PotatoNet – Outdoor WSN Testbed for Smart Farming Applications

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Abstract—**We present PotatoNet, an outdoor testbed for Wireless Sensor Networks (WSNs). Its primary focus is robustness, reliability and flexibility. PotatoNet is designed to operate without on-site maintenance for extended periods of time. It can withstand heat, dust and rain and has already been tested running outside for several months.**

I. MOTIVATION

Many testbeds for WSNs have been proposed with the goal of enabling users to test new methods for such networks in a more realistic environment. However, many of these testbeds have only been developed for indoor use [1], [2], [3], [4]. The difference between an outdoor and an indoor testbed is not only hardware. Of course, nodes in an outdoor testbed need to be weather proof, and withstand the environmental conditions specific to their application. However, because outdoor testbeds might be installed in remote areas, software and architecture requirements are equally important: When it is not possible to perform regular maintenance to the testbed equipment, and any hard- or software failure leads to a prolonged downtime, robustness and reliability become the main focus of hard- and software design.

Nowadays more and more WSN applications operating outdoors are developed. Smart Farming is an upcoming application area for WSNs, which are used to analyze and monitor the conditions of the soil and crops in order to optimize yield and minimize the use of fertilizer and pesticides. While PotatoNet is currently used for Smart Farming research, it has been developed to be a generic testbed that can be used for any outdoor scenarios. Smart Farming provides an especially challenging environment, as nodes not deployed in protected areas, but sit out in the open field. They are not protected from direct sunlight and the environment can get very rough [5]. Additionally, they need to be permanently water-proof as they are exposed to rain and irrigation (see Figure 1).

Nevertheless, there are also some outdoor testbeds deployed previously. Indeed, [6] reports the experience of running a testbed on a potato field and highlighted many challenges encountered when operating a testbed outdoors. Due to the complexities involved, many outdoor testbeds are rather special purposes WSN deployments like X-Sense [7] or ASWP [8] and do not offer the same flexibility and generic usability like indoor testbeds. With the PotatoNet we combine the robustness needed for an outdoor testbed with maximum flexibility.

II. IMPLEMENTATION

The overall architecture of PotatoNet is shown in Figure 3. The basic architecture consists of a central box providing management functionalities and distributing power to all nodes. For cost-efficiency reasons the nodes are designed to be cheap, while complexity and redundancy features are moved to the central component. We are using Ethernet with passive PoE to distribute power and managing field nodes. The sensor node's IEEE 802.15.4 interface is not required for management or operation of the testbed and can be used exclusively or experiments.

Several features in the architecture lead to PotatoNet's high robustness and resilience against failures:

- Every WSN node is paired with a small embedded Linux board running OpenWRT Linux. The separate programming platform is able to flash the sensor node using ISP. PotatoNet does not rely on bootloaders. This makes it virtually impossible to brick sensor nodes by flashing broken firmware.
- PotatoNet offers two separate Internet uplinks. The main uplink is using Ethernet and can be connected to a standard SOHO router. The management server in the central box includes a cellular data card. As long as the management server has power, it is possible to log into PotatoNet remotely.
- Power to field nodes can be switched on and off via software individually. In case a short circuit triggers a reboot, all field nodes are powered off. This allows switching them one by one identifying the faulty one. Once the faulty node has been identified, PotatoNet can run with the node powered off until it can be replaced.

A. Hardware

We use the INGA [9] WSN node version 1.6.1 in PotatoNet's field nodes. This node is a Dynamic Voltage Scaling (DVS) and Undervolting capable sensor node which is based on a design presented in [10]. However, PotatoNet can be adapted to other WSN nodes easily.

The programming platform inside each field node is based on the WRTNode[1]. The WRTNode is a USD 25 MIPS-based (Mediatek MT7620N) embedded Linux board with 680 MHz 64 MiB RAM which runs the embedded Linux distribution

[1] http://wrtnode.com

(a) Dust during dry days

(b) Exposure to direct sunlight

(c) Water from irrigation and rain

Figure 1: PotatoNet Environment

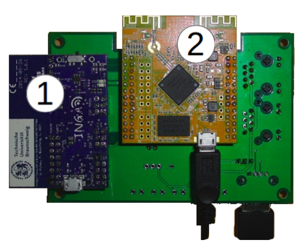
OpenWRT[2]. It supports many GPIO pins which are used for ISP programming of the INGA's two microcontrollers. By using Linux boards in field, in the testbed you can use the same software for programming or analyzing logs as you would do in your test setup on your desk. A large amount of standard Linux software is available for install directly from the OpenWRT repositories. Because each WRTNode includes a complete Wi-Fi implementation with PCB antenna, PotatoNet can also double as a Wi-Fi testbed.

We developed a special companion board that provides an efficient DC-DC converter to supply the WRTnode and INGA from the PoE supply voltage. The WRTNode and the INGA can be plugged into the companion board that includes two RJ45 jacks that can be used to cascade several field nodes.

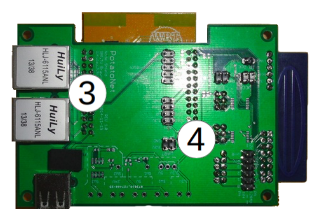
All components of the central box are mounted inside an 73 liter aluminum box (600 x 400 x 410 mm^3), We use rugged industrial connectors for Ethernet and Power to protect against dust and humidity (see Figure 2a). For the enclosure of the field nodes we use standard PVC-U tubing with 160 mm diameter. The enclosure consists of a drainage double socket closed with two socket plugs (see Figure 2b). As only one (or two for cascading) Ethernet cable needs to go into enclosure we used simple cable glands to connect the Ethernet cable and seal the enclosure. By doing so the actual RJ45 connector resides inside the enclosure and thus needs no weather-proofing.

(a) Central Box

(b) Field Node



(c) Companion board front side with INGA WSN node (1) and WRTNode (2)



(d) Companion board back side with Ethernet jacks (3) and extension headers (4)

Figure 2: PotatoNet Components

III. Lessons Learned

While developing PotatoNet we tried to keep an eye on costs, especially for the field nodes as the plan is to increase their amount steadily. However, a major cost factor you should keep in mind is the cost for cables. Overall, even in the initial deployment, PotatoNet includes more than 1 km of cables. One reason is, that in the deployment area cellular connectivity is very bad, so that using cellular networks for both uplinks was not an option. However, the nearest usable DSL landline was 450 meters away. For connecting the main uplink we covered that distance with a Wi-Fi bridge over a street and a dedicated VDSL link through a small forest.

As is common the research field is protected by an electric fence against boars and other animals. They are charged with short electric pulse up to 10 kV to shock any animal touching the fence. It turns out that the shielding of network cables lying near the fence is very good in capturing the jolts and distributing them throughout the testbed. Small shocks can be experienced when touching the shielding and ground at the same time somewhere in the testbed. This is not dangerous, but it shows that robust electrical design is a must.

IV. Conclusions

We presented the PotatoNet outdoor WSN testbed. PotatoNet is a generic testbed for outdoor applications of WSN nodes with a strong focus on robustness and availability. It is currently deployed in a Smart Farming scenario and will be successively extended with more field nodes in the future.

[2]http://openwrt.org/

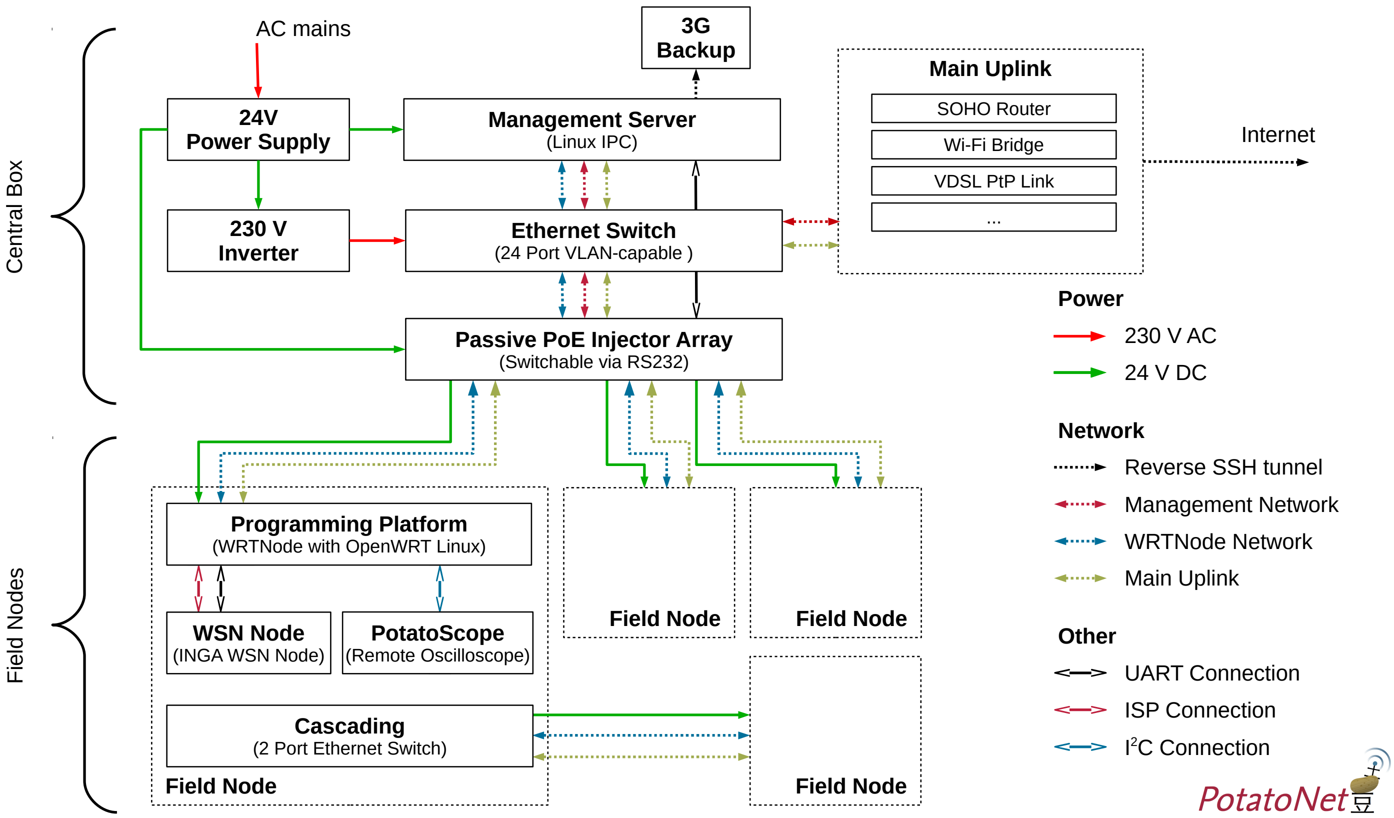


Figure 3: PotatoNet System Architecture

Software and custom-designed hardware schematics will be made available at the PotatoNet project page[3].

Acknowledgments

We would like to thank the VSD Dethlingen potato research station[4] for providing the field and technical support.

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