Poster abstract: The FlockLab Testbed Architecture

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Abstract

A vital factor for a successful deployment of sensor nodes is testing of all system aspects in a realistic setup. This work presents a testbed architecture which allows for detailed monitoring and stimulation of a wireless sensor node. In particular, time-accurate state extraction and power measurements are provided in a distributed, yet synchronized context. The FlockLab testbed architecture provides a distributed lab instrument, where detailed observations of every sensor node enable thorough testing. Software services allow for formulating testcases and reliable test data collection.

Categories and Subject Descriptors

D.2.5 [**Software Engineering**]: Testing and Debugging —*Diagnostics*

General Terms

Measurement, Experimentation

Keywords

Testbed, WSN, Testing

1 Introduction

Testbeds play a vital part when developing a WSN application. An important property is that they capture the dynamic and non-deterministic nature of wireless communication and hence capture realistic executions of software. Additionally, the embedded software is tightly coupled to the hardware, which necessitates joint (integration) testing, e. g., concerning timing properties. Hence, critical corner cases only occur on a testbed, not in simulation. Resulting problems can often only be detected by jointly analyzing different kinds of observations, e. g., logging over the serial port combined with measurements of the power consumption of a sensor node.

For general embedded systems, testing the software and the system's power consumption relies on expensive lab instruments such as logic analyzers and oscilloscopes. The presented *FlockLab testbed architecture* brings the functionalities of these tools into a distributed context for detailed testing of a sensor network. This is achieved by pairing a sensor node with dedicated hardware for monitoring and stimulation. Different services such as measuring power consumption and time accurate pin monitoring and setting are provided to a tester. By reducing accuracy of measurements to a sufficient level (e. g., tens of *us* temporal granularity across nodes), costs are significantly reduced to enable an affordable distributed lab instrument. Hence, in difference to previous testbeds, which only allowed for detailed measurements on individual nodes [1], numerous nodes can be observed in detail.

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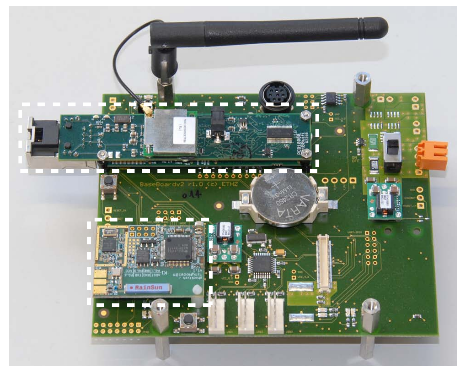

Figure 1. A sensor node/observer pair. A TinyNode (lower left) is attached to a Gumstix (upper left) via the observer board.

FlockLab provides the following contributions:

- FlockLab's observer based testbed architecture provides services for detailed testing of sensor nodes.
- The testbed architecture seamlessly merges data from all services into a consistent global view.

This poster particularly focusses on the hardware implementation of the observer and its basic software services.

2 FlockLab testbed architecture

The FlockLab testbed architecture relies on pairing each sensor node with a so-called *observer node*. Figure 1 shows a single sensor node/observer pair. The sensor node is in this case a TinyNode. The observer includes a Gumstix Verdex pro XL6P, featuring a 600 MHz XScale processor, 128MB RAM and 32MB Flash, and runs open-embedded Linux. A custom observer board offers the interfaces and means for detailed analysis and stimulation of sensor nodes. This pairing provides hardware support for minimally intrusive, yet powerful monitoring and stimulation of the sensor node.

Figure 2 presents an overview of the different interfaces between a sensor node and its observer: Apart from standard functionalities for logging over a UART or programming, it provides access to GPIO pins and means for voltage control and power measurements. Further extensions to include a JTAG interface or control of a programmable attenuator can be easily integrated.

FlockLab provides several services on the observer for using these interfaces for testing. These services include timed setting or monitoring of a GPIO pin, controlling the serial port e. g., via the TinyOS serial forwarder, and taking power measurements. GPIO pin monitoring and setting provide distributed logic analyzer capabilities. In particular, these pin services are accurately synchronized within tens of micro-seconds across nodes. Distributed voltage control and power profiling enable elaborate power consumption analyses under differing operating conditions. Voltage control allows for simulating battery depletion effects, which have shown to generate spurious defects in sensor networks [2].

Services have a common set of features: (i) Services may be started and stopped individually and (ii) all errors that occur during operation are reported. Starting and stopping can be performed on triggers. This may either be a timed trigger from the observer or a trigger initiated by the sensor node itself by utilizing a GPIO pin e. g., to indicate a sensor node-internal state change. This enables power measurements only during radio activity or RAM dumps on a hardware interrupt. Data from the different services is merged into a consistent local context. All collected data, e. g., logs, errors and executed actions, is stored in a SQLite database on the observer. Flash memory provides persistent storage. The powerful processor of the observer allows for local processing of the data.

The observers form a local area network. A high-bandwidth back-channel (wired or wireless) allows for reliable collection of all test-related data. It is also used for controlling test execution, e. g., to distribute sensor node images, test scripts and the observation setup. Additionally, standard network monitoring and maintenance tools for the testbed such as Zeroconf for auto-discovery of observers can be employed. Time synchronization of the observers facilitates merging the distributed logs into a global view.

3 Background and related work

Previous testbeds, e. g., Motelab [1], merely provide means for logging from and reprogramming sensor nodes and rather focus on scaling, configuring and managing a testbed. Notably, PowerBench [3] allows for distributed power measurements. However, FlockLab's distributed approach enables more accurate merging of measurement data with logging and timing data from the sensor nodes. More closely related in spirit are Kansei [4] and the Deployment Support Network (DSN) [5], which both feature a similar architecture: A sensor node is connected to another observing sensor node which can monitor and control the sensor node. The DSN has a similar feature set, but a BTnode as an observer has proven to be not powerful enough w. r. t. the granularity of power measurements and reliable or high data-rate logging. While Kansei also employs a Linux-class observer, it does neither feature power measurement support nor provide the services required for detailed node testing in a distributed context.

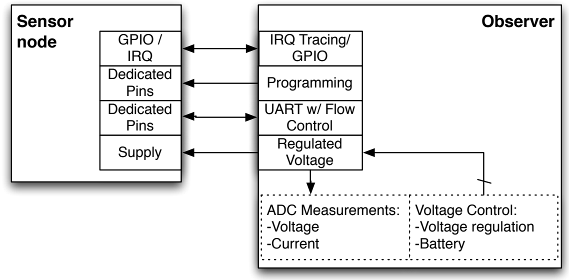

Figure 2. Sensor node/observer interface.

4 Conclusion

FlockLab is a distributed lab instrument for sensor network development. It relies on pairing each sensor node with a powerful observer to enable detailed monitoring and stimulation. This poster presents the novel observer node, which provides means for time-accurate setting and monitoring of GPIOs, power measurements and stimulation and logging over a serial port. FlockLab's software services allow for formulating test cases and reliably and synchronously collecting large amounts of logged data from the distributed sensor nodes. FlockLab can be used for detailed testing of sensor nodes, e. g., for devising conformance tests for power consumption [6]. Another example for using FlockLab is the extraction of the radio state for displaying state changes over time, e. g., between sleep, idle listening, sending and receiving. This is achieved by time accurate events over GPIO pins which identify communication between sensor nodes. Moreover, Flocklab allows for focussed power profiling: measurements can be started or stopped dependent on the system state as FlockLab can react on a trigger, such as a radio FIFO interrupt. This helps to reduce the overhead in terms of processing and storage.

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6 References

[1] G. Werner-Allen, P. Swieskowski, and M. Welsh, "MoteLab: A wireless sensor network testbed," in *Proc. 4th Int'l Conf. Information Processing Sensor Networks (IPSN '05)*, Apr. 2005, pp. 483–488.

[2] G. Tolle *et al.*, "A macroscope in the redwoods," in *Proc. 3rd ACM Conf. Embedded Networked Sensor Systems (SenSys 2005)*, 2005, pp. 51–63.

[3] I. Haratcherev *et al.*, "PowerBench: A scalable testbed infrastructure for benchmarking power consumption," in *Int. Workshop on Sensor Network Engineering (IWSNE)*, June 2008, pp. 37–44.

[4] E. Ertin *et al.*, "Kansei: a testbed for sensing at scale," in *IPSN '06: Proceedings of the 5th international conference on Information processing in sensor networks*. New York, NY, USA: ACM, 2006, pp. 399–406.

[5] M. Dyer *et al.*, "Deployment support network - a toolkit for the development of WSNs," in *Proc. 4th European Workshop on Sensor Networks (EWSN 2007)*, 2007, pp. 195–211.

[6] M. Woehrle, K. Lampka, and L. Thiele, "Exploiting timed automata for conformance testing of power measurements," in *7th Int'l Conf. on Formal Modelling and Analysis of Timed Systems (FORMATS '09) (to appear)*, September 2009.