

# FlockLab: A Testbed for Distributed, Synchronized Tracing and Profiling of Wireless Embedded Systems

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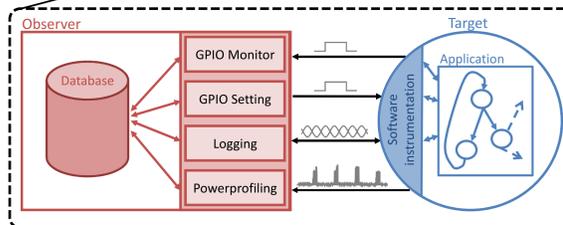
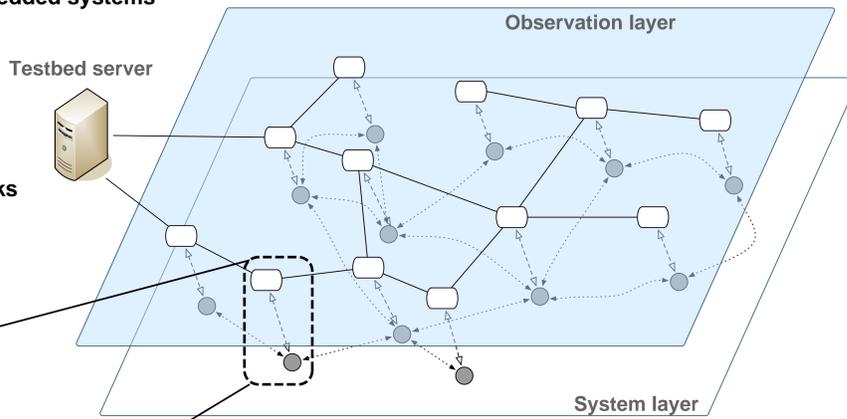
## Architecture

Debugging software for wireless embedded systems is difficult

- Non-deterministic environment
- Working close to resource limit makes systems extremely fragile

Testbeds for Wireless Sensor Networks

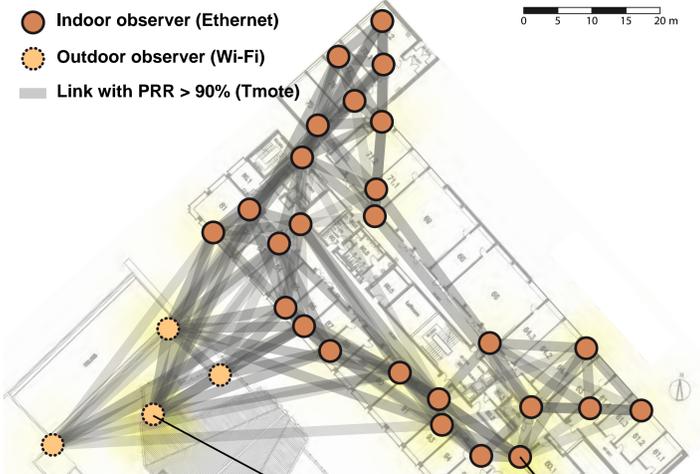
- Increase observability
- Enable testing on real hardware
- Help validate simulation results



The observation layer provides means to reprogram target nodes, monitor running programs, and interact with sensor nodes.

The system layer represents the actual sensor network, consisting of individual sensor nodes, wireless links and environment.

## Deployment



- 4x30 nodes
- Ethernet/Wi-Fi
- 4 outdoor observers



### FlockLab Highlights

Distributed power profiling on all nodes simultaneously at up to 56kHz

Monitoring of logical state changes through GPIO tracing at up to 10kHz

Trigger logical state changes through GPIO actuation

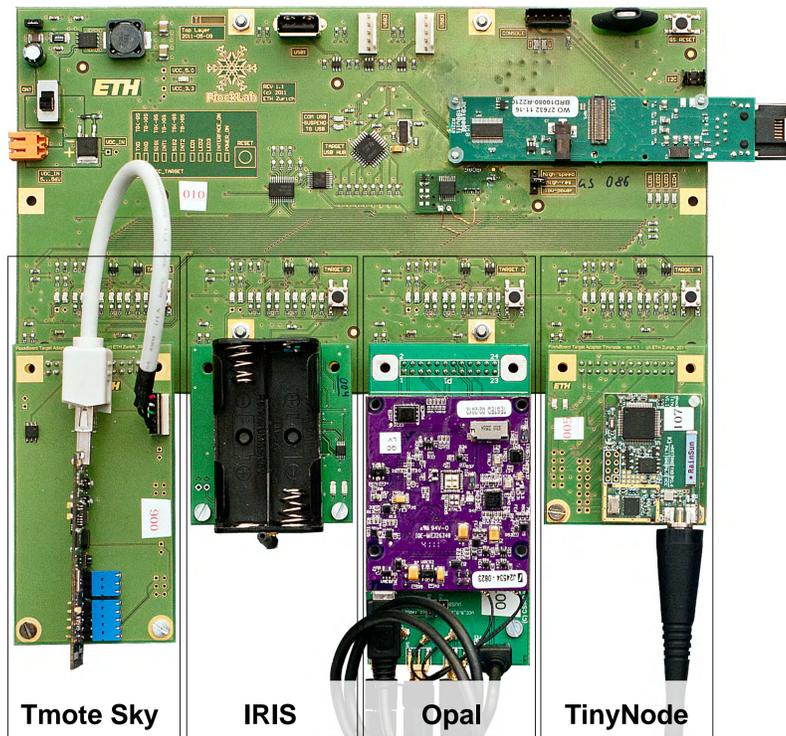
Adjustable supply voltage between 1.8V and 3.3V in steps of 100mV

Supports several node platforms and state-of-the-art operating systems:

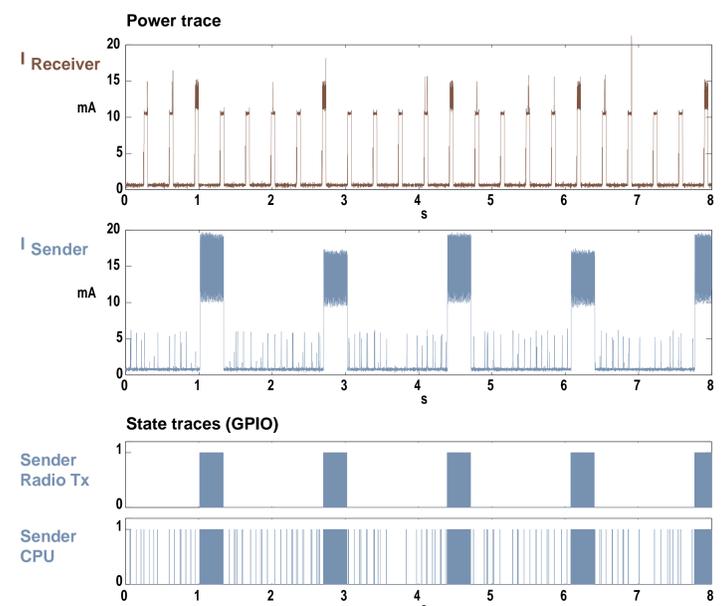
- Tmote Sky
- Opal (CSIRO)
- IRIS (IBM)
- TinyNode184

New platforms can be integrated with little effort and cost

Standard serial I/O services



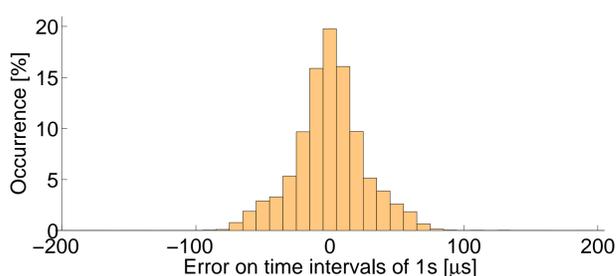
## GPIO and Power Traces



## Benchmarks

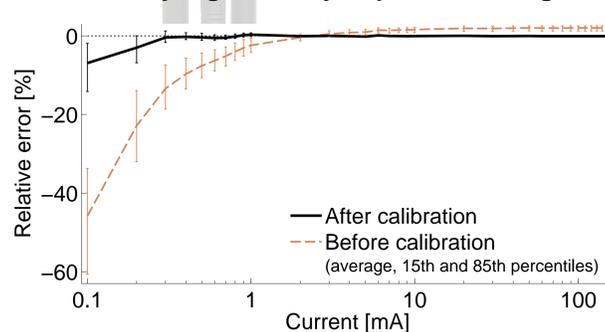
### GPIO Tracing on 30 Observers

- Average error on interval measurements:  $-0.011\mu\text{s}$
- Average pairwise error between observers:  $36\mu\text{s}$



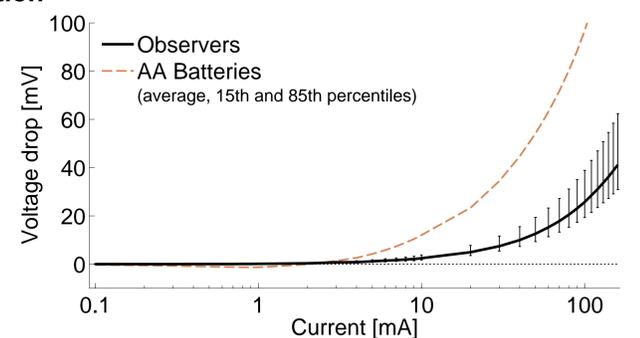
### Accuracy of Power Profiling

- Static power measurements
- Compared to high-accuracy power analyzer
- Accuracy significantly improved through calibration



### Stability of Target Power Supply

- Small voltage drop over 0-167mA range
- Internal resistance less than AA battery



FlockLab provides distributed, synchronized power and event tracing at high resolution and accuracy. The instrumentation circuit for power profiling has only minimal impact on the target supply voltage.