Wireless sensor networks in precision agriculture

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ABSTRACT

We present the initial setup of the Lofar Agro project that concentrates on monitoring micro-climates in a crop field. In addition to the agronomic experiment, Lofar Agro aims at gathering statistics on the wireless sensor network itself. These statistics will form the basis for simulations of algorithms in wireless sensor networks and will be distributed.

1. PRECISION AGRICULTURE

In the past few years, new trends have emerged in the agricultural sector. Thanks to developments in the field of wireless sensor networks as well as miniaturization of the sensor boards, *precision agriculture* started emerging. Precision agriculture concentrates on providing the means for observing, assessing and controlling agricultural practices. It covers a wide range of agricultural concerns from daily herd management through horticulture to field crop production [1, 2, 7]. It concerns as well pre- and post-production aspects of agricultural enterprises.

A facet of precision agriculture concentrates on site-specific crop management. This encompasses different aspects, such as monitoring soil, crop and climate in a field; generalizing the results to a complete parcel; providing a decision-support system (DSS) for delivering insight into possible treatments, field-wide or for specific parts of a field; and the means for taking differential action, for example, varying in real-time an operation such as fertilizer, lime and pesticide application, tillage, or sowing rate.

This article describes an experiment in field crop production, referred to as *Lofar Agro*[1]. The example application being deployed deals with fighting phytophtora in a potato field. Phytophtora is a fungal disease which can enter a field through a variety of sources. The development and associated attack of the crop depends strongly on the climatological conditions within the field. Humidity is an important factor in the development of the disease. Both temperature and whether or not the leaves are wet are also important indicators. To monitor these three critical factors, we instrumented a potato field with wireless sensors. The main goal of monitoring is to reveal when the crop is at risk of developing the disease and let the farmer treat the field or parts of it with fungicide only when absolutely needed.

In addition to the agronomic experiment, we wish to gather data and statistics on the behavior of a wireless sensor network in a real-world experiment. Furthermore, we wish to test the robustness of the energy-efficient T-MAC protocol that was developed by our group [5]. The remainder of this article describes our experimental setup and the statistics we plan to collect.

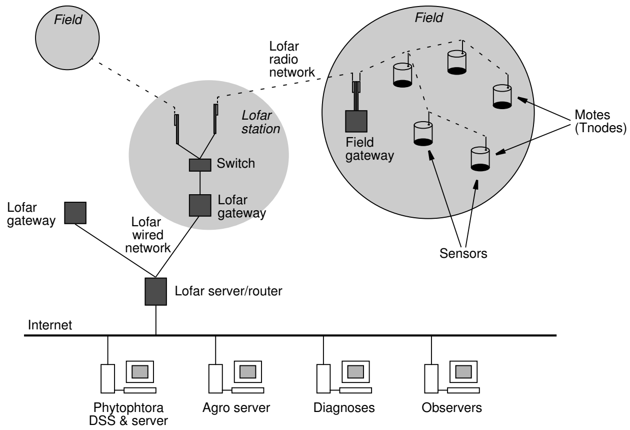

Figure 1: Lofar Agro setup

2. EXPERIMENTAL SETUP

Figure 1 shows the organization of the Lofar Agro experiment. A total of 150 sensor boards, namely TNOdes (see Figure 2), very similar to the Mica2 motes from Crossbow[2] are installed in a parcel for monitoring the crop. The nodes are manually localized so that a map of the parcel can be created. The TNOdes are equipped with sensors for registering the temperature and relative humidity. Earlier deployments have shown that the radio range is dramatically reduced when the potato crop is flowering [4]. To maintain sufficient network connectivity, 30 sensorless TNOdes act as communication relays. To further improve communication, the nodes are installed at a height of 75cm while the sensors are installed at a height of 20, 40 or 60cm. In addition to the TNOdes, the field is equipped with a weather station registering the luminosity, air pressure, precipitation, wind strength and direction. The humidity of the soil is a major factor in the development of the micro climate. A number of sensors that measure soil humidity are thus also deployed in the field. Finally, an extra sensor measures the height of the groundwater table.

[1]http://www.lofar.org/p/Agriculture.htm

[2]http://www.xbow.com/

Figure 2: A Lofar mote

A TNOde records the temperature and relative humidity every minute. For energy-efficiency considerations, the nodes are reporting data only once per ten minutes. To further save energy, the data sent over the wireless links is minimized by using delta encoding. In addition, we are currently investigating ways of compressing the data to save more energy on radio communication [3]. The T-MAC protocol cares for energy efficiency as well and impose the radio a duty cycle of 7%. The TNOdes use TinyOS as operating system. Data is thus sent using the multihop routing protocol MintRoute available within TinyOS [6]. In addition, the nodes are reprogrammable over the air using Deluge.

The data collected by the TNOdes is gathered at the edge of the field by a so-called *field gateway* and further transferred via WiFi to a simple PC for data logging, the Lofar gateway in Figure 1. The Lofar gateway is connected via wire to the Internet and data is uploaded to a Lofar server and further distributed to a couple of other servers under XML format.

3. STATISTICS COLLECTION

Beside agronomic purposes, the Lofar Agro experiment also aims at collecting live data about the behavior of the wireless sensor network itself. The goal is twofold. First, there is a need for monitoring the network while the experiment is running. Second, the data we collect should enable us to run simulations of algorithms for wireless sensor networks, such as localization algorithms.

The collected data and statistics allow us to rebuild the spanning tree used in the wireless sensor network and watch its evolution throughout the duration of the experiment. This spanning tree provides us with sensible input for simulating a wireless sensor network. Statistics also allow us to discover the dead links and nodes, check for vanishing nodes due to broken radio link because of foliage growth for example. We plan to collect information about the various neighbors of a node, parts of its MintRoute routing table, signal strength and link quality measurements, message rate and error rate in reception and transmission, and battery level. These statistics will be made publicly available.

4. RELIABILITY CONSIDERATIONS

The reliability of the wireless sensor network is of great importance as we want to prevent the loss of data and statistics. We implemented several mechanisms to make sure that all data and statistics are eventually delivered to the Lofar gateway. First, each node is logging both data and statistics in EEPROM and overwrites it only once acknowledged. Second, the Lofar gateway is checking once a day that all the expected data and statistics packets were received correctly. It uses a network-wide acknowledgment to signal the nodes which portion of their log can be safely reused.

Lost packets are handled in two ways. First, the T-MAC layer cares for up to three retransmissions of a packet. Second, dedicated software running on the Lofar gateway requests all packets that are still missing once a day. Missing packets are detected using sequence numbers. For data packets, we use a unique interval identifier composed of the node identifier, the day and a block number, which identifies a ten-minute block in a given day. For statistics packets, whose total number per day is not known in advance, we use a global sequence number per node.

The MintRoute multihop routing protocol [6] also plays a role in maintaining the reliability of the wireless sensor network. More precisely, it keeps routes estimates for each (active) neighbor and ensures that bad-quality links or malfunctioning nodes are evicted from a node's routing table and by-passed. In our deployment, we decided to let a node refresh its route estimates once per hour and switch parent if necessary.

5. STATUS AND ON-GOING WORK

At the moment, we are setting up the various connections and configuring the wired and wireless networks shown in Figure 1. A dozen of sensors are deployed in the experimentation field for test purposes. Mid-April, the potato crop was planted and the main of the sensors will soon be installed in the field. In June, we expect to have initial measurements data and statistics. The data collection will go on until September, time at which the potatoes are lifted.

6. REFERENCES

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