X-Sense RTD 2010

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FNSNF

GPS-equipped Wireless Sensor Network for High-accuracy Positioning

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ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

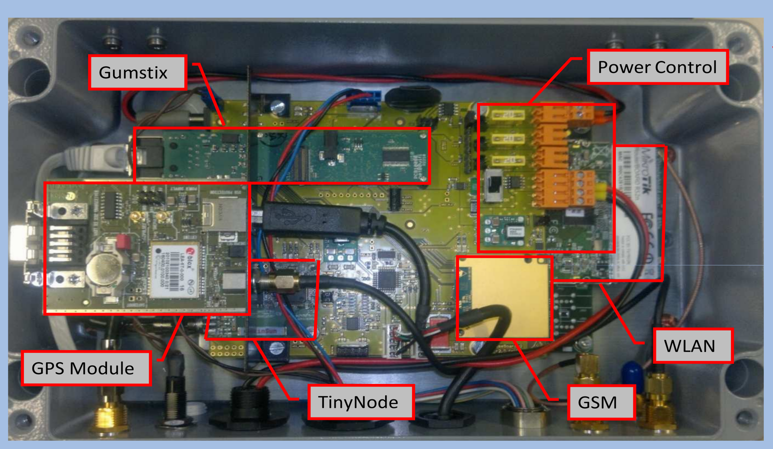
TIK Technische Informatik und Kommunikationsnetze
Computer Engineering and Networks Laboratory

> Motivation

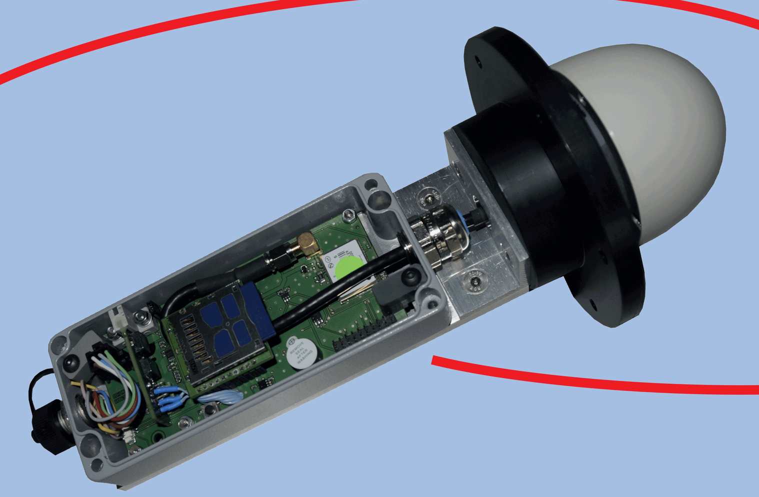
- Long-term distributed GPS measurements for high-accuracy positioning and scientific modeling.
- Differential GPS (DGPS) for sub-centimeter relative positioning accuracy.
- Low-cost wireless implementation for high temporal and spatial coverage.

Goal: Energy optimized GPS-equipped wireless sensor node for network-wide synchronized data acquisition.

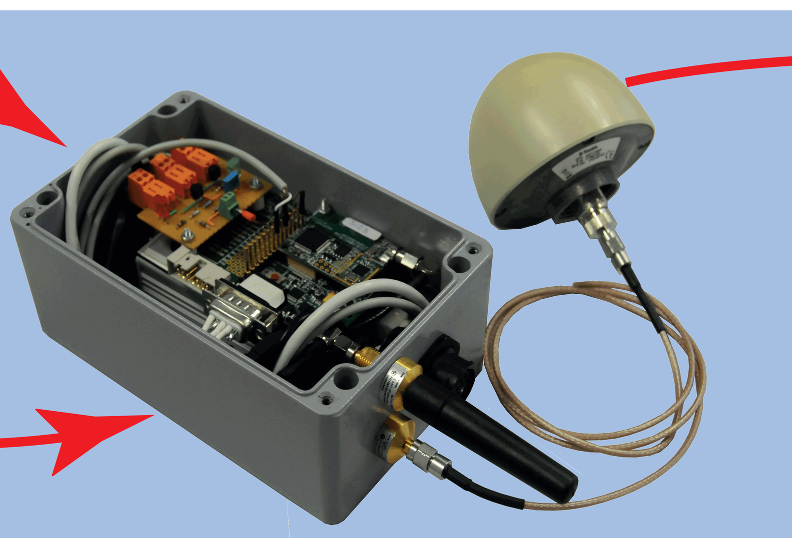
> Design Approach



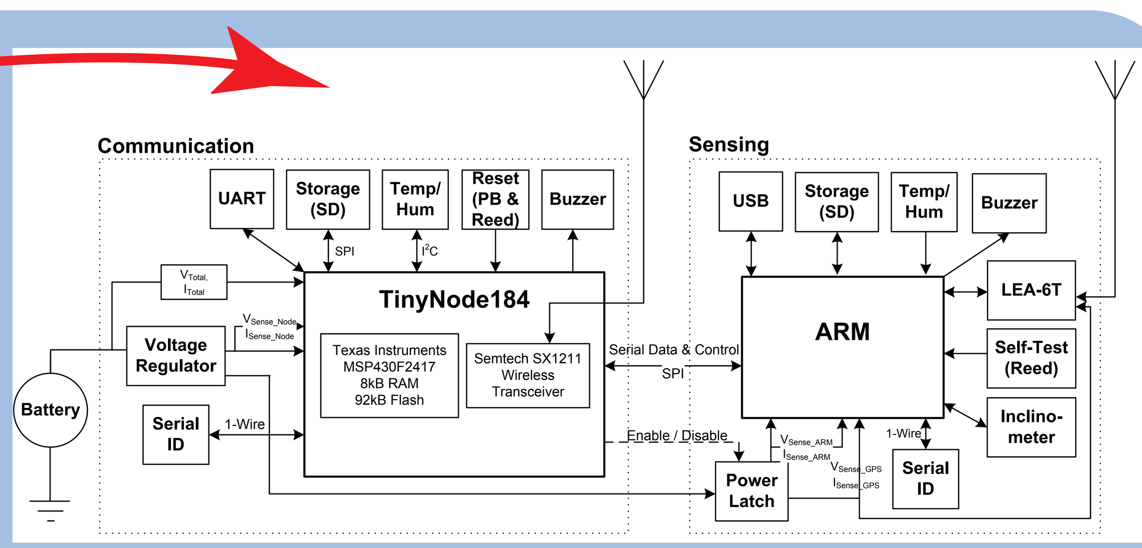
Over-provisioned CoreStation for on-site experimentation (IPSN '11).



GPS Logger for preliminary scientific analysis (WLF '11).



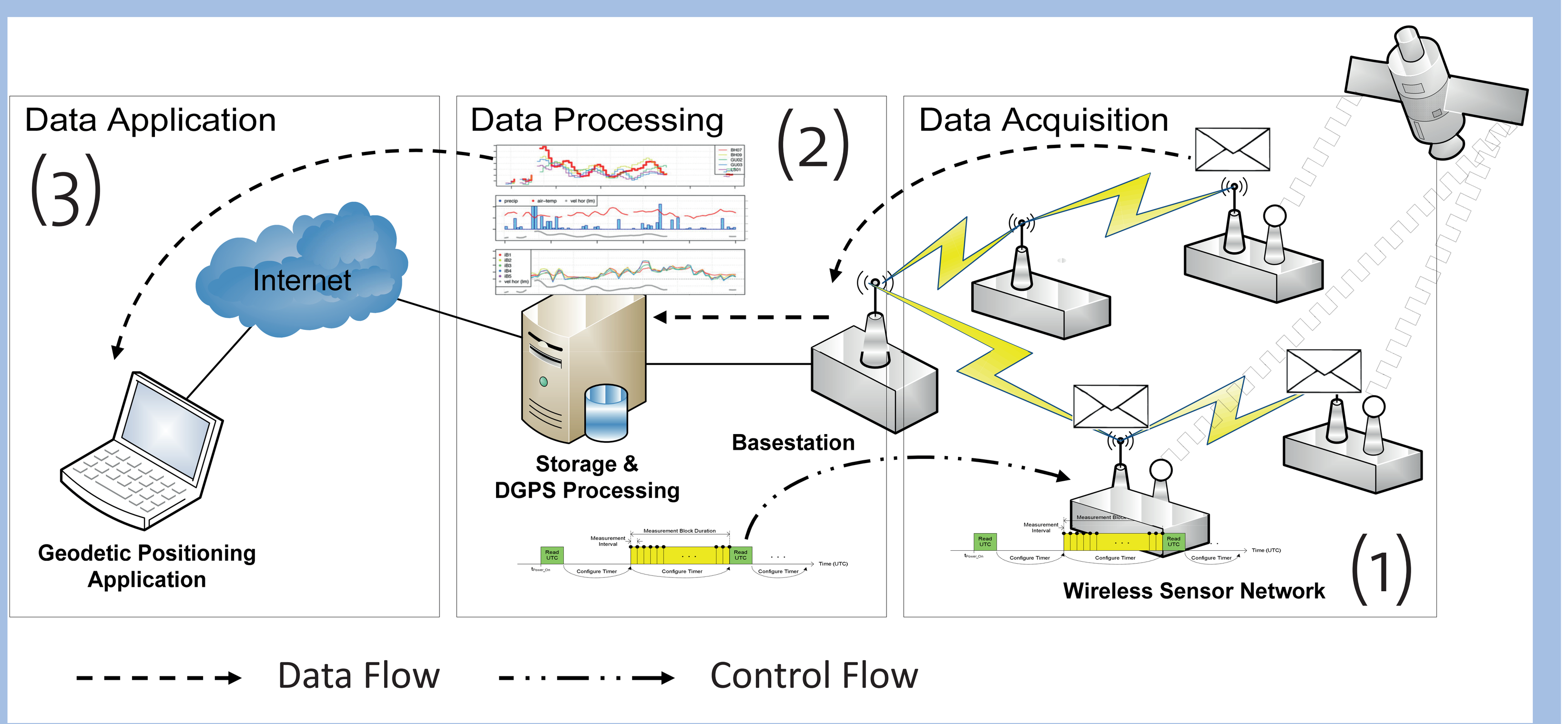
GPS equipped Wireless Sensor node prototype (EWSN '12).



Optimized GPS equipped Wireless Sensor node with dedicated sensing and communication controllers.

> System Integration & Features

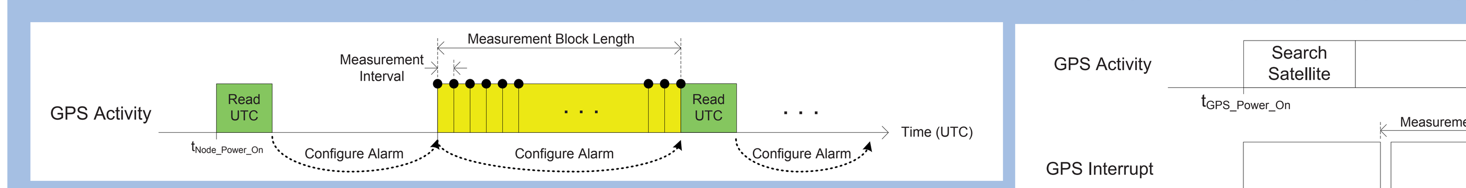
End-to-end System Integration



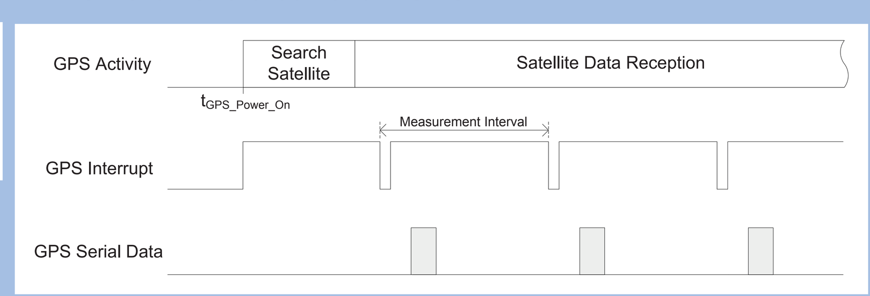
(1) Autonomous data acquisition at remote sites. (2) Processing of raw data on backend infrastructure. 3) Publication of processed position and health status.

System Features

- Autonomous operation at remote sites
- Low-cost & low-power implementation
- Resilience against harsh environments
- Real-time sensor data and health information for remote system observability
- Simple integration into existing infrastructure
- Network-wide synchronized measurement schedules & sensor readings
- Remote system control:
  - Schedule configuration (Start time, duration, sampling frequency)
  - Node reset
- Real-time schedule & system status
- Data redundancy (secondary storage)
- Reliable data transfer



GPS receiver provides UTC time which is used to schedule measurement blocks. GPS clock accuracy ensures aligned blocks during long-term deployment.



Network-wide synchronized measurements through GPS receiver interrupt.

> Evaluation

Energy Consumption

	i	Component	Current in mA (I_i)	Contribution in sec/min (α_i)	Energy in mWh
Measurement Inactive	1	Radio TX	30	0.12	0.3
	2	Radio RX	8	0.1	0.07
Measurement Active	3	Radio TX	30	0.32	0.8
	4	Radio RX	8	0.2	0.13
	5	GPS (POT high)	49	12	49
	6	GPS (POT low)	22	48	88

Summary of components and their contributions to total average current drawn (measured at 5V DC).

- Power dissipation of GPS receiver dwarfs that of radio
- Can achieve significant power reduction with GPS Power Optimized Tracking (POT) mode enabled.
- TinyNode184 consumption is negligible.
- Energy harvesting and advanced power management to extend lifetime.

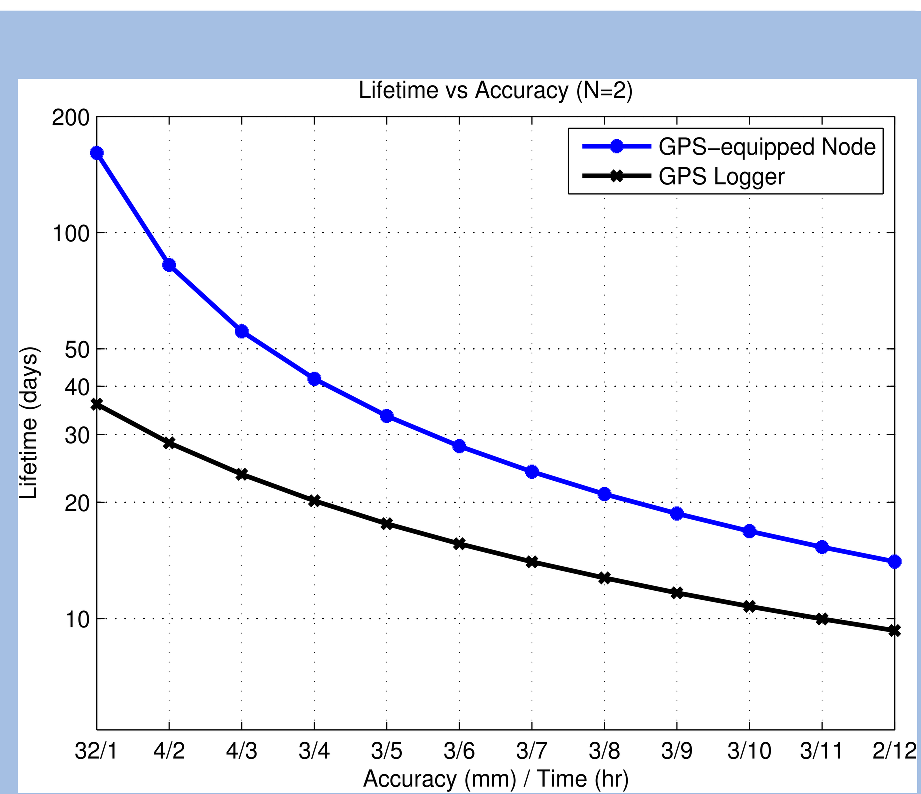
System Lifetime

- GPS measurement block duration determines maximum solution accuracy.
- System lifetime dependent on chosen measurement schedule.

Example deployment:

- 8 hour/day measurement schedule
- 30 second sample interval
- Consolidated hardware circuitry
- 14000mAh battery cell @ 75% efficiency

--> *40 days node lifetime*



Lifetime vs Accuracy with two 4-hour blocks per day

Data Yield & Latency

Outdoor experiment:

- 3 weeks for each 1,2,3-hop deployment with 5 nodes
- Sampling period: 30 seconds, 100% duty-cycle

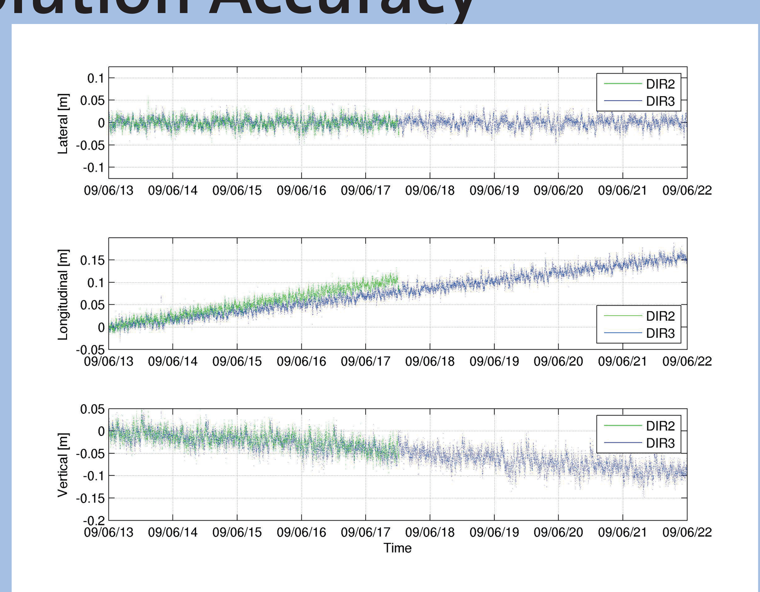
Network Topology	1-hop	2-hop	3-hop
Number of meas. intervals	15,120	15,120	15,120
Number of Dozer packets	126,662	133,641	133,085
Data yield	100%	100%	100%
Useful yield	99.99%	99.99%	99.99%

Data collection statistics of the test deployment. 99.99% of acquired data passes DGPS quality threshold.

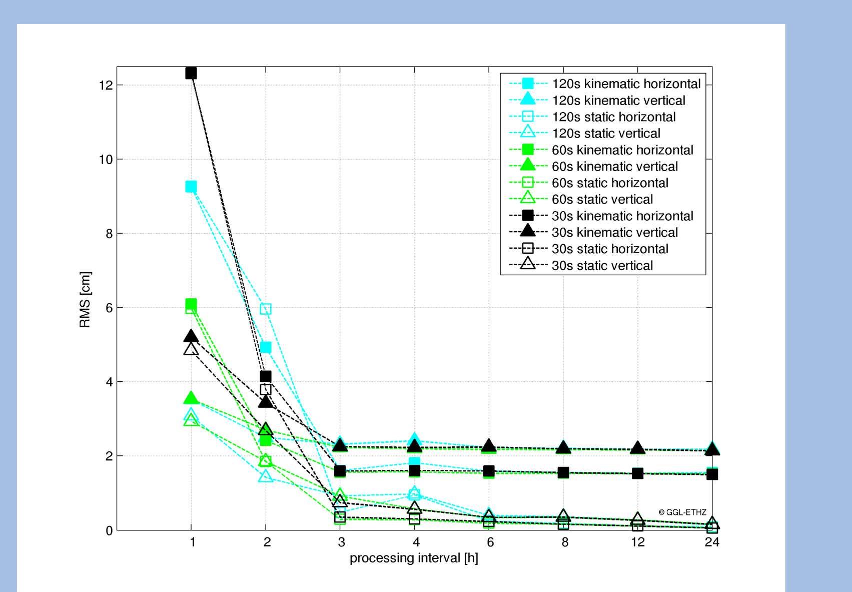
Network Topology	1-hop	2-hop	3-hop
Median (in sec.)	35	50	69
Mean (in sec.)	35.54	50.61	71.27
Mode (in sec.)	32	52	82
Variance (in sec.)	82.09	343.13	490.01

End-to-end network Latency (Single-hop: 99.6% within [20, 60] seconds, Multi-hop (2-hop): 98.2% within [20, 80] seconds)

Solution Accuracy



Differential GPS solution in 3D from X-Sense deployment.



Solution accuracy vs. measurement block length.

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