Demo: Design and Evaluation of MoleNet for Wireless Underground Sensor Networks

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***Abstract*—In this demo, we introduce a new sensor node for underground monitoring called the MoleNet. The MoleNet is designed especially for wireless underground operation. The development of the platform is part of a revitalization project in Cameroon. Due to certain constraints, the project terrain requires a complete underground deployment of the soil monitoring system. The underground channel is quite different from the terrestrial channel and hence presents new challenges for the researchers. The MoleNet strives to overcome these challenges. It focuses on an increased operational life and enhanced communication range. The current revision of MoleNet achieves almost 5 years of battery life, an underground to underground (UG2UG) communication range of 7.5m and an underground to aboveground (UG2AG) communication range of 80m.**

***Index Terms*—**Wireless Underground Sensor Networks, reforestation monitoring, agricultural monitoring, precision agriculture, MoleNet

Fig. 1. The MoleNet platform on the field

I. Introduction

The MoleNet sensor node is designed for the reforestation of a barren land at the Revitec [1] site in Ngaoundere, Cameroon. The MoleNet monitors the volumetric water content (VWC) of the soil and assists in the revitalization process. The project site presents a challenge as its soil is extremely dry. The particles in the dry soil become hydrophobic and hence they do not absorb much water. Even when it rains the gravity drains a large portion of water into the ground and the soil does not hold the water for a longer period of time. Most of the plants cannot withstand the dehydration stress and hence no plant grows in such areas. In order to address this dilemma, old coffee bags filled with soil and seeds are used in order to preserve more water during rainy periods. The structure of coffee bags allows the roots of the plants to grow into the soil below. In order to measure the effectiveness of the coffee bags, constant monitoring of the water content below the placed coffee bags is required. [2] Figure 1 shows the MoleNet sensor node before underground placement.

The main objective of this project is to monitor the VWC and temperature of the underground soil over a period of three to four years. In addition, the application demands the deployment of a complete underground wireless sensor network where all the sensor nodes must be buried underground except the base station. The MoleNet sensor node aims to meet these requirements.
In this demo, we focus on the design and evaluation of our new MoleNet platform at the single node level. More precisely, we present:

- The design and implementation of the MoleNet platform
- The evaluation of the MoleNet platform

II. Design of the MoleNet Node

The design of the MoleNet is based on widely used ”Wattuino Pro Mini” [3] that is powered by Atmega328p microcontroller. The MoleNet uses power efficient components to increase its operational lifetime. It is equipped with 8Mhz external crystal, power efficient MCP1703 [4] regulator, 25LC1024 1Mbit EEPROM [5] for data logging and RV8523 [6] RTC clock for maintaining the time locally and waking the controller from deep sleep mode. Different frequency bands were investigated to maximize the range between two sensor nodes. The authors in [7] already investigated that 2.4GHz band is not suitable for UG2UG or UG2AG communication. Therefore different transceivers for 868MHz and 433MHz ISM bands are scrutinized. HopeRF RFM69CW [8] 433MHz transceiver is then selected based on the UG2UG and UG2AG communication range. Figure 2 shows the top view of the MoleNet sensor node.

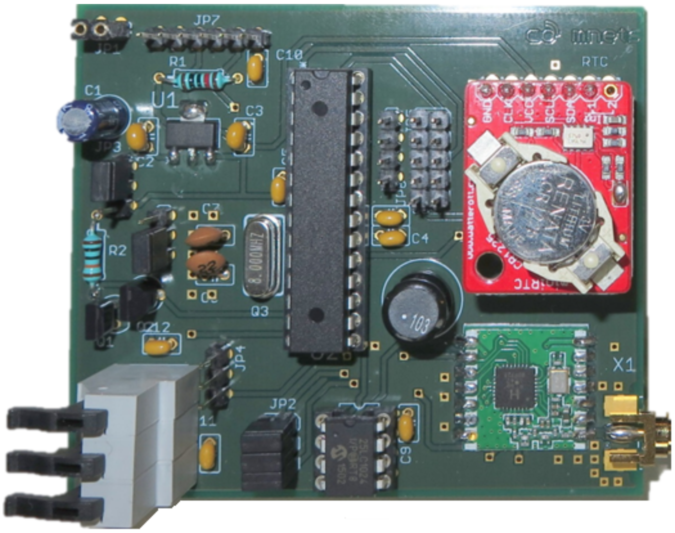

Fig. 2. Top view of the MoleNet sensor node

The MoleNet sensor node operates most of the time in deep sleep mode, the RTC clock wakes up the microcontroller for sensing and transmitting the data. After the successful transmission, the microcontroller again goes back to the deep sleep mode. In case of a failed transmission, the MoleNet stores the data into the external EEPROM and retries the transmission later. Figure 3 shows the power consumption in a single sense and transmit cycle of the MoleNet sensor node.

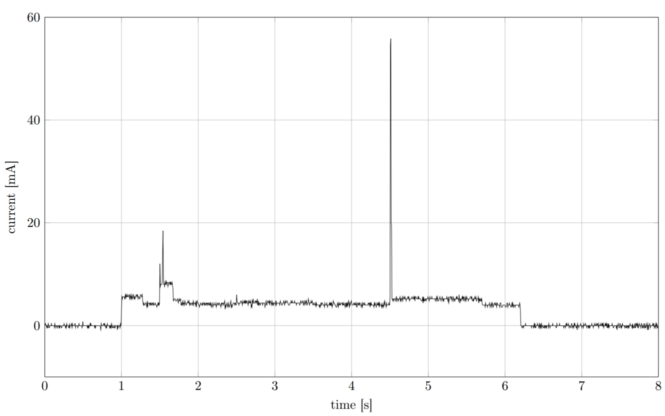

Fig. 3. Power consumption during one sense and transmit cycle

The hardware design and software implementation of the MoleNet sensor node is open source and is available on github.[1]

III. Measurement Results

Several experiments are performed for different transceivers, depths and distances. First, different transceivers for 433MHz and 868MHz are evaluated. The MoleNet node with 433MHz transceiver is buried in a depth of 20cm for determining UG2AG communication range. This configuration yielded an UG2AG communication range of 80m. Then the same experiment is performed for the 868MHz transceiver. The 868Mhz transceiver achieved a reliable communication range of 20m only. The 433MHz transceiver is then selected for further experiments.

The 433MHz transceiver is then used for investigating UG2AG communication for different depths of the buried node. The depth of the buried node is increased in steps of 10cm. For better realization the experiment is performed at two different locations. The receiver antenna is attached to a spectrum analyser. Figure 4 shows the received signal strength for different depths. The experiments at both locations show similar pattern. Usually a decrease in received signal strength with increase in depth is observed but at some instances this norm is not followed. Multipath propagation phenomenon can be one of the reasons for this behaviour.

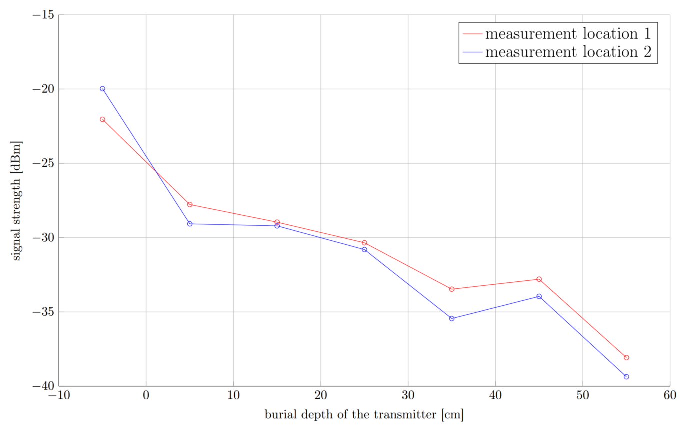

Fig. 4. Received signal strength for various depths

The 433MHz transceiver is then used for examining UG2UG communication in a depth of 20cm. The MoleNet sensor node with 433MHz transceiver is able to achieve a reliable UG2UG communication range of 7.5m. The MoleNet sensor node is also used for data acquisition at the Revitec project site in Ngaoundere, Cameroon. The Molenet was buried at the site for five days. The MoleNet operated uninterruptedly and withstood the extreme weather. Figure 5 shows the variation in volumetric water content (VWC) caused by heavy rains at the project site.

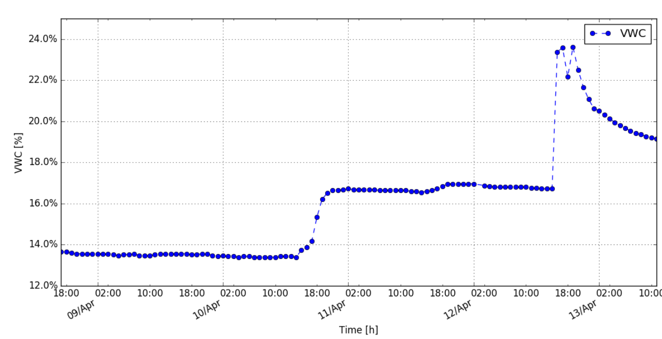

Fig. 5. Variation in volumetric water content (VWC) over five days

[1]https://github.com/ComNets-Bremen/WUSN

IV. Further Work

The current work will be extended to the deployment of a complete network of underground sensor nodes. A base station with GSM and GPRS communication capabilities will also be integrated. Techniques like reactive and adaptive sampling will also be incorporated to further increase the lifetime of the MoleNet sensor node. A testbed will be created near the University of Bremen to further investigate the challenges of multi-hop routing in wireless underground sensor networks.

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