Remote Controlled Performance Analysis of Embedded Wireless Sensor Networks

Albert Pötsch
Linz Center of Mechatronics GmbH
4040 Linz, Austria
Email: albert.poetsch@lcm.at

Stefan Hujber
Linz Center of Mechatronics GmbH
4040 Linz, Austria
Email: stefan.hujber@lcm.at

Andreas Springer
Institute for Communications Engineering
and RF-Systems
Johannes Kepler University, 4040 Linz, Austria
Email: a.springer@nthfs.jku.at

***Abstract*—Deciding which communication technology is optimal for a given wireless sensor network (WSN) application depends on many factors and is not always unambiguous. Only a comparison when deploying the network in the target environment with real hardware can assure that the system behaves as expected. Both hard- and software design can benefit when a suitable testbed infrastructure specific for embedded wireless networks is used during the development phase.**

In this demo, we present a testbed infrastructure for embedded low-power wireless networks and the possible analysis of the node's power consumption and the network's behavior.

The testbed is made up of a scalable setup of an Ethernet-based backbone of cost-effective distributed Linux Boards for basic remote programming, debugging and monitoring tasks as well as a dedicated high-performance power measurement system able to track the dynamic current consumption of sleeping ultra-low power sensor nodes in the μA-range up to several hundreds of mA of embedded Wifi-modules for high bandwidth applications.

I. Motivation and Introduction

The development of high performance embedded WSNs should always be accompanied by simulation and observations in reality to gain detailed knowledge about the actual network operation. Many factors have a big influence on the decision for a certain communication technology or protocol (e.g. Wifi, BLE, 802.15.4 based solutions, LoRa, RFID, NFC, UWB or Chirp based systems, mobile networks like GSM or LTE, other proprietary technologies etc.) and the used hardware and power source (e.g. energy harvester or batteries): The volume of sensor data (defined by resolution and sample-rate of sensors), requirements on transmission latency and real-time performance, network coverage, static or dynamic topology (mobility), power supply and expected battery lifetime, interoperability with other systems (e.g. gateway to the internet or other fieldbus systems), frequency bands (depending on legal standards and attenuation of materials), mandatory processing power for local computing, costs of hardware etc.

Using a testbed for automated and repeatable experiments is a proven way to evaluate various performance parameters of the network, as can be seen in related work in [1] or [2].

II. Demo Description

In this demonstration we present results obtained by experiments with our testbed infrastructure presented in [3]. Fig. 2 highlights the basic composition of the proposed evaluation tool. A key component of this testbed is a custom designed high- performance power measurement system introduced in [4] and shown in Fig. 3, featuring a *dual shunt resistor stage*. On the example of a ZigBee 3.0 compliant mesh network we demonstrate the usability of the testbed infrastructure:

- **Power consumption comparison** of different microcontroller architectures. Various IEEE 802.15.4 conform System-on-Chips (an old-fashioned 8 bit 8051-MCU, two different 32 bit ARM-Cortex-M MCUs) are observed, all performing the same ZigBee Door-Lock-Controller application. According to Fig. 1 the state-of-the-art multi-standard chip CC2650 (Bluetooth Low Energy and IEEE 802.15.4) clearly stand out with lowest peak-, average- and sleep-current but also has the highest price. The use of an additional power amplifier results in a significant increase of peak-current, but could help to reduce the number of nodes in a network and therefore also costs.
- **Parallel remote programming** of network nodes and automatic execution of predefined network scenarios.
- **Long-term logging** of the node's debug output.
- **Generation of controlled RF interference** and stimulation of partial network outages for testing self-healing mesh network functionality.

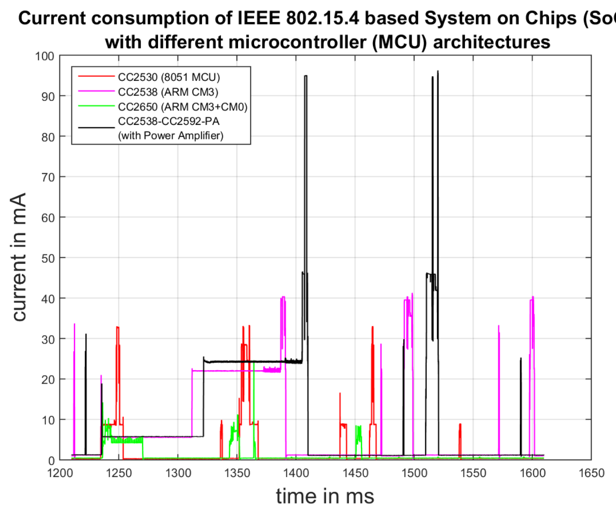

Fig. 1. Current consumption of different ZigBee-enabled System-on-Chips when transmitting a typical ZigBee Cluster Library command and waiting for acknowledgment.

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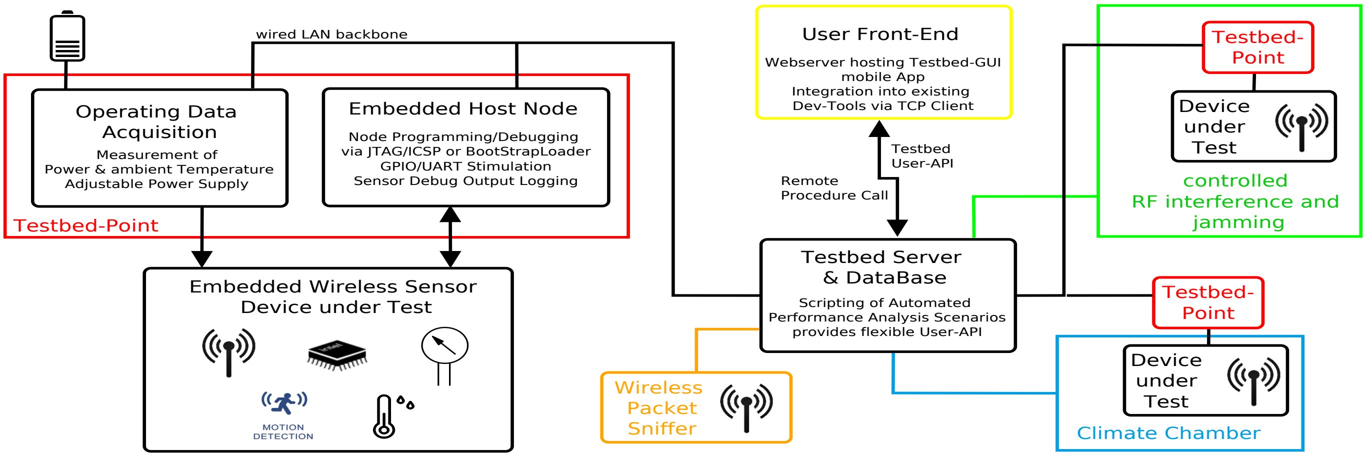

Fig. 2. Schematic overview of the proposed testbed, using low-cost Linux boards as Embedded Host Nodes for programming/debugging of the distributed wireless nodes and a customized measurement circuit for capturing operating data (power consumption, battery voltage, environmental temperature etc.). The Ethernet backbone guarantees a scalable testbed setup and is not in conflict with the wireless devices under test.

- **Remote sniffing of network traffic** for investigation of network outages allows for easy visualization of the actual network topology (Fig. 4) and the observation also in hazardous environment.
- **Remote setup of ZigBee-applications** running a generic Zigbee network processor (ZNP) image on the nodes enables quick execution of service- and discovery commands without time-consuming firmware-reprogramming.

III. Conclusion

Precise knowledge about each individual node's current consumption within a wireless sensor network and detailed insight into over-the-air network traffic obtained by the proposed testbed can help to find unexpected weakness of an assumed ideal network solution. It allows to instantly observe the networks behaviour during RF-disturbance and node's breakdown and to review the impact of fine-tuning of certain software-parameters across all network layers. Even minimal improvements in e.g. lowering the sleep-current consumption can be identified, supporting the developer to keep control about the more and more sophisticated embedded hardware architectures and software frameworks.

Acknowledgment

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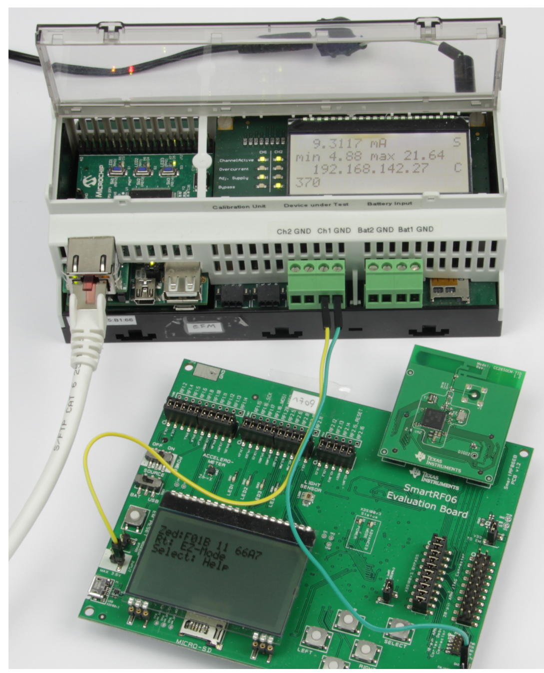

Fig. 3. Ethernet-enabled high dynamic power measurement system designed to capture the wide-range current consumptions typical for embedded wireless RF transceiver and microcontroller circuits.

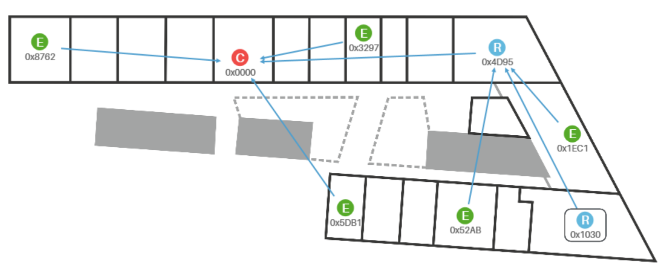

Fig. 4. Arrangement of ZigBee Nodes in the Sciencepark of JKU university campus. Network topology captured via remote access service of the sniffer device.