Demo Abstract: Accurate Power Profiling of Sensornets with the COOJA/MSPSim Simulator

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***Abstract*— Power consumption is of utmost concern in sensor networks. Researchers have several ways of measuring the power consumption of a complete sensor network, but they are typically either impractical or inaccurate. To meet the need for practical and scalable measurement of power consumption of sensor networks, we have developed a cycle-accurate simulator, called COOJA/MSPsim, that enables live power estimation of systems running on MSP430 processors.**

This demonstration shows the ease of use and the power measurement accuracy of COOJA/MSPsim. The demo setup consists of a small sensor network and a laptop. Beside gathering software-based power measurements from the motes, the laptop runs COOJA/MSPsim to simulate the same network. We visualize the power consumption of both the simulated and the real sensor network, and show that the simulator produces matching results.

I. Introduction

Power consumption is the most important metric in wireless sensor networks because reduced power consumption leads to increased network lifetime. Many different methods have been proposed to reduce the power consumption of sensor networks. Energy has been reduced by using more efficient protocols for topology management, routing, and radio medium access. The highest priority of these methods is to turn off the radio as much as possible because radio listening is generally the most power-consuming task in sensor networks. Evaluating the power consumption of a full sensor network has until now required tedious setups of oscilloscope circuits, capacitors, or on-board instrumentation. To evaluate the efficiency of a power-saving method, researchers must be able to quantify the energy consumption of many nodes in a network.

Software-based power profiling has enabled non-intrusive and scalable power profiling in real sensor networks [4]. The technique is based on measuring the time that each component is active and multiplying that time by the component's power consumption. This method of measuring energy is accurate, but by the nature of testbeds, it is typically limited in scale and mobility. Testbed experiments require setup, instrumentation, and infrastructure. Furthermore, the arrangement of the nodes is usually static and difficult to change. Simulations, on the other hand, scale well and handle mobility and repeatability with ease, albeit with a simplified model of the environment.

COOJA/MSPsim caters to researchers and developers who need to assess the power consumption on a network scale. By combining the accurate instruction-level emulation provided by MSPsim [5] with COOJA [8] sensor network simulator, we are able to measure the power consumption of multiple nodes in a network simultaneously and without the need for unwieldy instrumentation.

Although there are several sensor network simulators that are able to estimate power consumption [6], [9], their accuracy has only been shown in single-node experiments. In contrast, we have experimentally validated the accuracy of our power profiling tool in a simulated network.

II. Simulation-based Network-scale Power Profiling with COOJA/MSPSim

COOJA/MSPsim combines two separate tools developed earlier by us: COOJA and MSPsim. First of all though, we base our work on the idea behind Contiki's power profiler to measure the power consumption. This method essentially measures the activity time of each hardware component and multiplies it with the current consumption, which has been measured ahead and verified against the datasheets of the hardware. Since we do not run on real nodes, as Contiki's power profiler is expected to do, we have to supply the timing feedback to the estimator from an accurate instruction-level emulator. For this purpose we use our emulator MSPsim, which is able to emulate all relevant components of the Tmote Sky platform and the Scatterweb ESB platform.

In order to interconnect several emulated sensor nodes, we have integrated MSPsim into the COOJA sensor network simulator. Unlike other sensor network simulators, COOJA simulates nodes on different levels in the same simulation run. These levels include Contiki nodes on the OS level, non-Contiki nodes implemented in Java, or compiled firmware code for real nodes. COOJA executes the firmwares using not only MSPSim but also AvroraZ [2]. Both of these instruction-level emulators are capable of simulating complete sensor devices such as the Tmote Sky and the MicaZ. COOJA connects the simulated nodes using either of the following three radio models: a unit disk graph, a directed disk graph, or a multi-path ray tracer.

III. Evaluation

To evaluate the accuracy of our simulation-based approach, we compare the results of the energy estimation obtained through simulation with the results obtained through testbed experiments. For the testbed experiments, we implement all software in the Contiki operating system [3] and execute it on Tmote Sky nodes. The nodes use Contiki's software-based method to measure their power consumption [4]. We perform

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experiments with a tree-based data collection protocol called CoReDac [10],and the MAC protocols Low Power Probing [7] and X-MAC [1]. To compute the power consumption, we assume a voltage of 3V and a current draw of 20mA for listening and 17.7mA for radio transmissions, matching the values measured on Tmote Sky nodes by Dunkels et al. [4].

A. Data Collection with CoReDac

CoReDac is a TDMA-based convergecast protocol [10]. In contrast to many other convergecast protocols, CoReDac builds a collection tree that guarantees collision-free radio traffic. In our experiment, we compare the power consumption of two real networks with the power consumption of their corresponding simulated networks. Due to the limited size of our testbed, we simulate a network consisting of 15 nodes. Simulating larger networks is possible provided that CoReDac's parameters are changed accordingly to guarantee collision-free trees. The length of the reception slots does not depend of the number of nodes in the network. In our implementation, there is a small difference between the slot lengths of sibling nodes, and this difference depends on the order of the siblings. Therefore we expect the power consumption to be independent of the network size, but slightly varying among nodes.

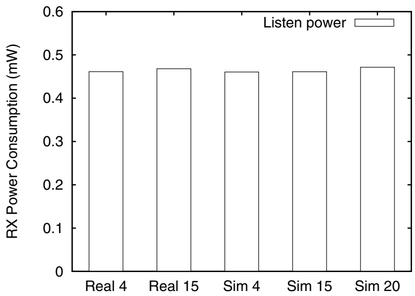

Fig. 1. The results from a testbed measurement of the power consumption of CoReDac (Real) and the simulation runs (Sim) agree with each other. The graph shows the power consumption of the radio in listen mode.

Figure 1 shows CoReDac's average power consumption per node of the radio in listen mode (RX power.) Real n denotes results from a testbed measurement with n nodes, whereas Sim n denotes simulation results from n nodes. The figure shows that the measured power consumption on real nodes matches the power consumption obtained with COOJA/MSPSim. Furthermore, the difference between the results does not increase with the size of the simulated networks.

In our demonstration we connect a real sensor network running CoReDac to a laptop. On the laptop, we also simulate the network using COOJA/MSPSim. Both networks are identical in that they consist of four nodes and a sink, and they run CoReDac with the same configuration parameters. We visualize the power consumption of the networks in Figure 2, which also demonstrates the accuracy of COOJA/MSPSim.

B. Low Power Probing and X-MAC

We have also evaluated COOJA/MSPSim's power profiling accuracy with two more complex MAC protocols: Low Power Probing [7] and X-MAC [1]. Using LPP, we simulate the power consumption in high packet transmission rate scenarios that matches the testbed results with a difference of less than 0.8%. For the more complicated X-MAC protocol, the difference between the experimental and simulated results is typically below 2%.

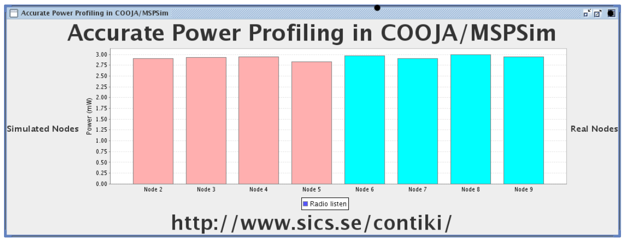

Fig. 2. Demo Screenshot: The four left columns show the power consumption of simulated nodes, the others the power consumption of the testbed nodes

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