

# A Wireless Sensor Network for Automated Irrigation Systems

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**Abstract**—The Wireless Sensors Networks (WSN) technology has spread rapidly into different fields and sectors, agriculture is one of them. WSNs for agriculture are used for their cost effectiveness to improve the productivity, profitability and sustainability of the whole farming system. This work focus on the design and implementation of an intelligent, low cost and fully automated irrigation system which will be able to provide full time monitoring. The system is composed of different types of nodes. Each node consists of a TelosB mote and adequate sensors and actuators. In addition, a gateway unit handles sensor information, triggers actuators, and transmits data to a java or web application. To maximize the lifetime of a mote the system was powered by an Energy Harvesting Module using a solar panel.

**Index Terms**—WSN, Sensors, Actuator, TelosB, Energy Harvesting, Solar Panel.

## I. INTRODUCTION

Traditional field irrigation is usually done manually and needs massive manpower and material resources. This leads to a deficiency of real-time and accuracy and is against the development trend of long-time agricultural production and sustainable utilization of water resources. Wireless sensor networks (WSN) [1] are extensively used in precision agriculture and smart irrigation to overcome these problems.

The aim of this project is the development a wireless sensor network which monitors an agricultural field. It consists of distributed nodes which are connected wirelessly to a central unit collecting all relevant data. The sensor nodes will be supplied from ambient energy, e.g. with solar cells in order to reduce maintenance efforts for battery change. These nodes gather detailed information about the state of the field and help to control and react to different circumstances. This study provides the reader with the main key characteristics of the developed nodes.

This paper is organised as follows: the next section gives a detailed description in terms of hardware and software of the device developed for the implementation of a WSN for precision irrigation. Section 3 present an energy management solution for the system. Section 4 describes the experimental results which confirm that the hardware and software solutions proposed lead to a good performance.

## II. AUTOMATED IRRIGATION SYSTEM DESCRIPTION

Efficient irrigation management is vital for successful crop growing. However, a WSN can facilitate monitoring of mois-

ture levels for crops and, in conjunction with an actuator, can take a decision whether to perform irrigation or not. This method can reduce the required amount of water. In addition, over-irrigation of crops can lead to nutrients being leached from the soil. This project focuses on the use of multiple sensors as a device to control the water quantity in an irrigation system in real-time. The design of the device is chosen because of its features that fulfil the requirement for low-power consumption, low cost, water's waste reduced, manpower reduced and reliable data communication between sensors nodes. This device is being developed with the following goals.

Each mote must be able to communicate with the gateway via a highly reliable radio module compatible with the IEEE 802.15.4 standard. This intends to offer the fundamental lower network layers of a type of wireless personal area network which focuses on low-cost, low-speed ubiquitous communication between devices. It is proposed to develop a system which detects soil and environmental parameters through a sensor node and displays measured values in real-time. It must be able to process orders received by the base station and display parameters of the environment received via desktop application or via web site in real-time. The system must be simple to use and receptive to the user's needs.

The following sections present the hardware part used in the sensor nodes that have been developed.

The prototype consists of three parts: the base station, the wireless sensor module and the software part. The base station will be attached to a laptop which records log files and displays all the sensor readings. The sensor module will wirelessly transmit sensor data to the base station. The software part consists of a Java application and a web site to log and display sensor data.

For implementation a TelosB mote [2] is used, which is an ultra-low power wireless module for monitoring applications, eco-friendly products and rapid application prototyping.

The low-power operation of the TelosB module is because of the ultra-low power Texas Instruments MSP430 F1611 microcontroller featuring 10 kB of random access memory, 48 kB of flash and 128 B of information storage. It can be powered by two AA batteries for several weeks. Wireless communication is provided by the Chipcon CC2420 radio module. This circuit combines low power and efficient operation with support for IEEE 802.15.4. It operates in 2.4 GHz. It also has an integrated

on board antenna with 50 m range indoor/125 m range outdoor.

These characteristics make it ideal for the watering system as it can easily be deployed everywhere while being independent of power installations. The TelosB works properly within -40 to 123.8°C which is suitable for the extreme weather conditions.

The System contains three different sensor nodes: a soil node, an environment node and a container node.

#### A. Soil Node

Measuring soil moisture is important to estimate the exact quantity of water needed for each plant in each field. Measuring temperature helps the farmer to estimate the exact time when plants are in need for water which is especially important in hot and dry seasons.

A resistive sensor was chosen for the detection of soil moisture due to its insensitivity to salinity and it does not corrode over time. The sensor used is a vh400 [3] soil moisture provided by Vegetronix. Indeed, it is small, rugged and of lower power. It measures the dielectric constant of the soil using transmission line techniques. Compared with other low-cost sensors such as gypsum block sensors, VH400 offers a rapid response time. Key features of this sensor include low cost with volume pricing, small size, low power consumption (17 mA), it measures the volumetric water content (VWC), the output voltage is proportional to the moisture level, it has a wide supply range of 3.3–20 volt directional current (VDC) and it can be buried and is water proof.

The soil temperature sensor is aDS18B20 provided by Maxim integrated [4] which is a lower-power consumption digital temperature sensor. The temperature measures between -55 °C and 125°C. Because of its small size, it can save many lead wires and much logic circuitry. It requires only one pin for communication and can be powered with 3 V. It consists of three wires. One is connected to the ground, one is connected to the voltage common collector (VCC) and finally the last one is connected to a digital-analogue convertor (DAC) channel pin.

#### B. Environment Node

The environment monitoring part consists of various types of sensors to collect environmental factors such as luminance level, temperature, relative humidity and wind speed. With the help of an integrated sensor in the TelosB mote, named Sensirion SHT11 [5], ambient temperature and humidity can be detected. Both sensors are seamlessly coupled to a 14 bit analogue to digital converter and a serial interface circuit. The tiny size and the low-power consumption makes the SHT11 the ultimate choice for even the most demanding applications including sensor networks. The water's application pattern is susceptible to distortion by the wind. Although the wind speed and direction are not controlled variables, their effect on irrigation uniformity is significant, so a farmer should take in consideration the wind speed when irrigating. In addition to those sensors, the node is equipped with a VORTEX anemometer [6] to detect the wind speed. It is a rugged sensor which can handle speeds from 5 to over 125 mph.

#### C. Container Node

In this part an actuator will be attached to the TelosB mote. When urgent conditions are detected on other nodes, a simple order will be given to the actuator to open the water valve for irrigation. To control the irrigation process, a solenoid valve provided by Rain Bird [7] is used with a telosb mote. It is an electromechanical valve that is controlled by an electric current. The electric valve is a low-power consumption device and it is powered with 24 V for 50/60 Hz. For the TelosB motes to be able to drive the valves a relay must be added. The relay is used for switching the amount of power with a small operating power. This way, when the TelosB mote triggers the relay, the circuit closes, the electro-valve opens and the irrigation process begins.

### III. ENERGY MANAGEMENT AND ENERGY HARVESTER

In order to control the whole system, a large number of sensor nodes need to be used. The high number of nodes excludes any kind of maintenance, such as battery replacement, after the system has been deployed. The lifetime of a wireless sensor node is limited to just a few short weeks or even days. Eliminating the wires has resulted in wireless sensor networks, but maintaining and changing batteries, especially in networks with a large number of nodes, will be very cost intensive.

To avoid these extra expenditures and to reach a long lifetime of the WSN, energy harvesting is a suitable solution. The use of energy harvesting technologies increases the autonomy of embedded systems. Therefore, two energy management techniques are applied to the system.

First, the used sensors are programmed with TinyOS [8], which is a component-based architecture and forms an event-driven operating system. The application was written for low power consumption that allows TinyOS to manage energy in the most efficient manner possible. By default, TinyOS provides low power radio operation through a technique known as Low-Power Listening (LPL). In this mode, nodes wake up very briefly to check for channel activity without receiving data. LPL consumes much less energy than existing scheduling protocols in non-condensed WSNs. In fact, the motes are only sensing adequate parameters and transmitting hexadecimal values to the base station. The conversion from hexadecimal to decimal and applying the formula to give the appropriate results is done by a Java-application to decrease the amount of computing realised by the sensor node.

Second, the system is equipped with an energy harvesting component. It consists of a transducer for the conversion of ambient energy to electrical to supply an electronic system.

There are many sources of energy harvesting such as light, vibration, thermal or biological sources available. In this work the sun is chosen as a source for energy harvesting. In particular, solar energy delivers a stable power income when used in outdoor applications.

The block diagram of a WSN node is shown in (Fig 1). It consists of a microcontroller (MCU), a radio communication part, a sensor block and the power module. When powered with a solar panel, a local charge storage or a battery is needed

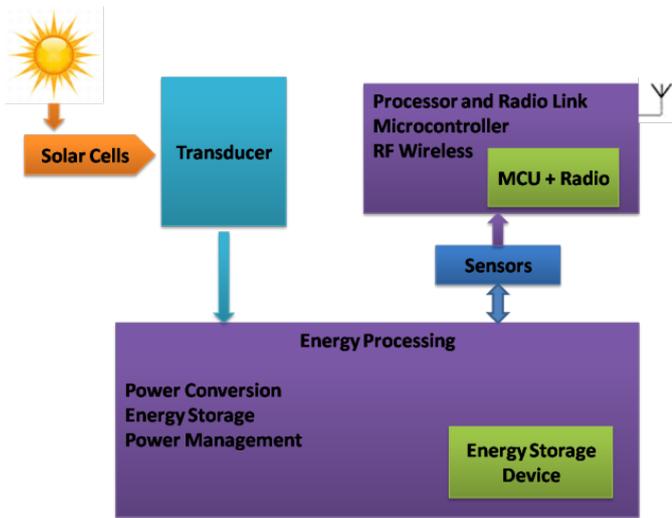


Fig. 1. Block diagram of a WSN powered with an energy harvesting unit.

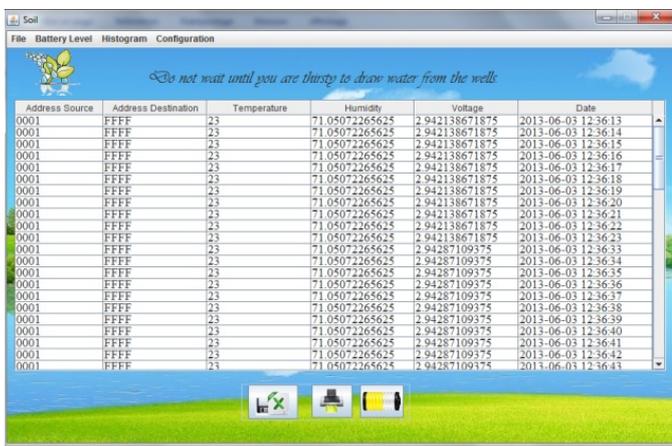


Fig. 2. Desktop application interface.

to store surplus energy for periods when sun irradiation is low or absent e.g. during the night, on cloudy weather or rainy days. Moreover, to maximize the lifetime of the sensor nodes the energy management presents a critical concern in wireless sensor networks.

#### IV. USER FRONT END OF THE WSN

The major objective of this work is to facilitate tasks for the farmer. The system helps the farmer to control the development of his crops at any time and anywhere. The system offers two types of interaction functionality, by serial connection and via the web.

One way for the farmer is to use the application installed in the computer (Fig 2).

The farmer be able to inform himself and he is able to observe changes in each node. Also, by knowing the characteristics of each plant, he can define the approximate threshold for all relevant parameters. In case of any problems an alarm will be set for the critical situation. Easily, without needing



Fig. 3. Web page application interface.



Fig. 4. Real time picture.

any additional knowledge, the farmer can make the suitable decision for the current situation.

The problem now is focused when the farmer is away from his farm. Therefore, the second way is to connect by web application (Fig 3) via his personal session anywhere, anytime.

The web page provides the farmer with similar functionalities as the desktop application. The addition in this application is the integration of Google maps, which enables everyone to access and have information about nodes and their locations. Once a value exceeds the threshold, a sound alert will be triggered and a new window will be opened which contains the name of the relevant station and the exception.

#### V. FIELD TEXT

A plant from the laboratory was used for testing the system. As each plant has its particular parameters, the concentration was on a small plant known as SPIDER plant. A picture of the real system is given in Fig.4.

To understand the system's behaviour facing climatic changes, needs of the spider plant in water, temperature, light and fertiliser have been studied [9]. The tested plant is undemanding for water. It prefers bright light and tends towards scorching in direct sunlight. However, it will grow in conditions ranging from semi-shaded to partial direct sun, which means that the light should be established approximately between 269.1 and 807.3 lux. In summer, this plant should be watered liberally, but during the winter the watering



Fig. 5. TelosB platforms and Energy Harvester Module.

has to be reduced. The spider plant does not resist below 50°F (10°C) or in cold wind. The air temperature must be kept between 40 and 85°F (4.5–29.5°C). Spider plants demand a fast-draining, well-aerated soil mix. When the soil moisture is below 10%, we need to irrigate. Understanding the plant's needs helps to compare the retrieved data from the sensors (Table 1).

Taking advantages from personal farmer experiences, some results could be concluded for better irrigation scheduler. The temperature should be maintained higher than 10oC also the soil moisture should be higher than 10 %. Weather temperature is maintained between 4.5°C and 30°C and the light between 269.1 lux and 807.3 lux. Reading the experimental results shows that the plant is well irrigated and its demands on water are well respected. If any of the experimental results exceed the threshold of these studied parameters, the system will alert the farmer about this problem to make the appropriate decision.

The following figure represents an application example which contains a receiver powered with EH module and a sender (figure 5).

## VI. CONCLUSION

Agriculture is one of the most important fields for each country, so applying new Precision Farming tools has become a necessity to improve the productivity, profitability and sustainability of this sector. In this paper, a study about a monitoring system was discussed, that can be used for efficient irrigation. In this paper, the architecture and the implementation of an automated irrigation system based on a WSN was presented. The system is composed of three typed of nodes; each type is composed from the TelosB mote and adequate sensors. The soil node will be used to measure soil moisture and soil temperature, the weather node is used to measure some environmental parameters, such as the air temperature, the air humidity and the wind speed. The last node is connected to an actuator, which allows the controlling of the opening of the irrigation valve if it is necessary. The data from each node will be transmitted to a base station where it will be recorded and constantly transmitted to the farmer's computer. This will permit him to take the proper action.

In the future, many improvements can be made to make the system more versatile, customizable, and user-friendly. One solution is to have an Android version of the system for smart phones for better real time control. Also, information could be exchanged via SMS on GSM network.

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