Wireless sensor networks for agriculture systems

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Abstract. This article describes the implementation of a wireless sensor network for monitoring the state of the environment in greenhouses. A distinctive feature of the work is low power consumption, low cost and the ability to monitor the entire history of measurements in real-time.

1. Introduction

Low values of a provision of vegetables with closed soil in Russia confirm the urgent need to create new-generation greenhouses with improved characteristics in comparison with the current indicators. To date, the vast majority of greenhouses do not use automatic systems. It is worth noting that recently there is a growing demand for various solutions of local greenhouses, for example, growboxes. Growbox is a box-shaped structure specially equipped with light and ventilation to maintain the necessary microclimate to efficiently grow various plants at home (closed ground). The growers can be of various sizes, from 30 cm square and larger, depending on the size of the plants and the targets pursued by the grower. The main task of a properly equipped growbox is to maintain the necessary conditions for plant development. To achieve the creation of optimal conditions, two basic elements are used in the construction of the correct system - lighting and ventilation. The main advantage of using growbox is the possible use it in house and office.

2. Related Works

There are a lot of samples of realized different monitoring systems in agriculture. In this chapter is under papers describes achievements and results in this area. Progress in an Internet of Things (IoT) area is allowing us to use different sensors for measuring and monitoring the real situation on greenhouses. In this subsection described works about using Wireless Sensors Networks (WSN) and applying for different controlling via actuators.

The paper [1] describes Wireless Sensor Network for Greenhouse Climate Control in India. The workgroup used IEEE 802.15.4 protocol (ZigBee) for creating a network. Greenhouse divides into several grids, in each grid on two levels of high established sensors. These sensors can measure temperature, relative humidity, which allow calculation greenhouse crops’ vapor pressure deficit (VPD). In network was used periodic sampling with averaged delayed transmission (PSDT) data-acquisition and transmission algorithm with 15 minutes delay of transmitting. This fact allowed us to use as a power source only two batteries AA type (3V). Server collects data from sensors and manages actuators, which responding to climate control in greenhouse.

A workgroup from Malaysia [2] created Wireless Moisture Sensors Network for monitoring and automatical watering crops. Greenhouse was divided into two areas. Nodes include different sensors such as temperature, humidity and moisture. Connecting nodes realized by XBee protocol. All data was collecting in a general connector, which allows display it in a real-time mode via GSM Modem. The
main research focused on evaluating two methodologies of irrigation efficiency: automated and scheduled. Results of the experiment show that automatical watering is more efficient rather scheduled. Also, this method allows for reducing water consumption to 1500 ml per day per tree rather than scheduled irrigation.

A research group from Indonesia [3] worked with Wasp mote Agriculture Kit. It can get information in real-time about these types of measurements: Temperature, Humidity, Soil Moisture, Atmospheric Pressure. Results of getting measurements were displayed in Web-server which allows monitoring all data online via personal computer and mobile phone. The authors also used ZigBee protocol.

Gerard Rudolph Mendez, et al [4] used WSN802G module (Wi-Fi) to get data about soil humidity and temperature which collect in a central server. Zhenyu Liao [5] used ZigBee protocol to collect data in real-time about these types of measurements: temperature, humidity, soil's moisture, and solar irradiance. The paper [6] describes Wireless Sensor Network based on an optical sensor, which allows converting the induction of chlorophyll fluorescence into an electrical signal.

3. WSN Deployment

3.1. Description of testbeds

Practical implementation of the tasks, including the most important thing - obtaining values from real conditions, was carried out in two places: Skolkovo Institute of Science and Technology (Moscow, Russia) and Michurinsk State Agro University (Michurinsk, Tambov region, Russia). Experiments were conducted with growing tomatoes. Two mini-greenhouses were created in the Center of Data-Intensive Science and Engineering in Skoltech. The basis was a grow cub with a total area of 6 square meters, in which lighting systems were added together with a cooling system. In these greenhouses WSN was installed with two nodes sending the collected information to the server.

3.2. Hardware

What does WSN mean? Wireless sensor networks have developed a lot recently. Such networks, consisting of many miniaturized nodes equipped with a low-power transceiver, microprocessor and sensor, can link together global computer networks and the physical world. The concept of wireless sensor networks draws the attention of many scientists, research institutes and commercial organizations, which provided a large flow of scientific papers on this topic. A great interest in the study of such systems is due to the wide possibilities of using sensory networks. Wireless sensor networks, in particular, can be used to predict equipment failure in aerospace systems and building automation. Because of their ability to self-organization, autonomy and high fault tolerance, such networks are actively used in security systems and military applications. The successful application of wireless sensor networks in medicine for health monitoring is associated with the development of biological sensors compatible with integrated circuits of sensory nodes. But the most widespread wireless sensor networks have been in the field of monitoring the environment and living beings.

3.3. WSN Architecture

Ideas of the Internet of Things (IoT) currently are gaining popularity in all areas of our life. Also, it is confirmed in [7]. Wireless Sensor Networks (WSN) is the main part of IoT conception. It contains nodes with different types and numbers of sensors (e.g. temperature sensor, gas sensor, light sensor, etc), server to collecting data and transmitter/receiver to send/receive data (Figure 1). Also, WSN include protocols to exchange information between nodes and server. The most popular protocols for these applications are Wi-Fi (IEEE 802.11), XBee (IEEE 802.15.4) and Bluetooth Low Energy (IEEE 802.15.3). In our case, we used Wi-Fi protocol with transmit power - 0.77dBm.
We have installed three nodes on one platform, which sizes 3x30 meters. The distance between nodes is 15 meters. Every node has temperature, pressure, humidity, carbon dioxide concentration sensors. A more detailed description of each sensor are show in the next subsection. Nodes send information from sensors every 30 minutes via Wi-Fi module to the local server and ThingSpeak online storage, where we can observe data.

In our deployment we use WaspMote sensor nodes to create WSN. WaspMote is an open-source platform to create IoT projects. Based on Atmel ATMega microcontroller, it allows supporting a lot of applications. The main reason to use this platform was the low power consumption, autonomous work, modular architecture and useful and simple interface of IDE. A power supply is presented by three Li-Ion re-charging batteries AA- type. Voltage of this charge is 3.7V and the capacity is 6600 mAh. According to these parameters, our WSN can be named autonomous because we have not to use third-party power sources. With the current low power consumption of this power source, there is enough for 1 to 1.5 months of operation without recharging the batteries, which is an important factor in WSN.

Thanks to the power management functions available in the WaspMote platform, we can use it. The mode of operation of nodes in the case of power consumption consists of three parts: the sleep mode, the heating mode of the sensors and the mode of transferring the received values to the server. Consider these modes in detail. In the sleep mode, the current consumption of the nodes is the smallest and is 30 \( \mu \)A. In the sensor warm-up mode, the current is added from the current consumed by each sensor plus the current of the platform in sleep mode, which gives a total of 18 mA. In the data transfer mode, the current consumption is 351 mA.

The main part of the WSN are sensors - they provide information for further processing. As part of the writing of these theses, a tremendous effort was made to select, adjust and commission the necessary sensors. The following sensors are used in assembled devices:

- Temperature sensor,
- Pressure sensor,
- Humidity sensor,
- Carbon dioxide level sensor,
- Light sensor.

Figure 1. Typical WSN Architecture
3.4. Data Storage
We used two separate storage for data collection: ThingSpeak service and local server. ThingSpeak is a platform for projects built on the concept of "Internet of Things". This platform allows you to build applications based on data collected from sensors. The main features of ThingSpeak include data collection in real-time, data processing and visualization. This application not only allows you to send, store and access data but also provides various statistical methods for processing them. ThingSpeak is an open-source project. It is a platform and application for storing, processing and retrieving data from devices via HTTP protocol over the Internet or a local network. The basis of the platform is the channels into which data is sent for storage and visualization. Each channel includes 8 fields for any data type, 3 fields for the location (latitude, longitude, height), and 1 status field. When registering in ThingSpeak your channel, you can immediately send data to it, process it and access it with your applications. The channels support XML, JSON and CSV data formats. The data is sent to the ThingSpeak HTTP POST request.

4. Result and Discussion
Figure 2 shows a graph of temperature dependence in the greenhouse versus time. The frequency of receiving data from the sensors once in 30 minutes. The data is of a numeric format, the sample is represented by 819 values. Data were obtained from the BME280 sensor, part of the WSN.

Figure 3 shows a graph of humidity dependence in the greenhouse versus time. The frequency of receiving data from the sensors once in 30 minutes. The data is of a numeric format, the sample is represented by 819 values. Data were obtained from the BME280 sensor, part of the WSN.
Figure 4 shows a graph of carbon dioxide concentration dependence in the greenhouse versus time. The frequency of receiving data from the sensors once in 30 minutes. The data is of a numeric format, the sample is represented by 819 values. Data were obtained from the MH-Z19 and MH-Z14A sensors, parts of the WSN.

Figure 4. Carbon dioxide concentration

5. Future Work
In further work, we will optimize the light to control the growth rate of the plants. We will develop a machine learning model that can predict the cumulative square of leaves based on historical data. Using this model, we can empirically show that we can reduce the total amount of energy we use without significantly slowing growth.

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