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GREENHOUSE ENVIRONMENTAL MONITORING SYSTEM USING WIRELESS SENSOR NETWORKS

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Abstract: *The main task of the implemented solution is to choose the optimal hardware architecture design, to minimize the data communication rate and to define the energy-efficient algorithm in order to save the total energy of the sensor node. The ultimate goal is to design a pepper environmental monitoring system which should be easy to implement, use and maintain, built of low-cost and low powered components.*

Key Words: ***Environmental Monitoring System/Sensor Node /Efficient Algorithm***

1. INTRODUCTION

Wireless sensor nodes are small devices that include three basic components: a sensing system for data acquisition from the physical environment, a processing unit for data processing and storage and wireless communication component for measurement data transmission. In recent research, the focus is especially based on low power feature of the sensor nodes because the power consumption is always a challenge for wireless nodes, supplied with batteries [1-4].

For applications in wireless sensor networks one important challenge is to design sensor networks that have long system lifetimes. The challenge is especially hard due to the energy constrained nature of the devices. So, this need to minimize the energy consumption and to maximize the lifetime of a system makes the design of wireless sensor networks difficult.

The development of crop production procedures would increase energy efficiency in agriculture and enable sustainable development [5]. Furthermore, the use of renewable technologies on farms is considered as essential, but not single factor to influence modern and energy efficient agriculture. In fact, cleaner production procedures and renewable energy technologies along with reliable real time monitoring systems based on WSNs would contribute in creating the adequate conditions for development of sustainable agriculture.

Power consumption in sensor nodes is result of four modes: in the sleeping mode, where the processor and the radio are idle, waiting to be awaken up by an external event, then it enters in processing mode. The most power demanding state is the transition from processing to transmitting (or receiving) state, where sensor increases about 50% of the power consumption relative to the processing state. So, a good choice is to maintain sensors in maximum efficiency operational modes, switching between active and sleep modes in a low duty cycles. Communications tasks usually take much more time to complete then the data processing and are responsible for most of the devices energy consumption.

Our aim was to develop a non-robust, low maintenance and low cost wireless sensor network system which would be used for optimization of greenhouse crop production. This measurement system is implemented in real scenario in pepper greenhouse for environmental parameters monitoring, such as temperature and humidity.

2. MEASUREMENT DESIGN SYSTEM

Very important consideration in any wireless application is to choose the right sensor node. Comparison between different sensor nodes can be made according to general parameters, processor and memory, communication capabilities, sensor support and power consumption. The type of the sensor node that would be used depends from the current application and should be a compromise between the size, cost and power consumption

2.1. Hardware design

The sensor nodes that are used in this experiment are eZ430-RF2500 from Texas Instruments (TI) [6]. The nodes integrate MSP430 family of ultra-low power microcontrollers and CC2500 low-power wireless radio frequency transceiver.

The two main core components of the sensor nodes are MSP430F2274 microcontroller [7] and 2.4 GHz CC2500 radio transceiver [8], which are suitable for low power, low cost wireless applications. The target board can be used as a stand-alone system with or without external sensors or using sensors incorporated in the existing design. For the application purposes SHT11 [9] temperature/humidity sensor is used as an external component.

It is very important to select the suitable sensor which can survive the high temperature and the high humidity of the greenhouse environment and also has high sensitivity and reliability in a measurement range for the crop cultivation. In the design of the measurement system, the selection of the microprocessor is critical to the whole design of the measurement system. The ideal microprocessors are those that have large memory, powerful computational capability and consume ultra-low power.

The architecture of the sensor node is shown in fig. 1.

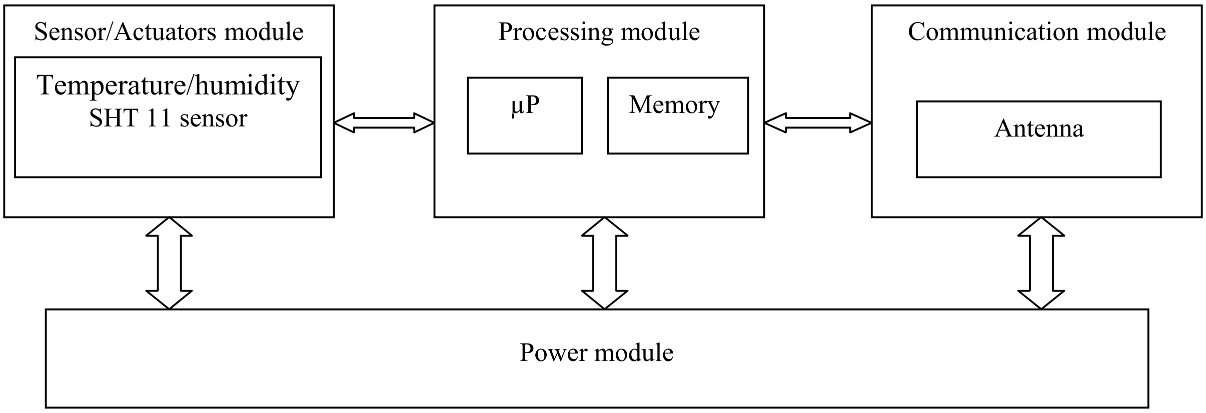

Fig. 1. *The architecture of a wireless sensor node*.

2.2. Software design

The eZ430-RF2500 sensor nodes use IAR Embedded Workbench Integrated Development Environment (IDE) or Code Composer Studio (CCS) to write, download and debug an application.

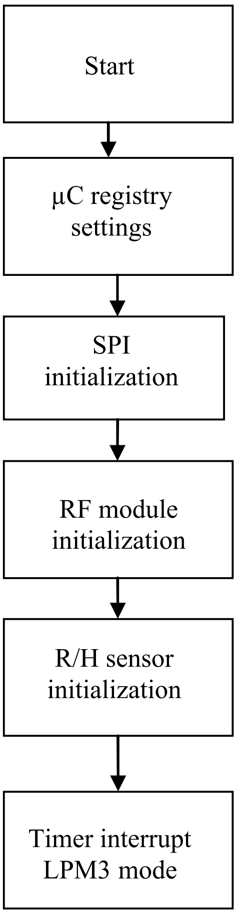

Fig. 2. *Microcontroller algorithm description.*

The USB debugging interface enables the sensor boards to remotely send and receive data from a computer using MSP430 application universal asynchronous receiver/transmitter (UART).

The communication between the base station and end nodes can be established in regular time frames, which can vary from few seconds to several hours. According to the application requirements the communication rate can be variable, very often (in seconds) or the measurement data frequency can be defined in hours. Therefore, these parameters should be chosen carefully in order to create an optimal measurement system.

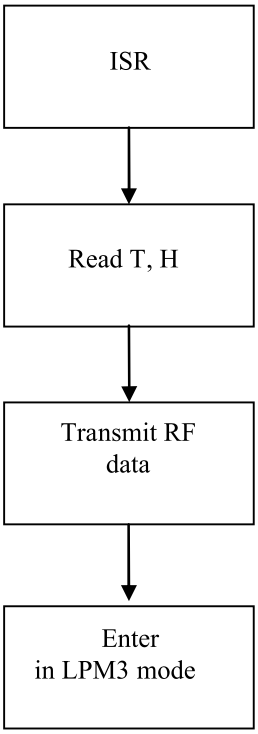

Fig. 3. *Data transmission algorithm.*

To optimize the battery power consumption, the sensor nodes should be placed in low power mode, every time when they are not active. Most of the time the sensor nodes are in low power mode (LPM3), waking up once a half hour to sample the environmental parameters and send the measurement results to the network base station (fig.2). All sensor nodes are identical and send data on demand to the base station which is connected to the USB port on a computer (fig.3).

3. PEPPER GREENHOUSE MONITORING APPLICATION

For a certain area of the greenhouse, it is necessary to calculate the number of sensor nodes (transmitters). The number of sensor nodes that should cover the greenhouse area also depends from the transmiting power of the sensor nodes.

The transmitter sends data packets for temperature and humidity every half hour, after that the microcontrolle enters in low power mode LPM3 in which it remains until the next dispatch. The data from end nodes are collected in the central base station.

The sensor nodes are additionally equipped with solar cells, which is increasing the battery lifetime. The solar cells can be used in sunny days, when the sun is mostly intense, while at night and in foggy days the measurement system is using the battery charge.

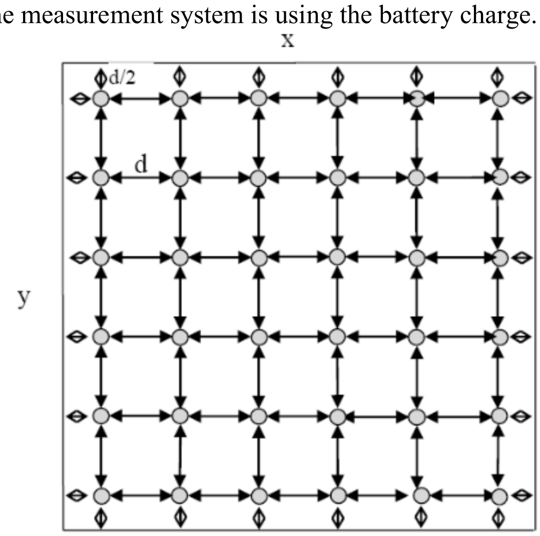

Fig. 4. *Positions of the sensor nodes in the greenhouse*

The architecture of a wireless sensor network system comprises of a set of sensor nodes and a base station, enabling communication between them and gathering local information to make global decisions about the physical environment. The architecture of the system is presented in fig. 4.

Data measurements for the environmental parameters such as temperature, humidity and light are recorded every 30 minutes with a set of sensor nodes each separated 30 m from the base station [1]. This network consists of an access point (base station) that measures its own temperature and wirelessly receives temperature measurements from sensor nodes. Sensor nodes measure their temperature and then enter a low-power mode to reduce battery usage. All sensor nodes are identical and send data on demand to the base station which is connected to the USB port on a PC.

Pepper is one of the most sensitive vegetable products and it is essential to control the optimal environmental parameters for high quality production. The optimal temperature value that has a positive influence of the development of the pepper crops is between 20 and 25 ºC. In sunny days the temperature should be maintained between 25-28 º C, at rainy days should be 20-22 º C, while at night the temperature may vary in the range 18-20 º C. The lower temperatures should not be below 16-17 º C. Beside the temperature, another important parameter for normal growth of the agricultural plant is the air humidity. The optimal values for pepper agricultural plant is between 60% and 70%. The extremely low values of humidity in a combination with high temperature values may cause negative effects on the growth of the plant. The highest humidity value in a pepper greenhouse should not exceed 70%.

Another parameter that directly influences the pepper crops is the soil acidity. Soil pH is a measure of the amount of calcium in the soil. In dry climate the soil for pepper production should be alkaline, while in wet climate the soil should be acid. Soil with pH below 7.0 is considered acid, while soil with pH values above 7.0 has alkaline nature. These values should be adjusted accordingly of the type of the agricultural crop. For pepper vegetable the optimal values for soil pH is between 5.5 and 6.5. The measurements of soil moisture and pH were done by using a simple instrument shown on fig. 5. The temperature, humidity and soil pH should be continuously monitored in order to determine the right time for watering or draining the crops.

Fig. 5. *Soil moisture and pH measurement instrument*

Graphical representation of the monitoring environmental parameters: temperature and humidity is presented in the programming language Labview. On the figure 6 is given the block diagram of the measured environmental parameters. The first block in figure 6 defines the connection with the serial port of the computer. Other tab controls in the block diagram present the data analysis and storage of the measurement data in data base.

The system used for measurement and data collection is the basis of the monitoring and control system for precision agriculture. The optimal values for quality crop and sustainable pepper production should be: 20-25 ºC for temperature and 60-70 % for humidity in the pepper greenhouse. The pH value of the soil should be in the range of 5,5-6,5.

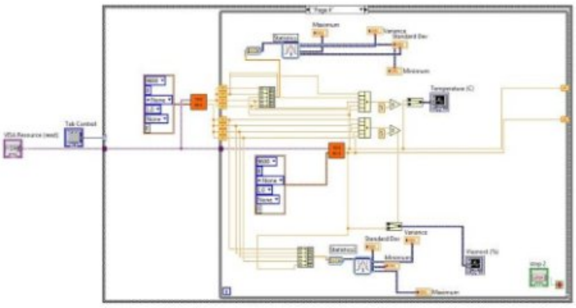

Fig. 6. *Block diagram of the monitoring environmental parameters.*

The graphical presentation of the measured parameters is given on Figure 7. The measured data can be stored and analyzed. By analyzing the data obtained from the sensor nodes, the base station would make a decision according to which appropriate tasks would be performed.

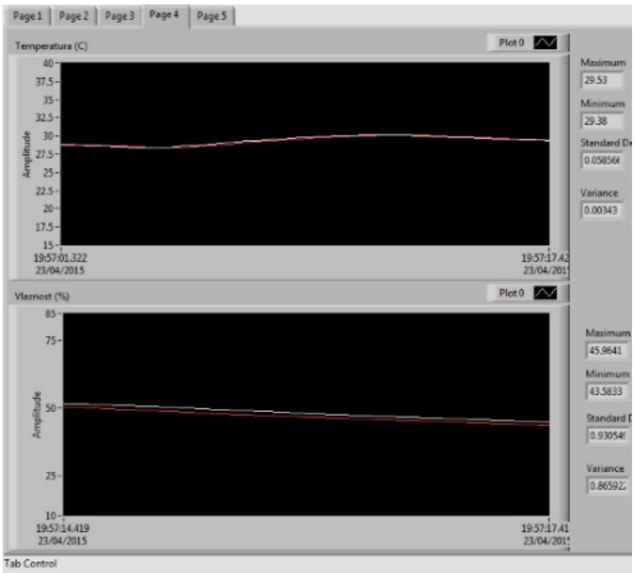

Fig. 7. *Graphical representation of the monitoring environmental parameters.*

The measured temperature values are between 10º C and 45º C. So in this case, the temperature fluctuations are higher than the optimal conditions, therefore showing that in this particular case, the process of monitoring and control should be implemented in order to provide the optimal crop conditions. The humidity measurement results are near the upper optimal value which is 70%, while the measured acidity of the soil is 6.0 pH, which is in the range of the allowed values.

4. CONCLUSION

The paper presents the development of a WSN application for precision agriculture, which is deployed in a pepper vegetable greenhouse. In particular, the paper presents the experimental setup and the preliminary results of the part of the application used for data measurement and data collection as well as initial concepts for improving the monitoring system. The proposed architecture is designed in order to improve the quality in agricultural production and would decrease the management and farming costs.

The environmental parameters such as temperature, humidity and illumination should be continually monitored and controlled in order to provide optimal crop conditions. The WSN application for precision agriculture would enable the users to receive data related to product growth and take appropriate management measures such as remote control for drip irrigation and fan facilities with the guidance of the expert system.

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