IoT FOR FARMING: A SMART SOLUTION PROPOSAL

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Abstract

This paper shows a proposal for a scalable, simpler and smarter crop management to enable a company, independently of its size, to face new industry challenges. The introduction of Internet of Things (IoT) solutions could actually lead to an improvement of the quality, quantity, sustainability and cost effectiveness of agricultural production. The chosen scenario is a small company that produces legumes, asking for an automatic irrigation system, crop monitoring through a Wireless Sensor Network (WSN) and other smart features to simplify the routine operations.

I. INTRODUCTION

The rising phenomenon of the IoT is transforming the agriculture, allowing farmers to deal with the new requests from the industry. Since the consumption needs of the global population are increasing, a lot of companies are trying to find new solutions to face critical issues such as water shortages, limited availability of lands and the difficulty to manage crops during the entire process of production. Several case studies propose the introduction of WSNs to collect data and analyze critical parameters. This first approach is necessary but no more sufficient as the demand for smart irrigation systems and automated decision support has increased.

A WSN is a wireless network composed of distributed autonomous devices using sensors to monitor environmental conditions. It has been shown as a WSN could be a good starting point for a lot of IoT applications and this is especially true for the scenario addressed in this paper. Furthermore, the possibility to provide connectivity to the Internet through a gateway is even more convenient to enable remote management of the smart devices and remote analysis of the environment. The wireless protocols involved in a WSN may vary and strongly depend on the application requirements. In the scenario described in this paper, the IEEE 802.15.4 (ZigBee) and the IEEE 802.11b (Wi-Fi) standards are used, the first one to send data among the nodes of the network and the second one to establish a communication between a gateway of the WSN and an administration device.

ZigBee is a wireless networking standard that aims at remote control and sensor applications. It is suitable also for operation in harsh radio environments and in isolated locations. As mentioned before, ZigBee technology builds on IEEE standard 802.15.4 which defines the physical and MAC layers. Above this, ZigBee defines the application and security layer specifications enabling interoperability among products from different manufacturers. The distances that can be reached transmitting from one station to the next extend up to about 70 meters, although very much greater distances may be reached by sending data from one node to the next in a network. The main uses for IEEE 802.15.4 standard are aimed at control and monitoring applications where low levels of data throughput are needed. Furthermore, a low power consumption profile can be maintained, for battery powered devices such as sensors, setting a low data rate. ZigBee operates in unlicensed radio frequency bands, including 2.4 GHz, 900 MHz, and 868 MHz. For this reason, some interferences with Wi-Fi may generally occur but in this specific scenario, due to the long distances between the devices, this is not an issue.

The IEEE 802.11b is a Wi-Fi standard developed by the IEEE for transmitting data over a wireless network. It operates on a 2.4 GHz band and allows for wireless data transfers up to 11 Mbps. This version of the 802.11 standard has been chosen for simulation purposes but another version, such as 802.11g, could be used as well.

In the following sections, some related works will be described, showing the most interesting solutions they propose. Subsequently, a new approach, to comply with the requests of the company for this application scenario, will be presented. Subsequently, a performances evaluation of the system will be shown.

II. RELATED WORKS

Several years have passed since the automation in the agricultural industry has become necessary, but in these last ten years, new proposals and new approaches, following the evolution of mobile and embedded devices, have been presented. As described in [1], the introduction of a WSN, in scenarios where nodes are battery powered devices and where power consumption is a key element, has made necessary the development of optimized routing algorithms. Taking an energy efficient WSN as a base, several papers about different applications for smart agriculture, described how to improve and optimize single aspects involved in the production processes. The authors of [2] introduce a water management system to save water and maximize productivity. A very interesting detail of their implementation is the possibility to irrigate at a variable rate depending on a distributed in-field sensor network.

A more convenient option could be to activate electromechanical systems using sensors as triggers as simulated in [3]. The authors present preliminary ideas and the results obtained from the simulations of a WSN with event-based control applied to a greenhouse temperature control system are described. Even in an industrial farm scenario, similar methods are necessary to prevent some issues that a too high inner temperature of the fields can cause.

All these studies agree with the introduction of a WSN in this kind of applications and highlight the advantages that such a network could actually bring. What still seems to lack though is a decision support system to fully automate routine operations. Provide this kind of system in scenarios where the manual control is still present, become even more difficult because manual control is based on the operator's opinion and often have no quantitative basis, as described in [4]. The authors try to solve this problem collecting and organizing data from sensors distributed in the area of interest, to quantify the critical parameters and provide real-time decisions.

What described in the previous paragraphs can be achieved with the IoT by giving to distributed smart objects, all connected to each other, the capability to collect data, analyze it and choose what's the best practice to adopt in a precise state of the entire system. Since the IoT market is expected to grow quickly in the next years, solutions, such as those analyzed in [5], will be more frequently adopted to remotely monitor crops with the aid of an information management system.

III. THE PROPOSED APPROACH

The company involved in this case study owns 5 hectares of land where grows four types of legumes including 1 hectare used for beans, 1 for the green beans and peas, and other 2 hectares for asparagus. It's necessary to pay particular attention to the latter since their growth is influenced by two critical factors: the amount of nitrogen contained within the soil and the soil internal temperature.

The company, in order to obtain an adequate soil temperature for the growth of the asparagus, uses some thin metal foils that are double-sided: white and black. The first one is useful to reflect sunlight to decrease the inner temperature of the ground, the second one is used to absorb sunlight and heat the ground. One of the requests made by the company is to provide an automatic system able to detect the soil temperature, thus avoiding an operator to carry out the measurement several times a day, also capable to automatically decide which side of the metal foil is more appropriate to use. The system proposed in this paper, shown in Figure 1, is organized as follows:

- 10 automatic irrigation pumps, calibrated according to the type of legume, using algorithms that take into account the water needs of each crop. All the pumps are equipped with a controller that receives data from the temperature and soil moisture sensors, submit them to a fuzzy logic controller and thereafter sends them to a power controller which, by means of a specific algorithm for each individual crop, calculates how many cubic meters of water should be delivered and for how long, depending on the temperature and humidity of the soil;
- 10 temperature sensors, powered by a non-rechargeable 2000 mAh battery. Due to the low power consumption of this sensors, the batteries are replaced every two or three years;
- 10 soil moisture sensors, equipped with the same battery. They have a structure similar to the temperature sensors;
- 15 soil nitrogen sensors, powered by the same battery used in the other sensors. Inside of them there's a logic system which periodically gathers, 10g at a time, soil samples up to reach a total amount of 100g. These soil samples are then analyzed from the sensor;
- 1 switcher, constituted by a controller and a mechanical device. The controller receives the data from the temperature sensors and submits them to a fuzzy logic controller which determines whether to use the white or black face of the metal foil. According to the value returned from the controller, the foil is then switched to the desired side by the mechanical device;
- 1 gateway that allows to forward the messages exchanged between the nodes of the WSN and an administration client;
- 1 administration client, useful to show the collected data and the general status of the system to the operators and farmers.

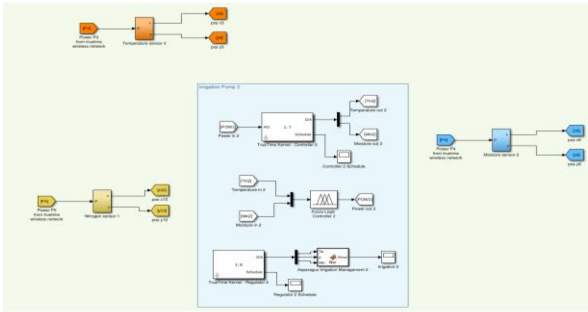

Figure 1: From left to right: a soil nitrogen sensor, a temperature sensor, an irrigation pump and a soil moisture sensor. The pump receives data from the sensors and delivers the optimal amount of water.

The network has a mesh topology, useful to ensure proper communication and the reliability of transmission between nodes. Thus, if some messages are lost or it is impossible to deliver a given message, the system is able to work properly receiving the messages from another network node. For all the sensors and the irrigation pumps, the 802.15.4 ZigBee protocol is used and it is also useful to preserve the battery life of all devices. The transmission power is set to 6 dBm to reach as many nodes as possible by limiting energy consumption. The data rate was set to 30 kbits/s, sufficient to quickly transmit the packets. To allow the communication between the gateway and the administration client, a WLAN was implemented using the 802.11b protocol.

IV. SCENARIO

This scenario has been simulated with Matlab / Simulink using TrueTime [6]. The simulation has been carried out immediately after the sowing period, in the spring, with a temperature that varies between 15 and 28 degrees centigrade and a soil moisture percentage between 50% and 90%. To effectively test if the projected system could assure reliable results during a long period, even a simulation of two years and a half has been executed.

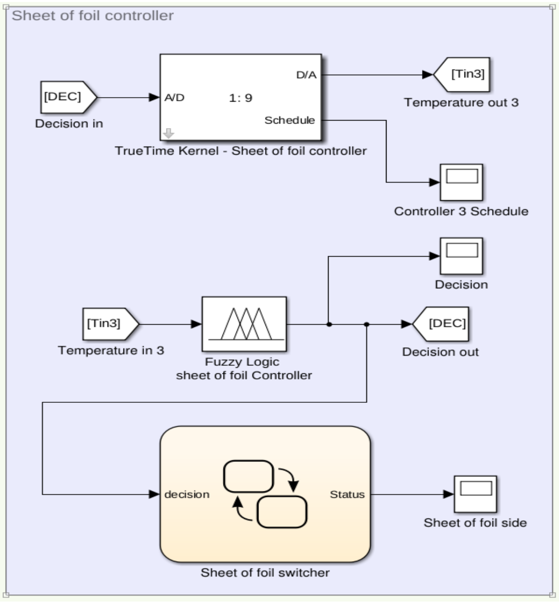

Figure 2: Internal components of a metal foils switcher. From up to bottom: the controller receives the data from the sensors and submit them to a fuzzy logic controller. Accordingly to the value returned by the fuzzy logic controller, a side of the metal foil is chosen.

As described in the previous section, the company owns 5 hectares of land and to provide the right amount of water accordingly to the needs, 2 irrigation pumps per hectare have been installed. The irrigation pumps are equipped with a controller to receive and analyze the data sent by the sensors and if a battery-powered sensor doesn't work anymore, the irrigation pump controller tries to fetch messages from other near sensors. Thanks to the mesh network topology this process can assure always new and reliable data to be processed by the devices that need them.

Another device required by the company is the metal foils (Figure 2) switcher for the cultivation of the asparagus. To simulate this device a flow chart controller has been used, in this way the side of the foils can be switched according to the value returned by a fuzzy logic controller.

Taking advantage of a mesh topology built upon a WSN, no pre-existing infrastructure is required to create a network in remote areas. In the system proposed, the nodes of the network can forward messages to other near nodes allowing an efficient routing even if the network changes or a node stops working. A gateway is then used to connect the mesh cloud to a WLAN containing the administration device which provides the data collected to the operators.

V. PERFORMANCE EVALUATION

For the presented scenario two main issues could be critical, the collapse of the mesh cloud due to an overload condition or to a change of the network morphology. To test the first potential issue a simulation of one hour has been carried out: to test the network at full load the simultaneous send of the packets to all the reachable network nodes has been set. Thanks to the mesh topology of the network and the implemented algorithms, the irrigation pumps and the switcher have successfully ignored the unnecessary data packets.

The second issue mentioned above is typically caused by battery-powered nodes, indeed when a battery runs out the node can't transmit its data neither forward the messages sent by other nodes of the network.

To test this issue and to provide a more realistic view of the entire working system, the duration of the simulation has been set to 788400000 seconds which are about two and a half years. With a data rate of 30 kbit/s, a transmission power set to 6 dBm, transmitting one message per minute the batteries run out after 2 years.

Another important parameter that has been tested in this simulation is the throughput. In the simulation period of 788400000 seconds 643860000 packet has been sent between the nodes of the network, multiplying this value by the minimum frame size, which is 272 bits related to the network, and dividing by the duration of the simulation it is obtained the value of 222.13 bit/s.

VI. CONCLUSIONS

The intent of this paper is to illustrate one of the possible implementations of the "smart objects" concept, useful to support the agricultural labor management.

Future developments in this field of interest could be the introduction of advanced algorithms for the diagnosis of diseases affecting the crops and new machine learning techniques to bring the agricultural industry to a new level of automation.

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