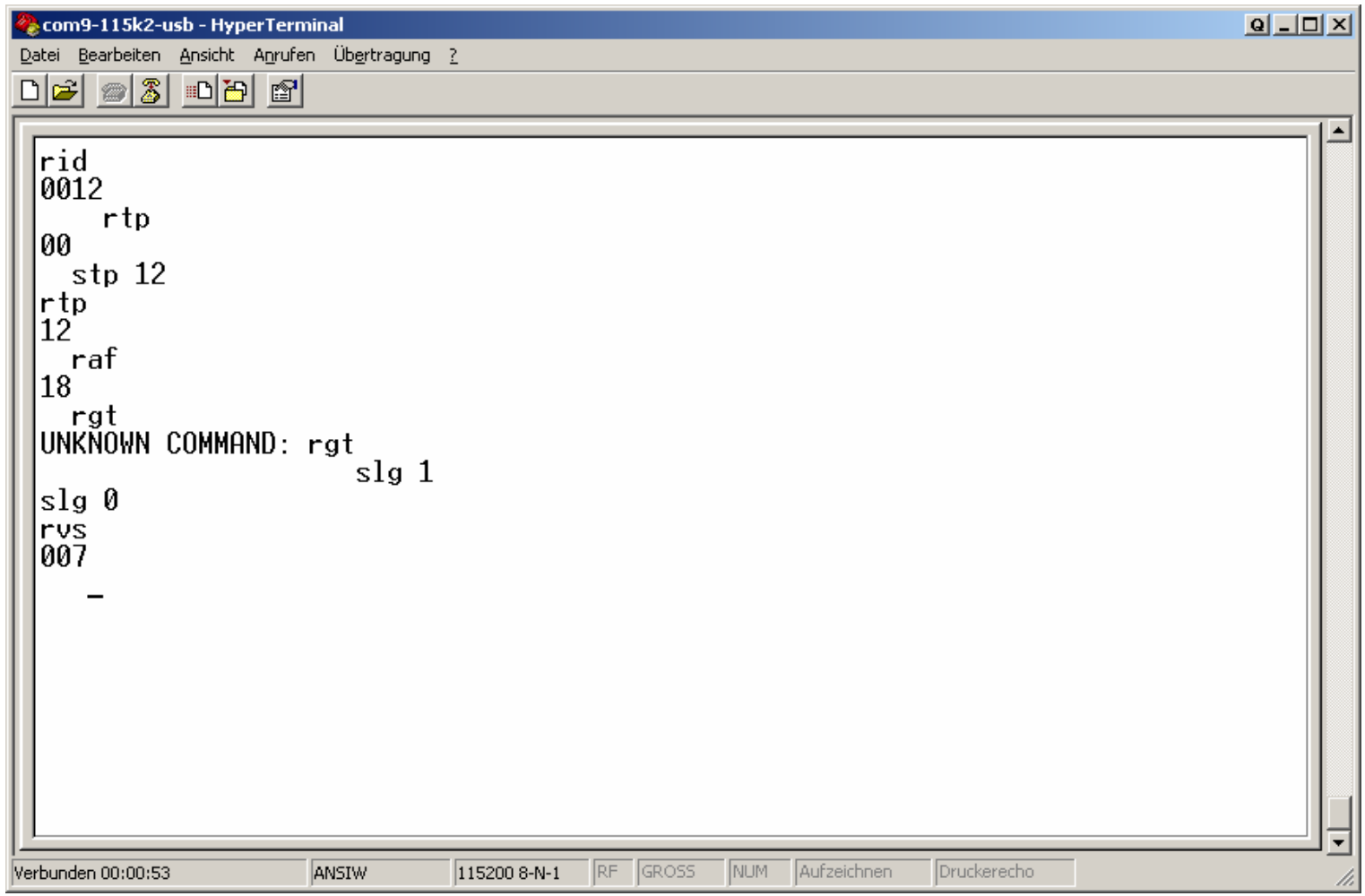
How to adapt the network to new tasks?

How to support node exchange (long-term administration)?

- Over-the-air flashing
- Separation into firmware and tasks

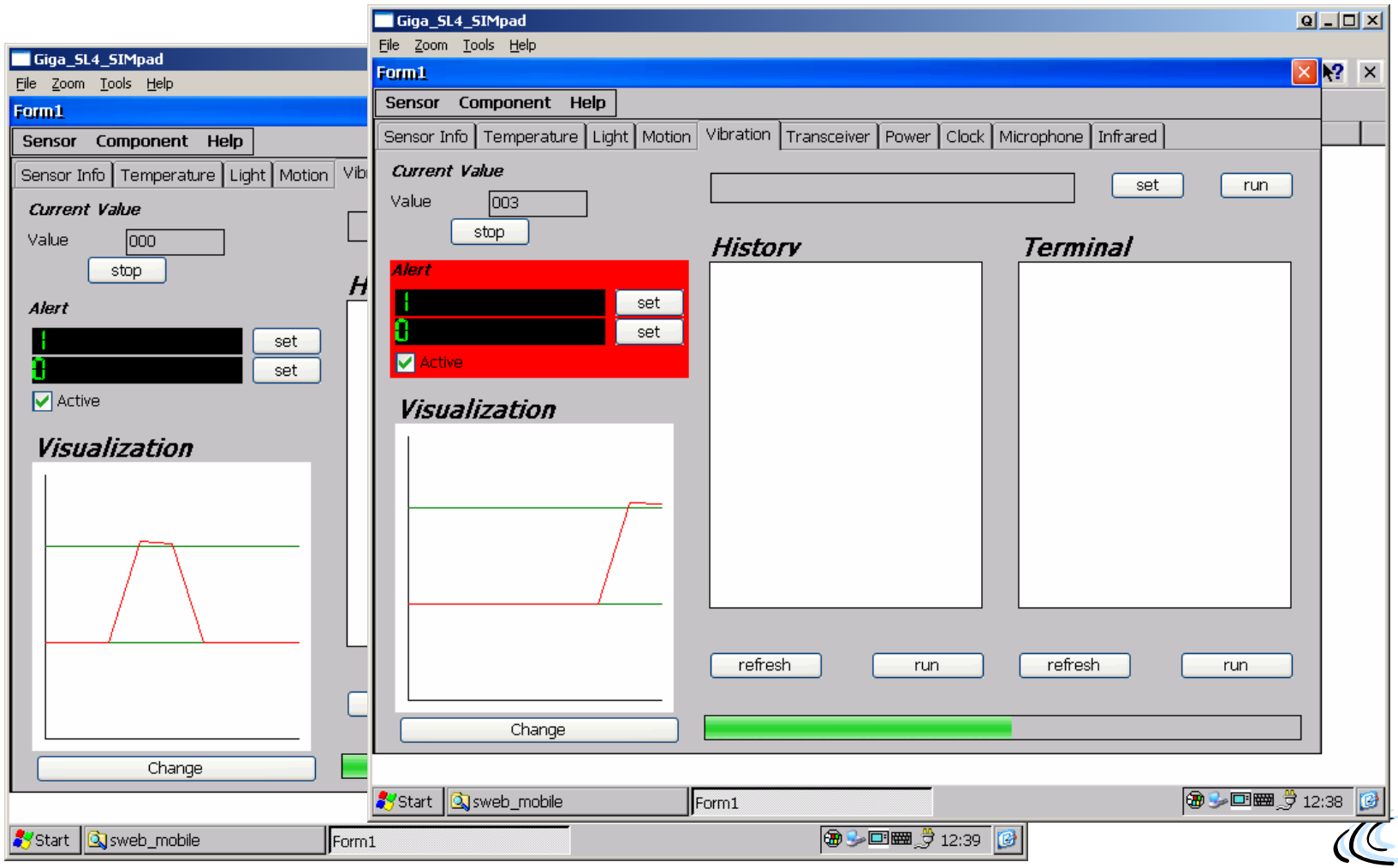
Where we started …

Serial port to each node



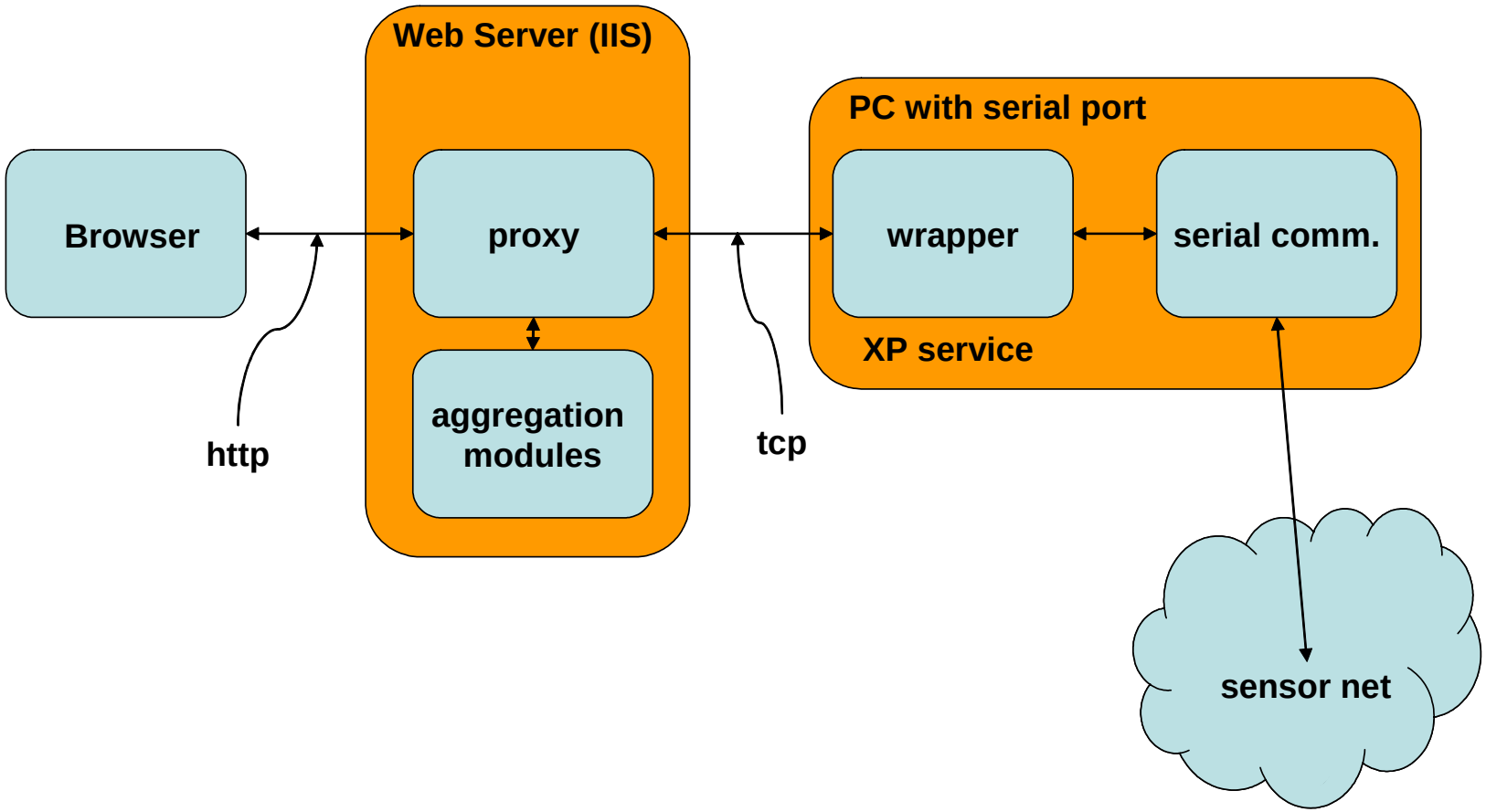
GUI

Serial cable attached to PC / Win CE device



Internet Access

Straightforward connection of WSN and Internet



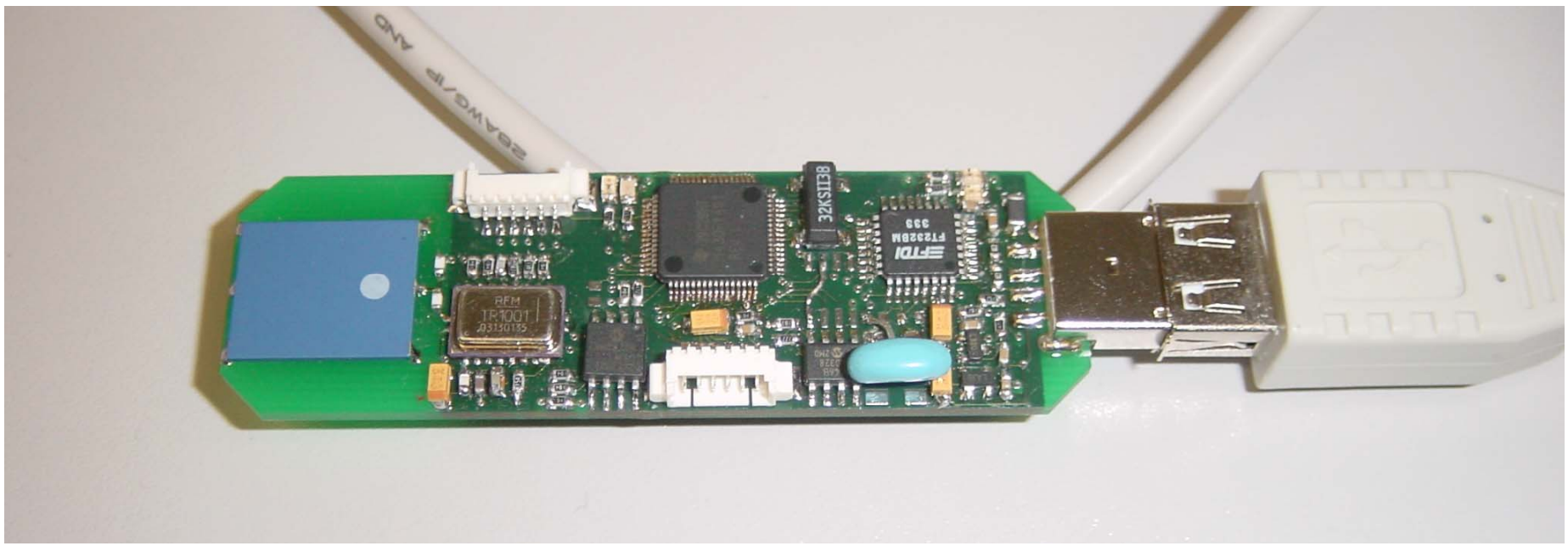
Consequence

PCI board for additional 8 serial ports

Result: ScatterFlasher as Convenient Gateway

USB → MSP430 → 868 MHz transceiver

- Standard USB, Integration into Windows
- JTAG interfaces for initial programming and programming of other devices
- OTA flashing: point-to-point, broadcast (near future: reliable multihop)

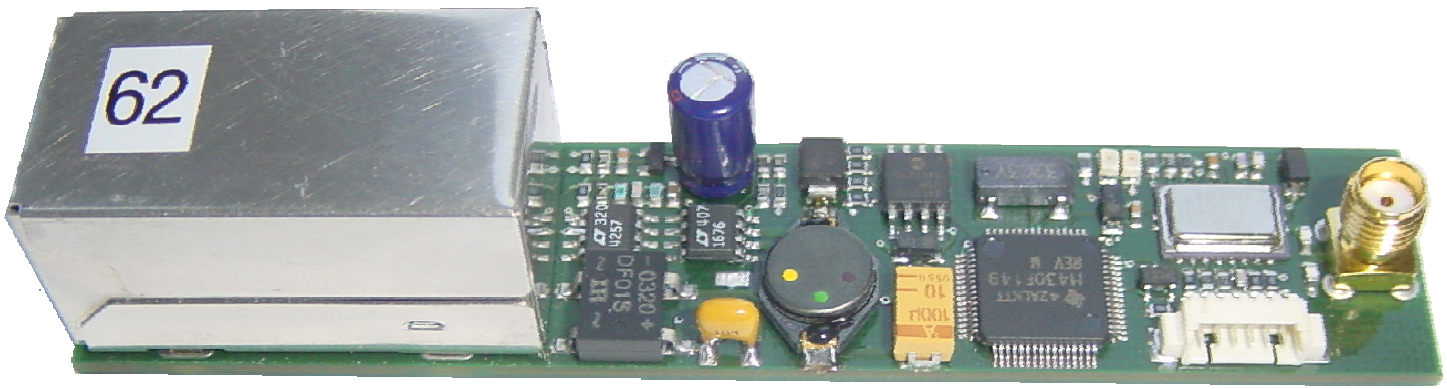


Another Gateway: Ethernet to ScatterWeb

RJ45 Adapter for 10/100 Mbit/s Ethernet

- Power-over-Ethernet (802.3af)
- Standard Internet protocols (IP, TCP, HTTP, HTTPS, ARP, DHCP)
- Integrated Web server providing applets for sensor net control

Access of ScatterWeb from any browser on the net (secured)



Code Distribution

Heidemann, Estrin et al.:
Multihop Code Distribution for Sensor Networks

- Ripple transport protocol:
  nodes advertise their versions, local retransmissions
- Drawback:
  long latency

Experimental results needed for quantitative comparisons:

- Ripple vs. Flooding
- Hierarchical segment mapping (hop-to-hop)
  vs. Sliding Window (end-to-end)

Outlook: Research Topics

Different Protocols for different tasks

- Directed Diffusion-like for sensor tasks
- Reliable protocol for updates (TCP?)

How to guarantee timely updates?

How to realize simultaneous updates?
(imagine switching to a completely new routing protocol, packet format, kind of “Active Sensor Net”)

- Phase I: Download of new firmware to all nodes
- Phase II: Simultaneous flashing of all nodes

Reproducible Experiments

Scenario:

Compare a routing protocol in simulation and reality

1. Write a task that implements your new routing protocol
2. Upload task to all nodes
3. Let it run
4. Switch back to old system after a defined time period!!!

Scripting

Scripting:

1. Upload a script to all nodes
2. Let the firmware sync all nodes,
   start new routing on all nodes simultaneously
3. Let all nodes log relevant events
4. Switch back to normal operation, report results

How to script events?

- Pre-calculate an event for each node
- “fake” an event locally

Sensornets as Distributed Database

Interface to a WSN is a DB interface

- View the sensor net as physically distributed objects of a database

Example

- SELECT AVERAGE (temp) FROM sensors

Data aggregation

- COUNT, MIN, MAX, AVERAGE, SUM

S. Madden, R. Szewczyk, M. Franklin and D. Culler (2002):
Supporting Aggregate Queries over Adhoc Wireless Sensor Networks

Aggregation

Reduction of network load

- Central approach vs. physically distributed objects

Groups

- Group identification
- Membership is based on sensor values
- Aggregation of attributes within a group

Leaf nodes

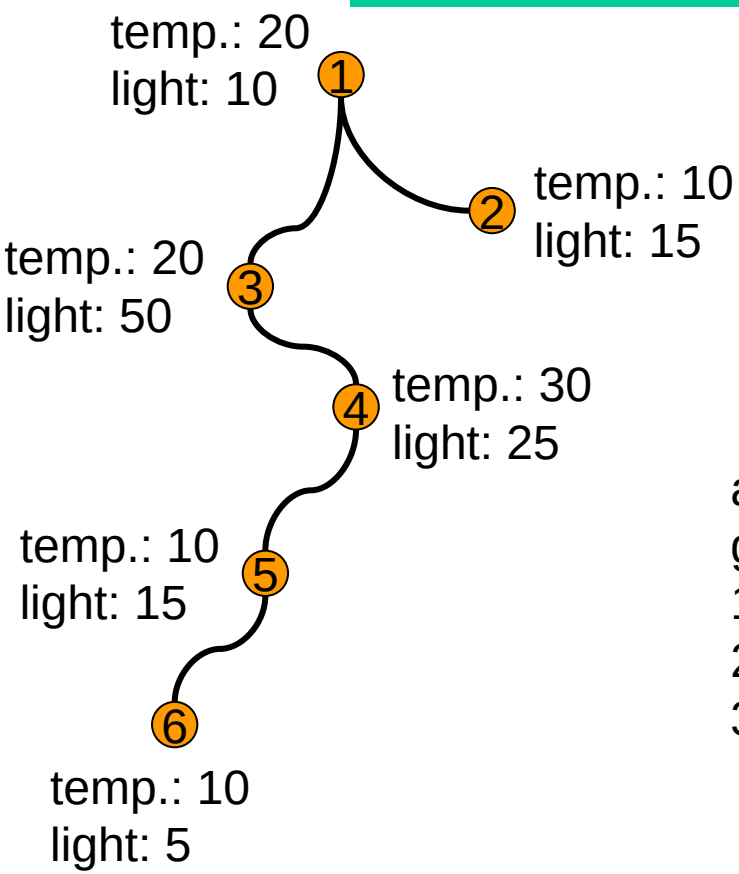
- Marking of messages with group ID

Inner nodes

- Aggregation, if messages within the same group
- Artificial delays useful for aggregation with neighbor nodes

Example

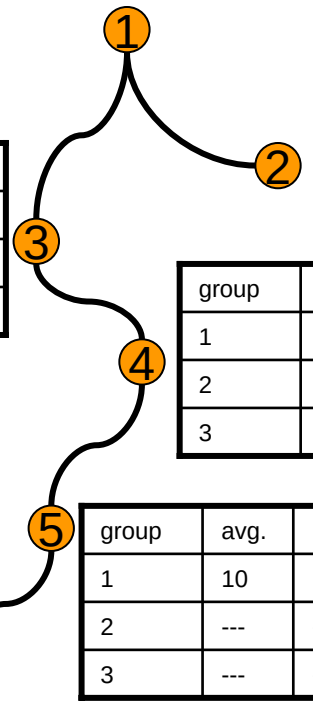
```
SELECT TRUNC(temp/10), AVERAGE (light)
        FROM sensors
        GROUP BY TRUNC (temp/10)
```



average (light)
groups:
1: 0<temp.<=10
2: 10<temp.<=20
3: 20<temp.<=30

group	avg.	
1	18	6,5,2
2	30	3, 1
3	25	4

group	avg.	
1	10	6,5
2	50	3
3	25	4



group	avg.	
1	10	6,5
2	---	---
3	25	4

group	avg.	
1	10	6,5
2	---	---
3	---	---

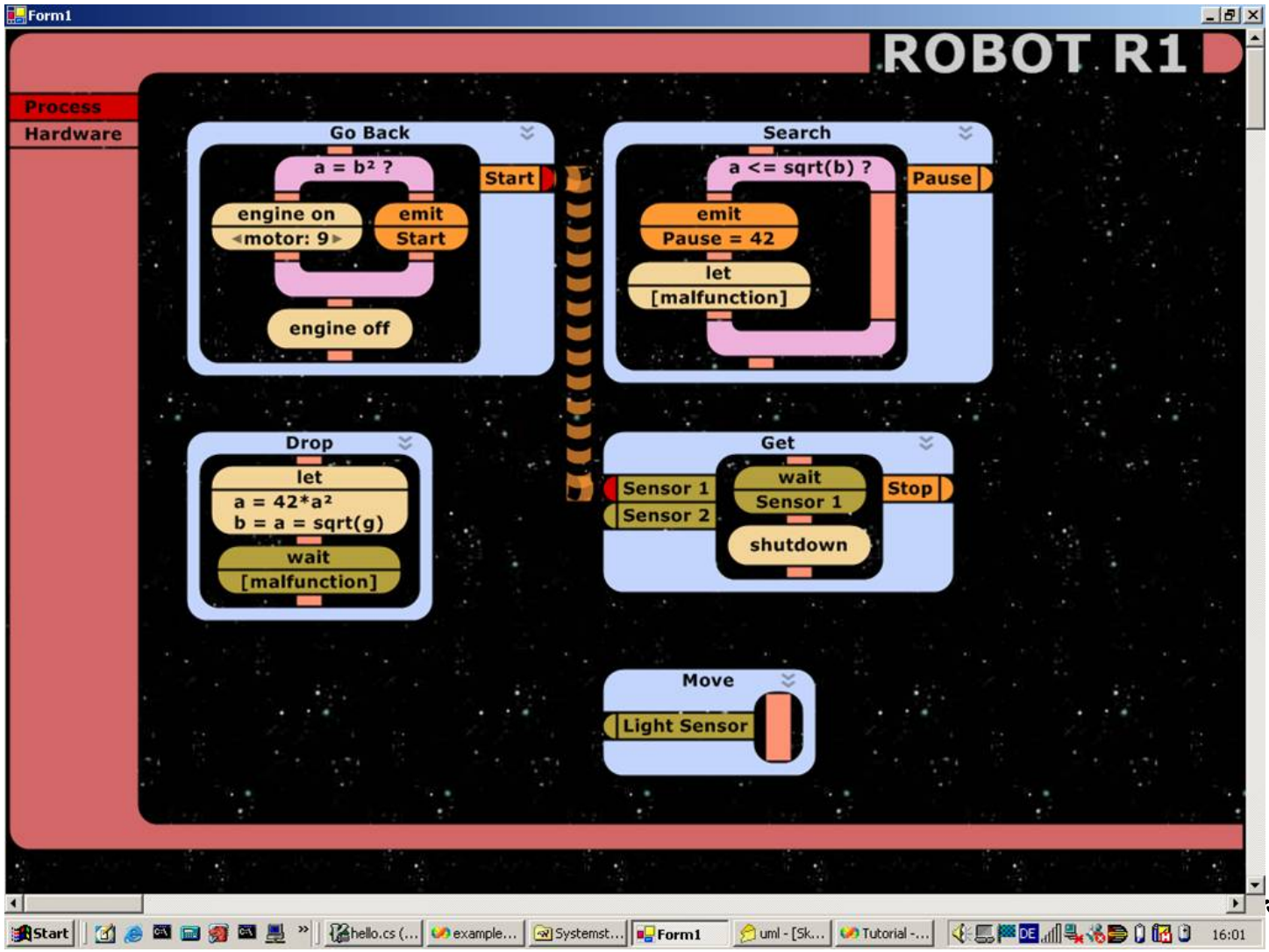
Activities with SICS

TCP/IP for sensor networks [Dunkels, Voigt, Alonso, Ritter, Schiller: Connecting Wireless Sensornets with TCP/IP Networks, WWIC2004]

Use Contiki and µIP [Dunkels: Full TCP/IP for 8-Bit Architectures, MobiSys2003]

- Operating system with very small footprint
- TCP/IP stack with very small footprint
- Web server already runs on the ESB
  - Thanks to Adam Dunkels!
  - Check it out: http://193.10.67.150/

Activities with TU Berlin – Lego-like Programming

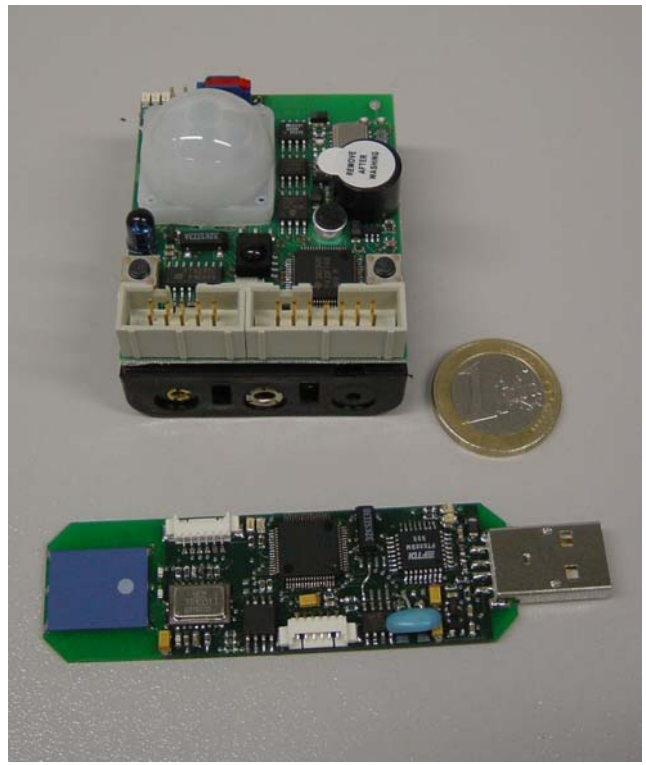


Conclusion

ScatterWeb platform available

- Sensor nodes
- Embedded web server
- Scatter flasher

Open & fully documented HW&SW!

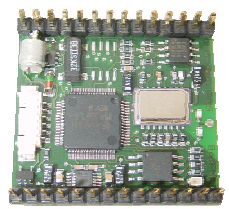


Initial work – still continued

- Routing (DD & solar aware)
- Energy conservation
- Data aggregation
- Localization
- Management

Current & Future Activities

- Smaller nodes, new RF (UWB)
- System aspects (TinyOS, security, middleware, …)



Scenario

Gamers enter a subway station

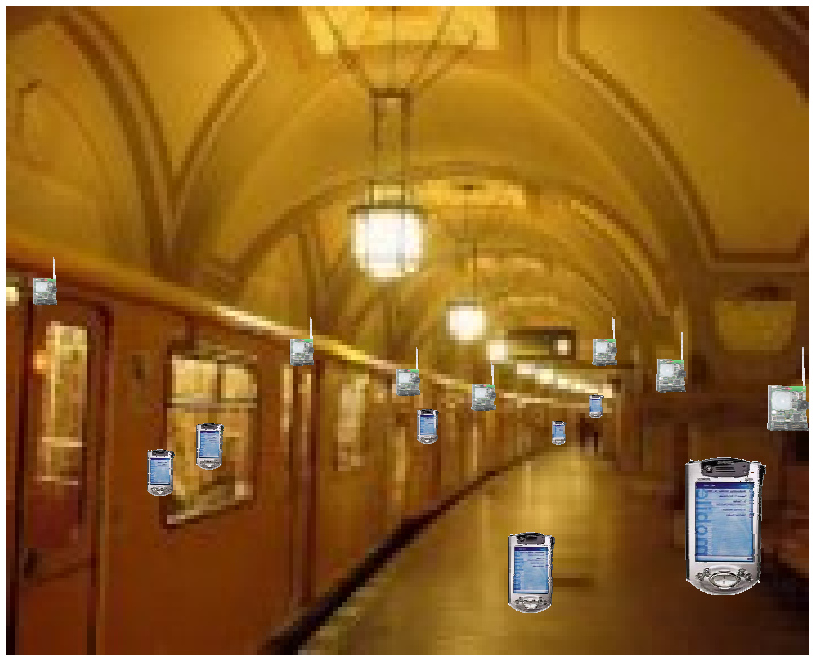
Discover other gamers and games

Communication within piconets and multihop

Leaving high-scores and gamer tags

WSNs

- Support gaming
- Help merging virtual/real reality
- Movement detection, access point, data forwarding, …



Berlin subway station

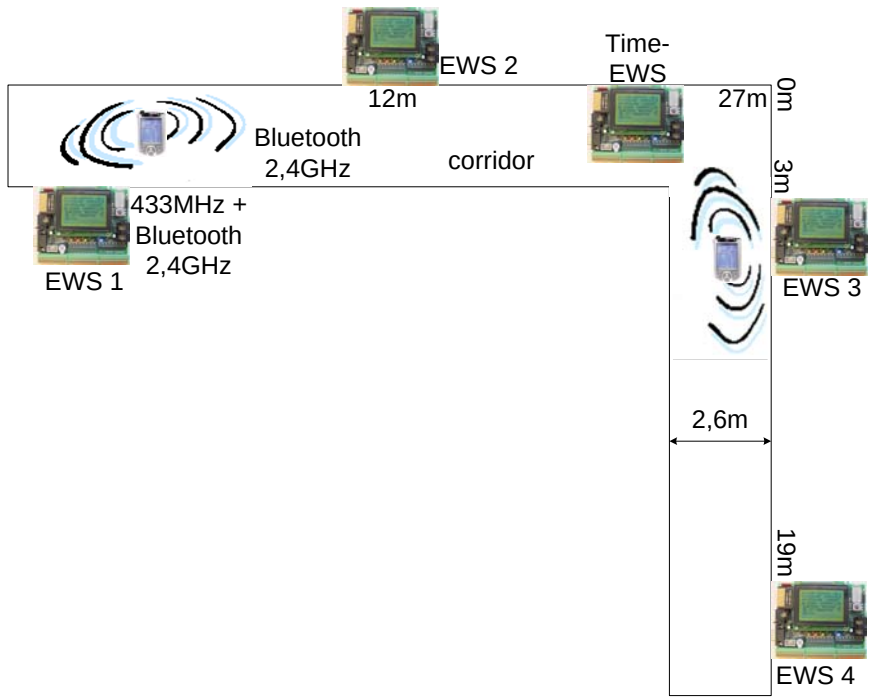
Prototype

Infrastructure

- Embedded Web Server with several radio interfaces
- 2,4 GHz Bluetooth, communication with PDAs, mobile phones
- 433/868 MHz RF for infrastructure

Ad-hoc

- Set-up of “infrastructure”
- Direct gaming between PDAs



Research Areas of the CST Group @ FU Berlin

Embedded Internet systems

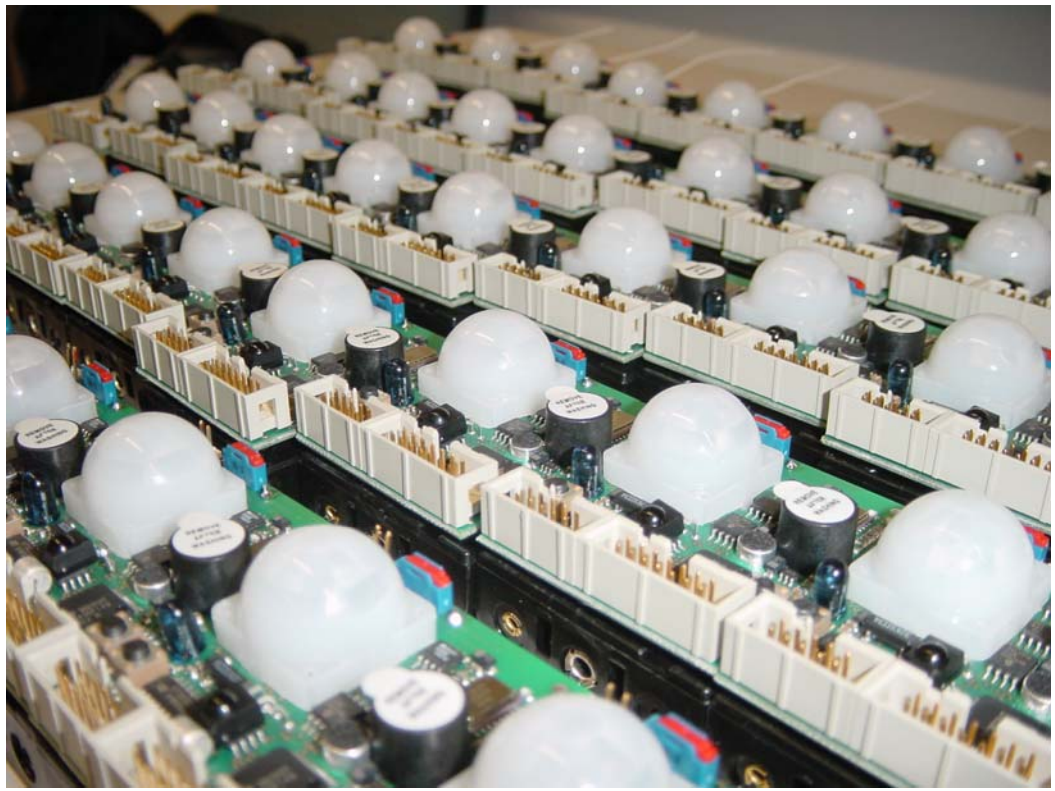
Peer-to-peer networks

QoS for Web Services

Mobile Entertainment

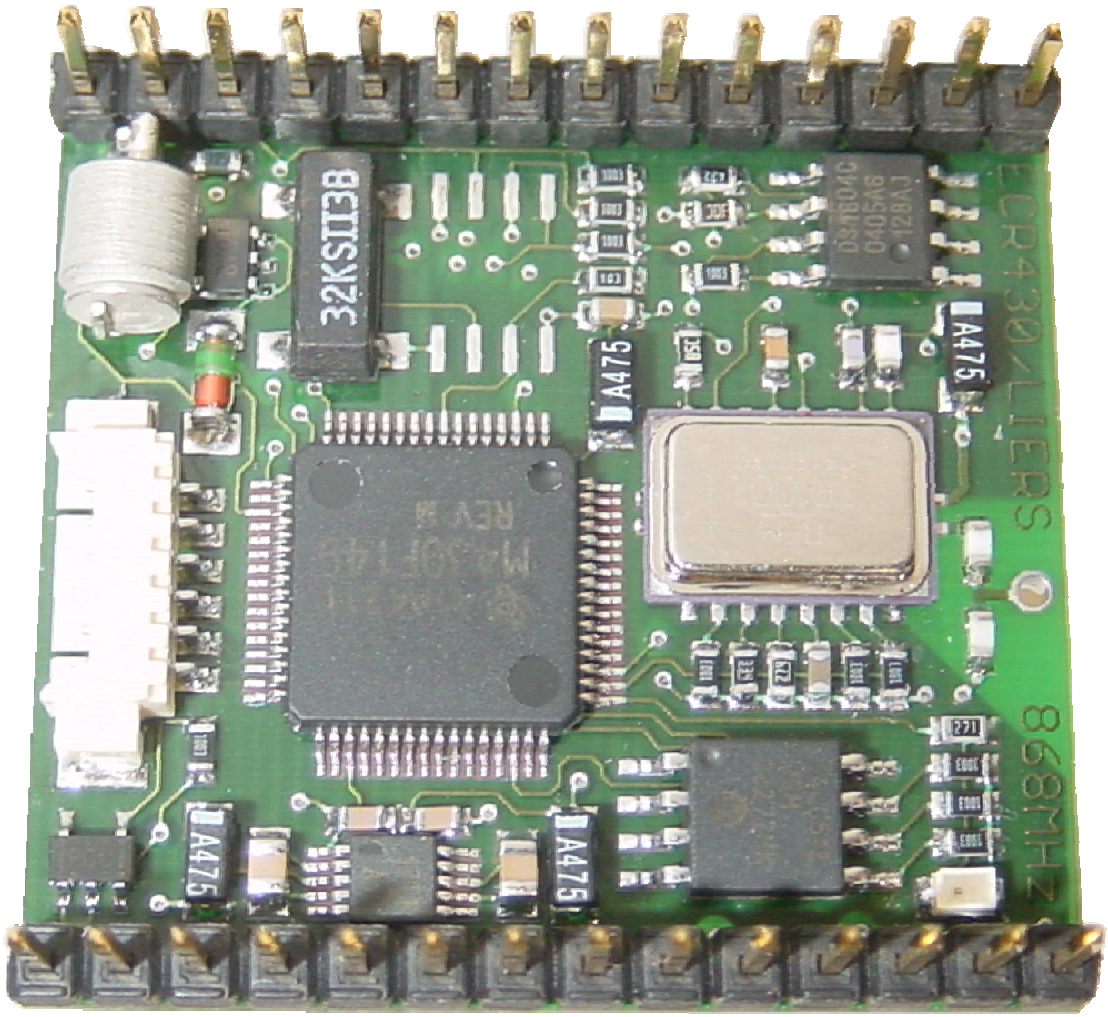
Sensor networks

Ad-hoc networking

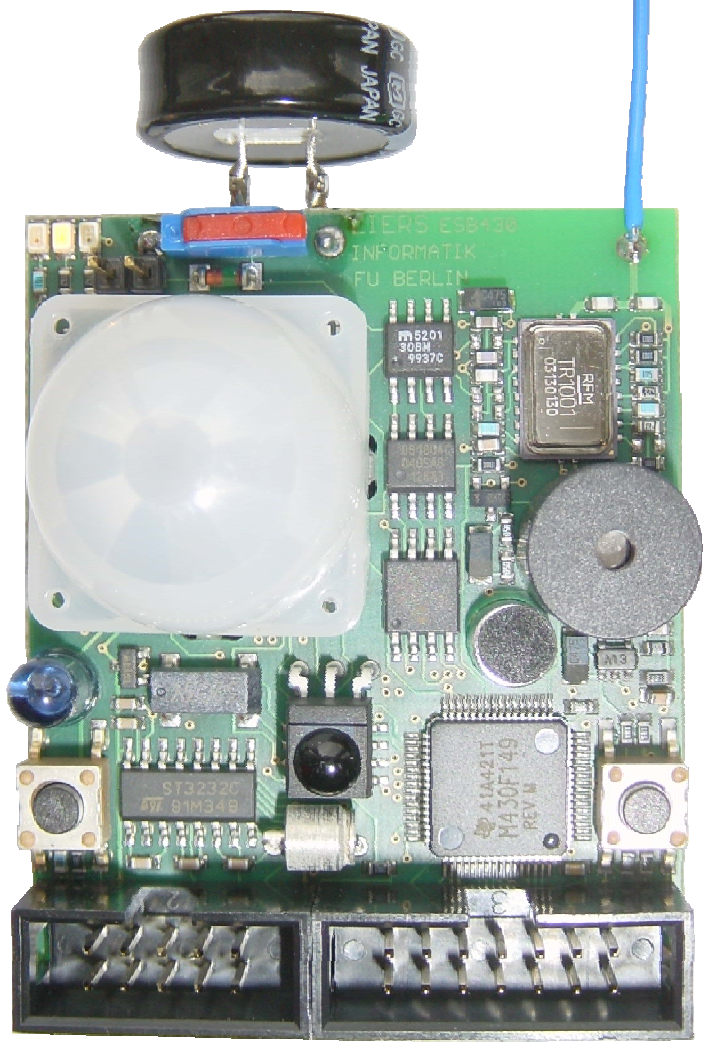


„Peer-to-peer web and Internet services with quality-of-service support for embedded systems in mobile and wireless ad-hoc network environments.“

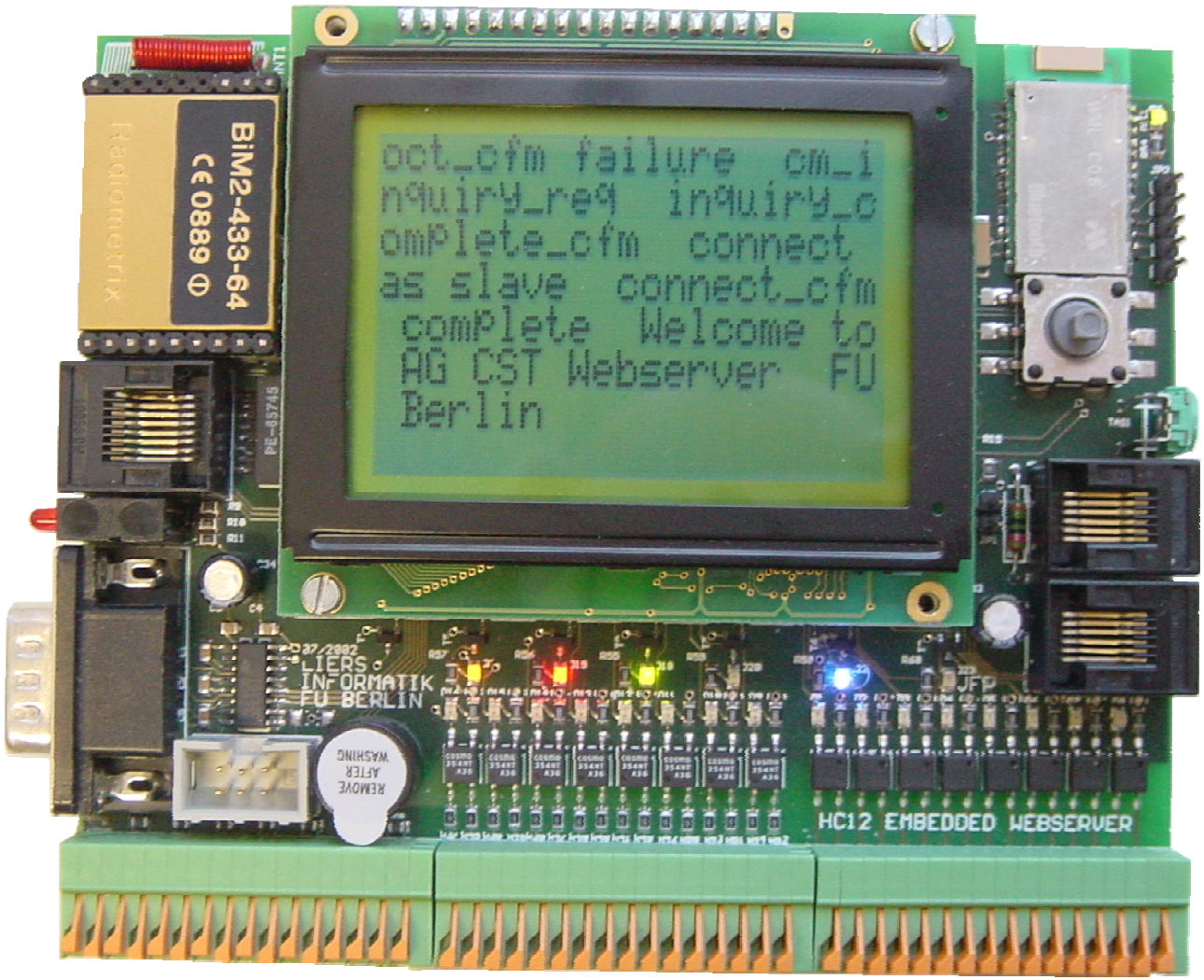
ESB Radio Only Module



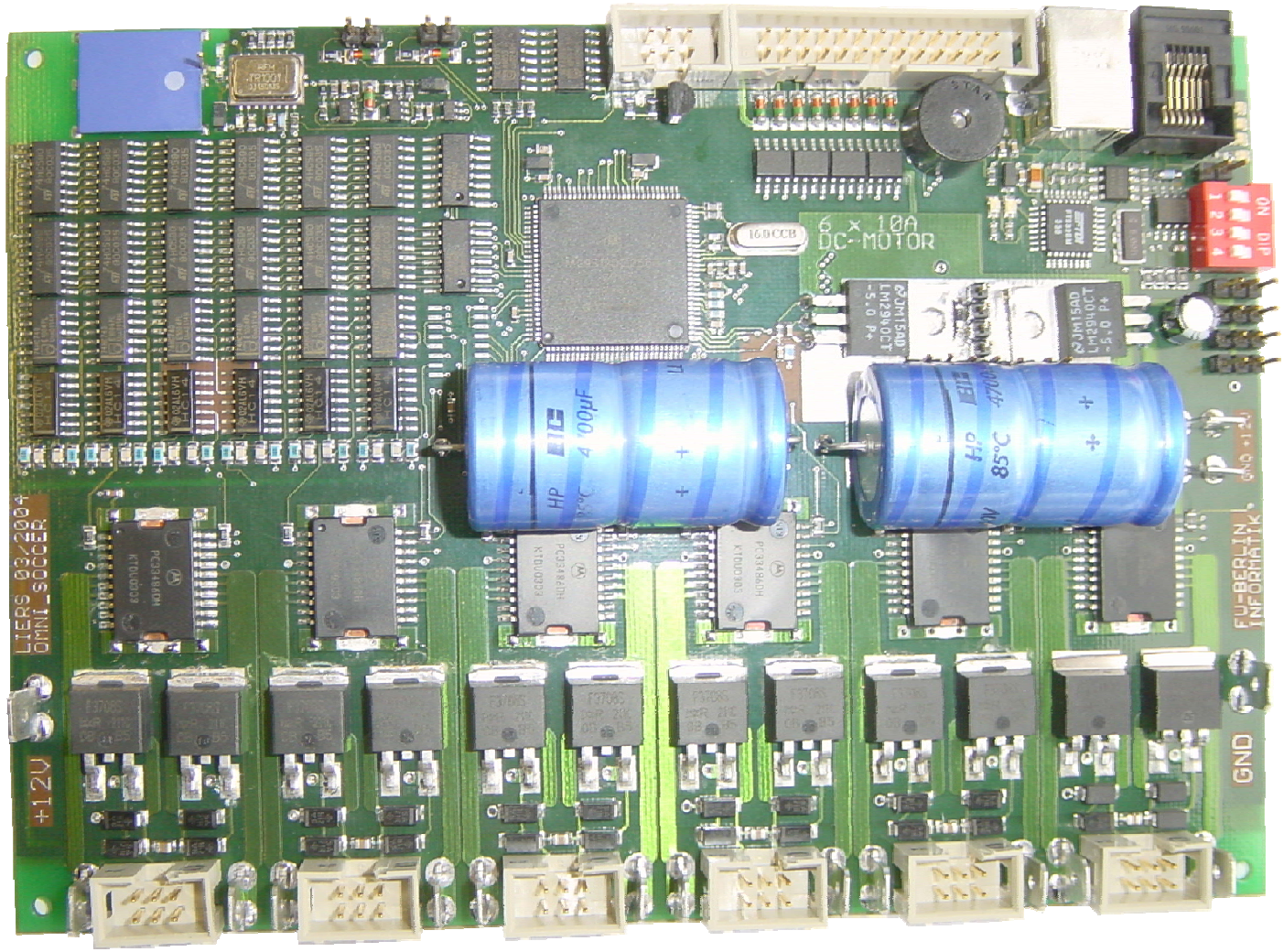
ESB2 Full Featured



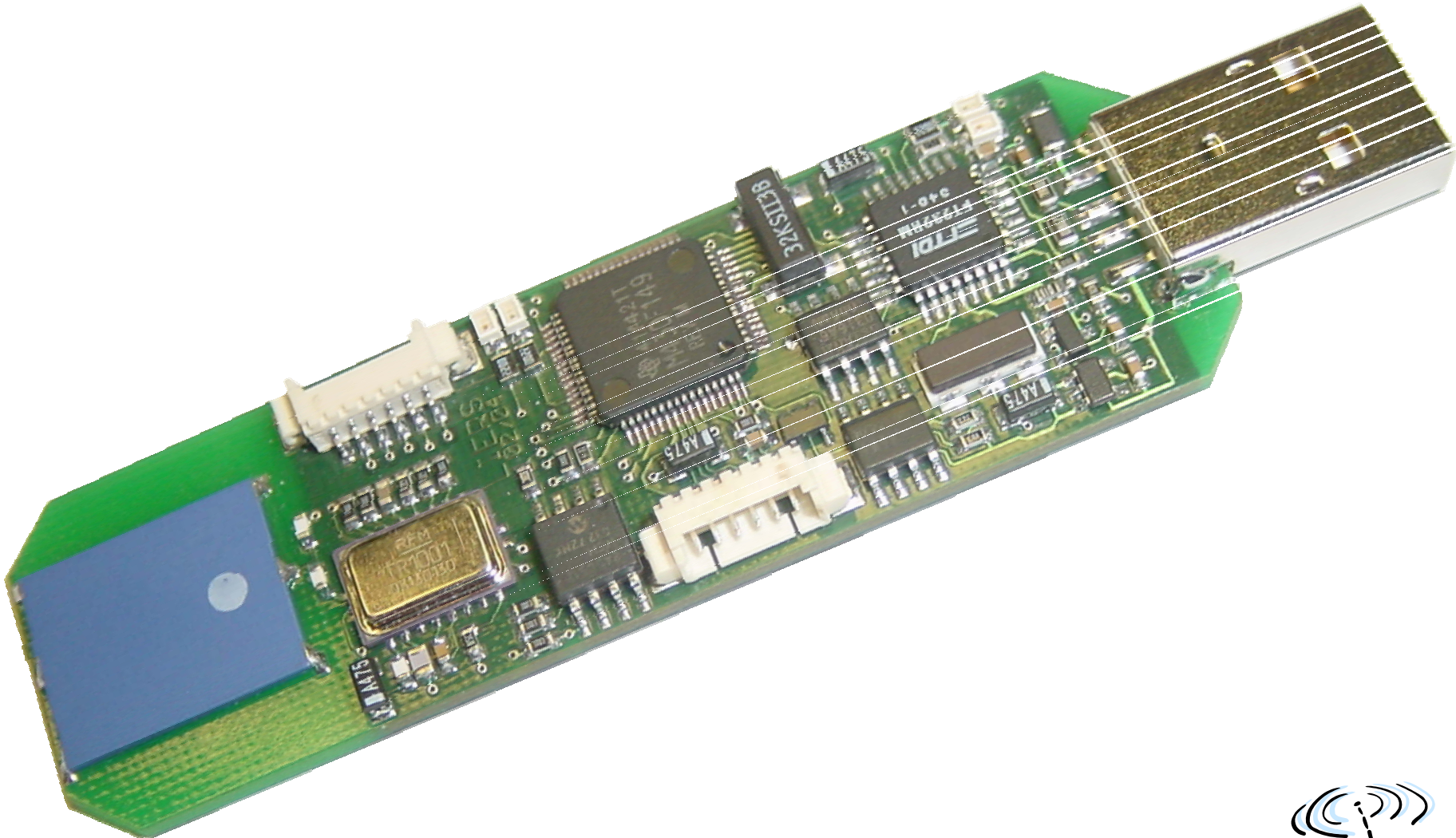
Embedded Web Server



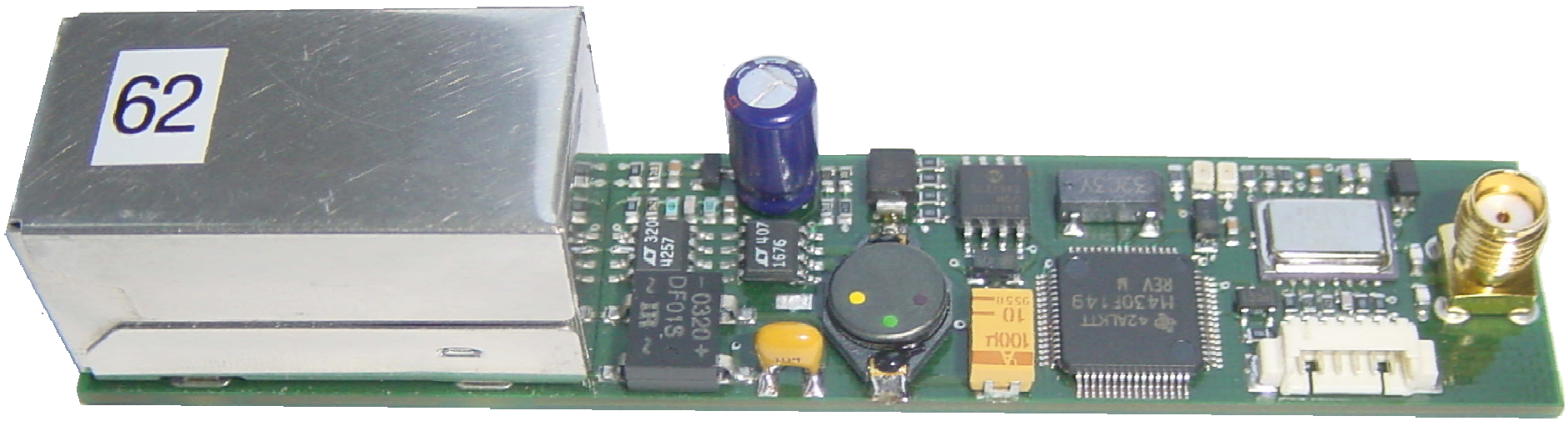
MidSize Controller Board



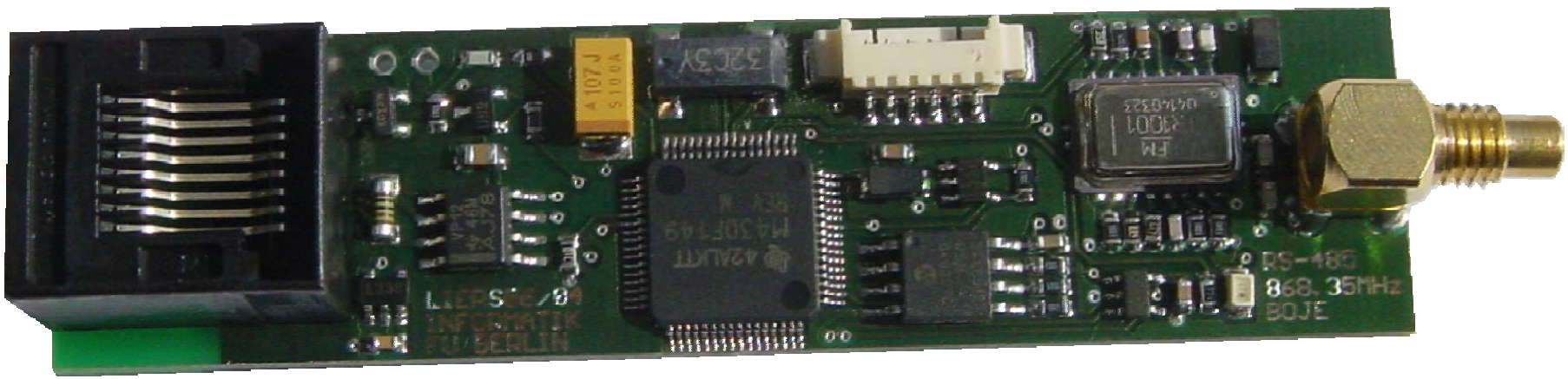
ScatterFlasher



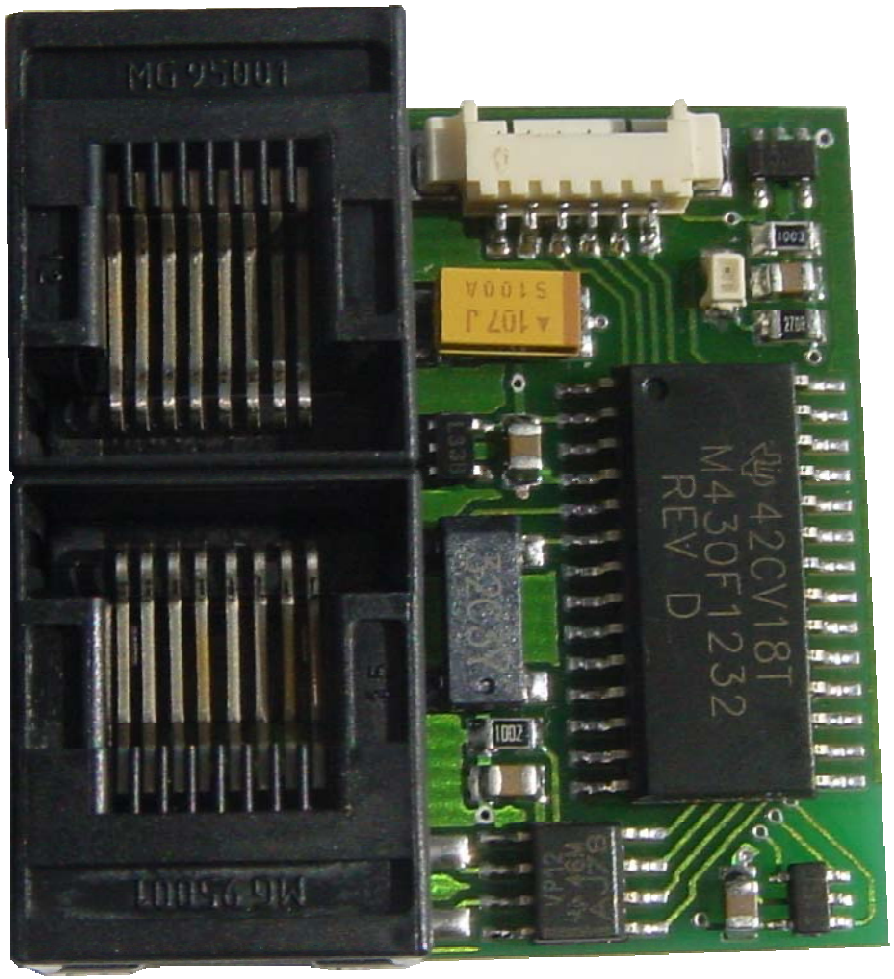
Ethernet Webserver – ScatterWeb Gateway



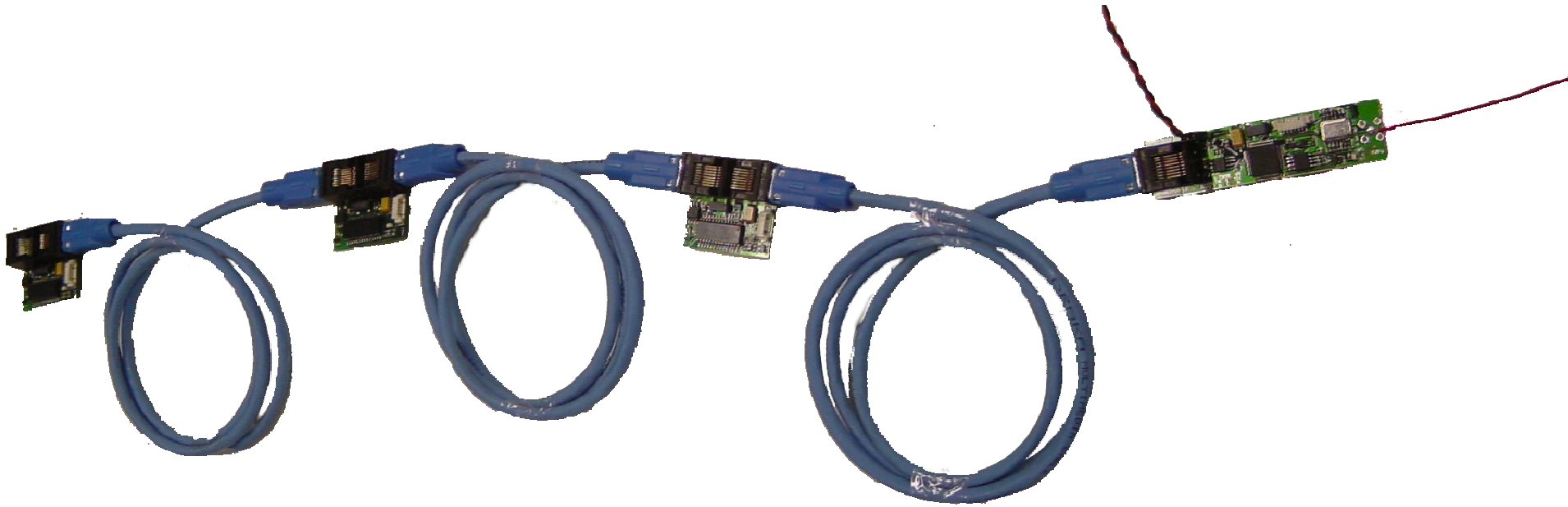
Buoy Sensor Node RF



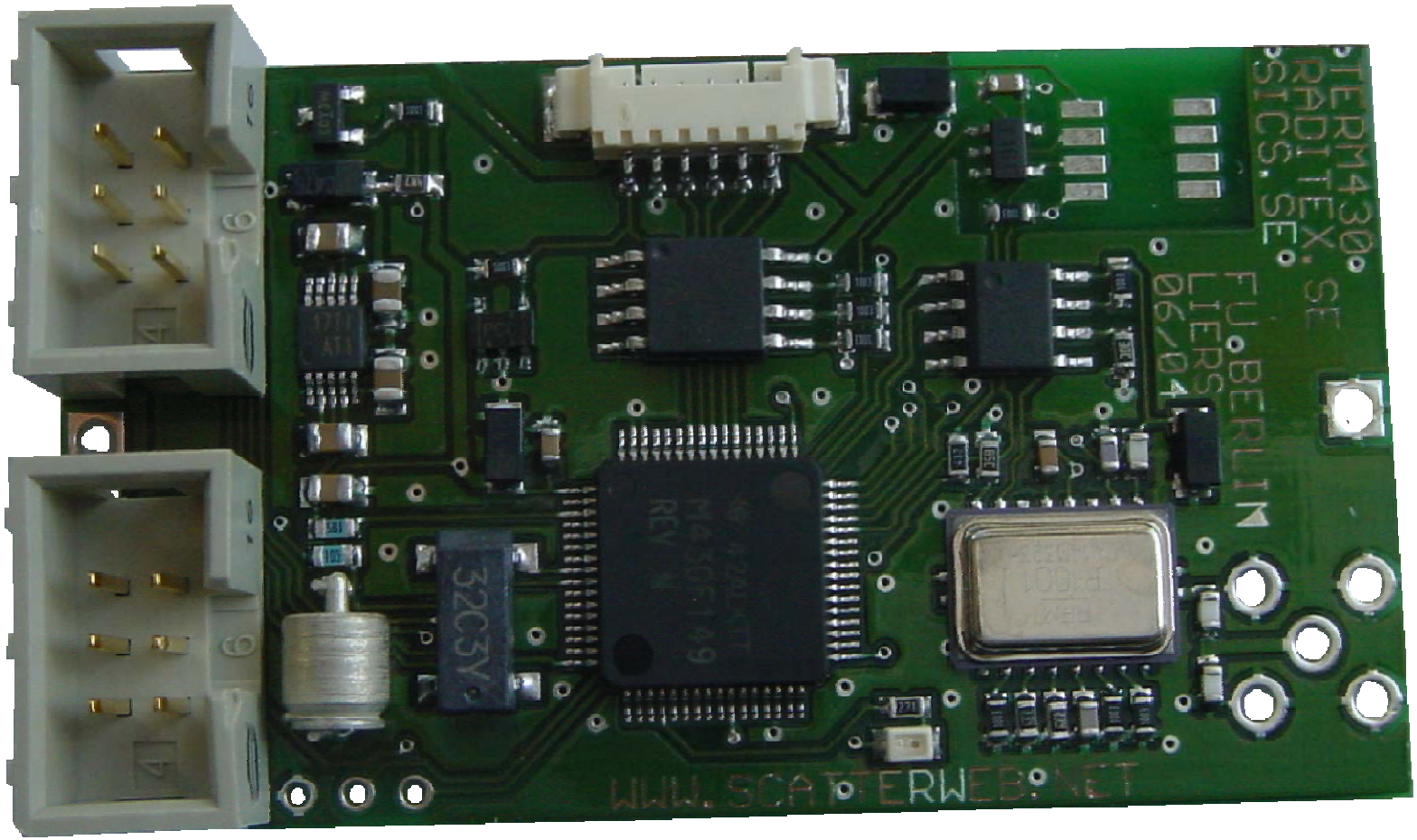
Buoy Sensor Node



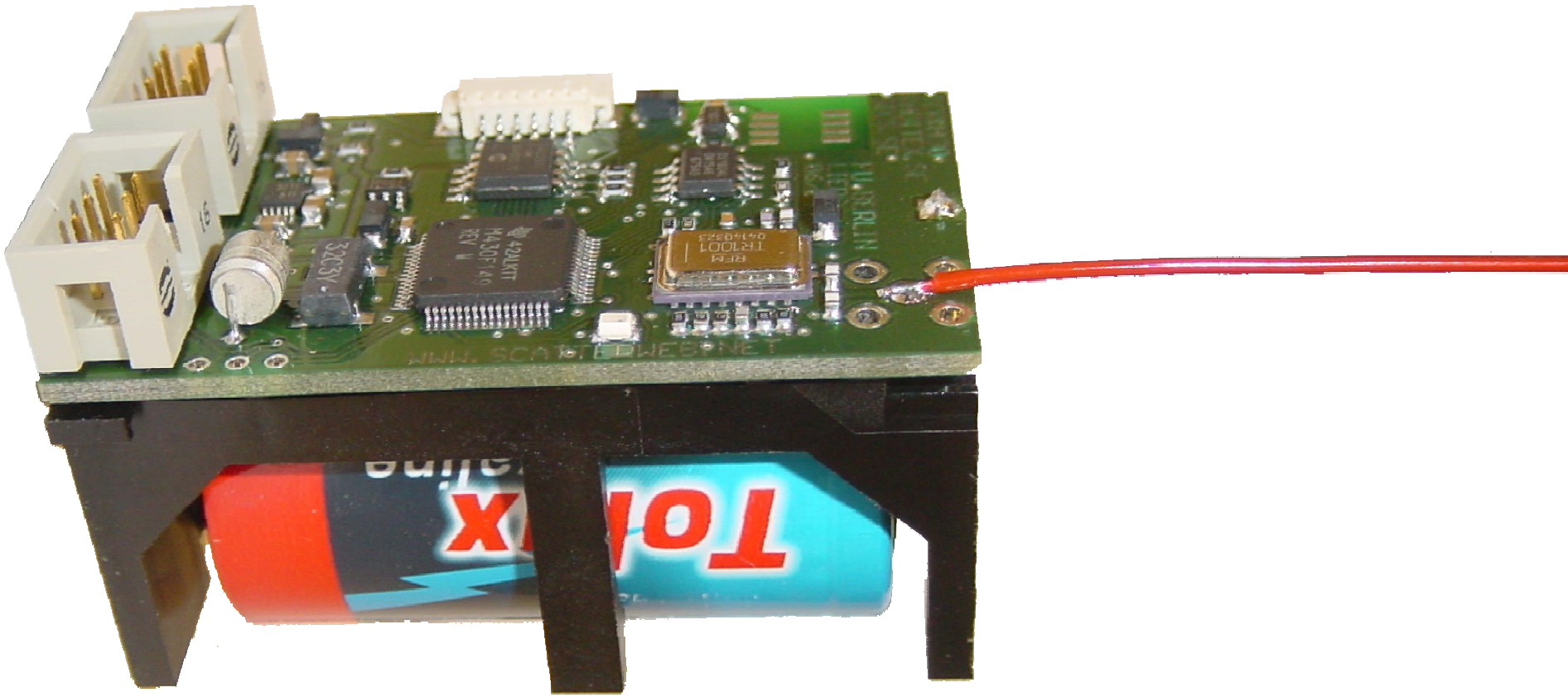
Buoy Sensors (configured)



Temperature Sensor Node



Temperature Sensor Node (with Battery)



Sensor Node with Camera (prototype)

Camera facing a mirror

Picture taken and transmitted by a sensor node