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Abstract:

This demo paper describes the usability and effectiveness of our distributed energy measurement system for WSNs. The system is composed of several micro-controller-based oscilloscopes - named PotatoScope. The intention of PotatoScope was to enable a scalable and dependable energy measurement for challenging environmental conditions, e.g., WSN outdoor deployments. We will present the general architecture by using two of our nodes and demonstrate how to measure energy consumption of nodes in our testbed. Certainly, the PotatoScope can be used standalone to measure energy comsumption of other devices, such as other micro controllers or single-board computers, e.g. Raspberry Pis. The demo will introduce a GUI, that displays information directly on a computer. Both the PotatoScope, including the hardware layout and the firmware, as well as the distributed energy measurement system is free to be used in own projects.

Demo: PotatoScope – Scalable and Dependable Distributed Energy Measurement for WSNs

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***Abstract*—This demo paper describes the usability and effectiveness of our distributed energy measurement system for WSNs. The system is composed of several micro-controller-based oscilloscopes – named PotatoScope. The intention of PotatoScope was to enable a scalable and dependable energy measurement for challenging environmental conditions, e.g., WSN outdoor deployments. We will present the general architecture by using two of our nodes and demonstrate how to measure energy consumption of nodes in our testbed.**

Certainly, the PotatoScope can be used standalone to measure energy comsumption of other devices, such as other micro controllers or single-board computers, e.g. Raspberry Pis. The demo will introduce a GUI, that displays information directly on a computer.

Both the PotatoScope[1], including the hardware layout and the firmware , as well as the distributed energy measurement system[2] is free to be used in own projects.

Fig. 1. Photo of the PotatoNet

I. Introduction

Energy is one of the scarcest resources in Wireless Sensor Networks (WSNs). Thus, a plethora of energy efficient protocols and power-management techniques have been proposed [1], [2]. To evaluate the effectiveness of these mechanisms, an adequate energy measurement is inevitable. Using models [3] or profiling [4] tools is often not applicable. Especially for outdoor deployments the strong connection between the power-dissipation of a sensor node and the partly extreme environmental conditions are less considered.

To face this challenge, we extend our outdoor testbed for WSNs *PotatoNet* [5] with a scalable and dependable distributed energy measurement system (DEMS) [6]. Some nodes of the testbed are equipped with an accurate and high sampling oscilloscope. These oscilloscopes – named *PotatoScope* – are based on a low-cost micro-controller – the STM32F205VCT – and are designed to allow temperature insensitive energy measurement.

Firstly our demo provides background information about PotatoNet, and the measurements taken in [6]. Furthermore, we present the PotatoScope, which is used for measuring the energy. Besides showing the collaborative usage within the PotatoNet, we will demonstrate how the PotatoScope can be used standalone to measure energy consumptions of other devices, such as a Raspberry Pi.

[1]https://gitlab.ibr.cs.tu-bs.de/potatoscope/
[2]https://gitlab.ibr.cs.tu-bs.de/potatonet/

The rest of the paper is structured as follows: Section I-A describes the PotatoNet and section I-B introduces the architecture of the PotatoScope. The contents of the demo is presented in section II.

A. PotatoNet

The outdoor testbed PotatoNet was developed to evaluate WSN scenarios under real environmental conditions, in particular for *Smart Farming* applications. A photo of the current setup is shown in figure 1. The left circle shows the central box while the right one shows a field node. The general architecture is shown in figure 2. The testbed consists of a central server that has two up links: a primary LTE link and an additional but slower cellular connection, that can be used as a fall-back if needed. It basically is a industrial-type computer and a switch to connect all the field nodes.

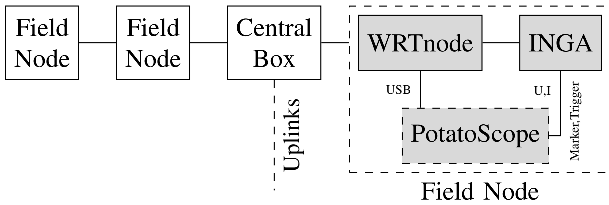

Fig. 2. PotatoNet architecture

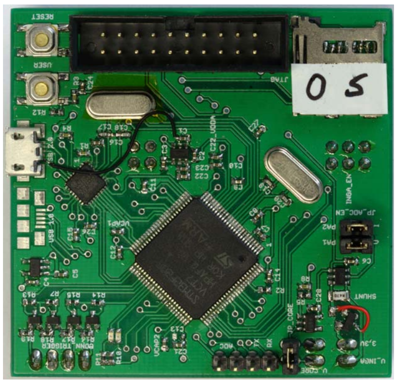

Fig. 3. PotatoScope

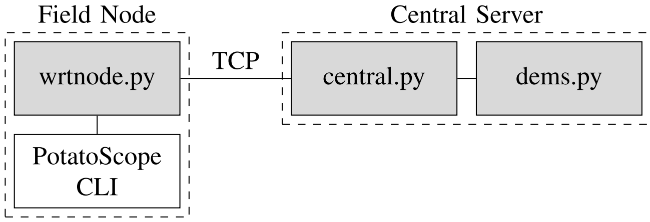

Fig. 4. DEMS

Currently, there are 18 *field nodes* within our testbed. All nodes consist of a WRTnode and the actual sensor node. The WRTnode is used for maintenance tasks and monitoring of nodes. Power over Ethernet (PoE) is used for power supply of the nodes and communication with the central server.

Half of the nodes is additionally equipped with a PotatoScope to measure energy of the sensor node.

The sensor node is represented by the Inexpensive Node for General Applications (INGA) [7]. However, the INGA is used exemplarily and can be replaced against other sensor nodes easily.

More details about the PotatoNet and first experiences of long-term evaluations have been presented in [8], [5].

B. *PotatoScope*

The PotatoScope shown in figure 3 is a small microcontroller based oscilloscope. We use the STM32F205VCT MCU with an integrated 12-bit ADC to take the measurements of voltage and the current of a sensor node, using a shunt resistor. The shunt resistor and the current sense IC can be easily exchanged to measure different ranges of voltages and currents.

A microSD card is used to store measurement data. As storage is limited across WRTnodes and even the central server, each microSD card stores the measurement data for each PotatoScope locally.

For reading measurements and configuring the PotatoScope we use our own protocol. We implemented a USB driver and a simple protocol, realized over USB 2.0 with an external USB Phy. The PotatoScope has different modes, that will be explained shortly:

single shot mode This mode will take a single measurement. The measurement will start right away, if the trigger is disabled. Otherwise the measurement will be started, when one of the trigger signals changes from low to high, or a trigger command is send via USB.

triggered mode This mode is the same as the single shot mode, except that multiple measurements can be taken consecutively and the trigger is always enabled. This mode is particular useful when using it in our testbed, because the INGA sensor node can take control of measurements that are taken.

live mode This mode is specially designed for use with a computer. Data is directly transfered to the computer without involving the microSD card, allowing for high sample rates of up 2 MHz. A simple Qt-based Graphical User Interface (GUI) (see Figure 8) can be used to quickly display measurement data.

For more details on the PotatoScope see [6].

C. *DEMS*

The Distributed Energy Measurement System (DEMS) is the system that we implemented to perform measurements across multiple nodes. It consists of different python scripts, that are executed on the WRTnode and the central server. Field nodes can be grouped to perform such measurements on only parts of the testbed. Figure 4 shows the overall architecture.

The *wrtnode.py*-script communicates with the PotatoScope using a special Command Line Interface (CLI). It wraps data so it can be send to the central server using a TCP connection, and, vice versa, it takes messages from the central server and translates them into CLI calls. The central server uses two different scripts. *central.py* is a TCP server that holds all connections from the field nodes and saves meta data of measurements in a local SQLite database. Finally, the user interface is provided by *dems.py*. It sends commands to the central.py script, and takes receives from it. Data can be directly requested from specific nodes and either be saved on the local hard disk or be plotted into a much smaller PNG image, that can be easily transferred over the uplinks, as bandwidth is limited due to the cellular connections.

II. Demonstration contents

This section will describe the two parts of our demonstration. The first part, described in section II-A, is about the DEMS, that we use to comfortably run and manage measurements. The second part will show how to use the PotatoScope in live mode and to measure higher currents compared to our regular use case.

A. *Online measurement*

The first part of our demo is to demonstrate the usability of distributed energy measurement as it is used in the PotatoNet. An overview on this demo is shown in figure 5. The laptop takes the role of the central server. Using a console, the user

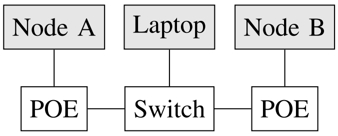

Fig. 5. on-line measurement

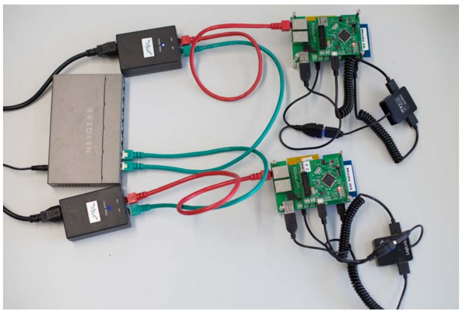

Fig. 6. Setup of the demo

can start and stop measurements, or request status information about the PotatoScope of each field node. Furthermore, measurements can be listed and directly plotted using *gnuplot*.

An exemplary photo of the setup is shown in figure 6. A USB hub connects both the sensor node and the PotatoScope to the WRTnode. The WRTnode is connected to a PoE injector and finally to a switch.

The investigated WSN application running on the nodes is a sample project that sends data from node A to node B. With our system we are not only able to detect coarse grain events like turning on the transceiver, but with the use of the marker signals of the PotatoScope, we can also get deep understanding of what is going on within the radio driver or user application. We will show how the signals can be used in the code, with a small library we wrote for the sensor node. In the plot of the measurement, these markers can be used to correlate current consumption to specific parts of the software.

B. Offline measurement

The second part of our demo will give insights to the live mode of the PotatoScope. For this we use a modified version of the scope, to measure the energy consumption of another device, such as a Raspberry Pi. The measurement setup is shown in figure 7.

The PotatoScope is directly connect via USB to a computer. The devices supply voltage and current consumption is measured by the PotatoScope. For this demonstration we will show how different states (e.g. turning WLAN on and off) can be measured.

The GUI is based on Qt and detects connected PotatoScopes. We can take multiple measurements for comparison and save data in CSV format. In addition, the GUI can show the current energy amount required by the device. In the demo we will show how the GUI can be used to get quick measurements of energy consumption of different devices, such as a sensor node or a Raspberry Pi.

Fig. 7. off-line measurement

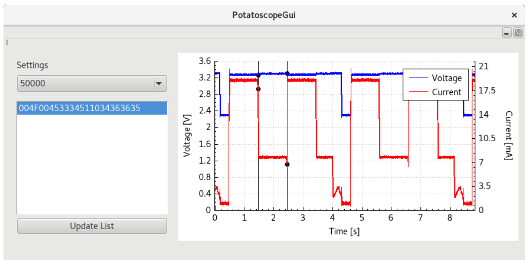

Fig. 8. GUI

Figure 8 shows a screenshot of a GUI. Measurements can be taken directly from the GUI. In this example the sensor node's transceiver is turned on and off every second. Additionally the node is reset every four seconds. Markers can be positioned using mouse left respectively right clicks to calculate energy consumption and time between markers.

III. Space and/or other equipemtn-specific requirements

Our demonstration setup will require a table of at least 1.5m x 1m, a power supply and a monitor to display results. A possible setup is shown in figure 6.

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