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Study on wireless underground sensor networks for remote irrigation monitoring system

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Abstract

Wireless underground sensor networks (WUSN) has wide applications in environmental information monitoring. It plays a vital role in the handling and management of water resources for irrigation. Because it prevents radio interference, improves real-time acquisition of information and reduces energy consumptions. In this work, WUSN was used to collect soil temperature and moisture information of an irrigation system. The base station used the sensor nodes to collect the data in a particular area. All nodes in the networks were the same and energies were constrained. According to the schedule, WUSN nodes turn on or off their radio module to save energy. When the collected data was less than the threshold value, the base station would inform the controller perform a motor control action through setting the corresponding. In this paper, system used data fusion method for saving energy to send collected data to the base station. The testing showed that the system was successfully implemented on a real-time remote monitoring for irrigation. The result was a low cost, highly reliable and simple infrastructure for the collection of soil data over a distributed area in agricultural environments.

Keywords: *Wireless underground sensor networks, sensor nodes, remote motoring, irrigation*

1. Introduction

Irrigation is an essential component of crop production in many areas of the world. China has been following the traditional methods as an agricultural country in the aspect of irrigation. In the irrigation system, energy availability is one of the important factors . Wireless sensor networks (WSN) helped the farmers to save the money that usually spent on labor to do the watering and fertilizing, and also reduced the monitoring load [Fukatsu and Hirafuji,2005; Sebastia,2006; Agele *et. al.*, 2011; Kima *et. al.*, 2011; Considine *et. al.*, 2004]. It was possible to monitor and control the conditions in order to obtain maximum productivity from the farm. WUSN is a natural extension of the WSN phenomenon to the underground environment [Akyildiz *et. al.*, 2009; Sun and Akyildiz, 2008]. Automatic irrigation based on WUSN was done with the help of valves and pumps. The controller interpreted the data that given by the sensors. According to the need of soil, the controller turns on both the valve and motor. WUSN is an emerging technology that has a wide range of potential applications including the fields of intelligent irrigation, border patrol, sports field maintenance, and infrastructure monitoring. WUSN have several remarkable merits, such as concealment, ease of deployment, timeliness of data, reliability and coverage density [Akyildiz and Stuntebeck, 2006; Li *et. al.*, 2007; Zhao *et. al.*, 2012; Silva and Mehmet, 2010; Akyildiz *et. al.*, 2002; Xin and Mehmet, 2010].

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WUSN is a new research subject, at present, most existing solutions are wired. Those underground sensors that are wireless require above ground antennas and are only capable of direct communication with a centralized base station. WUSN devices are deployed completely below ground and do not require any wired connections [Akyildiz and Stuntebeck, 2006]. Wireless communication within a dense substance such as soil or rock is, however, significantly more challenging than through air.

Wireless underground sensor networks have been investigated in many contexts recently. The concept of WUSN and the challenges related to the underground wireless channel have been introduced in [Akyildiz and Stuntebeck, 2006]. In [Li and Wen, 2008], network system structure of wireless underground sensor networks system aiming at intelligent transportation system and maintenance of the near surface soil (such as golf courses, a football field) was designed. In the laboratory of [Bogena *et. al.*, 2009], wireless signal attenuation of ZigBee wireless transceiver module of the 2.44 GHz frequency was researched by using soil column in different soil types and the water content.

The remainder of the paper is organized as follows. We first provide an overview on proposed system. The materials for the experiments and the experimental methodology are described in Section 3. The experiment results for the collection of irrigation information using WUSN motes are presented in Section 4. Finally, the summary of the paper and its key contributions are discussed in Section 5.

2. Proposed System

With the help of highly accurate sensors, the remote monitoring system for irrigation become the more precise and automation system. The manpower requirement for farming is one of the major factors holding back the farmers, but, here, man power requirement is very less. The irrigation system is conducted with the help of sensors, solenoid valves and pump. The controller interpreted the data that given by the sensors. According to the need of soil, the controller activated the motor. The main objective of this paper is to provide a remote monitoring system for the wireless underground sensor networks used in an automated irrigation system.

In the system, WUSN nodes measure the level of soil the temperature and moisture. In the initializing of the network, the base station assigned address to node and each node had a unique address. When the base station required node to collect the soil temperature and moisture of a particular area, it could broadcast the sensor node deployed address. All the sensor nodes could receive this address, but only the addressed node made respond to this request through sending back the present the soil temperature and the moisture value of that region. After getting the value of the soil temperature and the moisture level, the base station compared them with the threshold value that were already stored in the database. If the measured value was less than the required value, the controller did the necessary actions. The data collected were sent through GPRS communication to remote control center to realize the remote monitoring. The structure of system is shown in Figure 1.

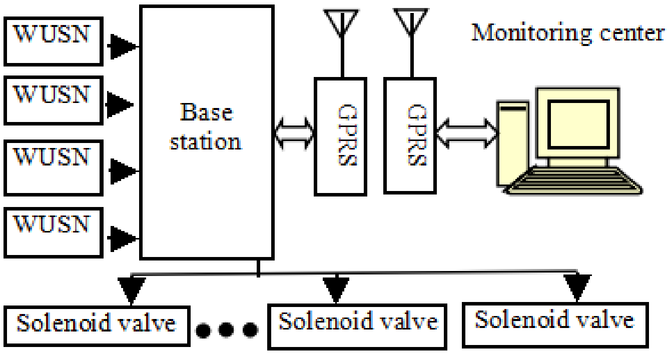


Figure 1. Structure of Remote Monitoring System for Irrigation

3. Materials and Methodology

Wireless node:

The block diagram of WUSN sensor node is shown in the Figure 2. The node's controller program correct and format sensor values and then output the results to the onboard transceiver device. In order to minimize the energy consumption, most time of the sensor node is in the receive mode. The measurement of sensor and data transmission occur whenever they are requested by the base station.

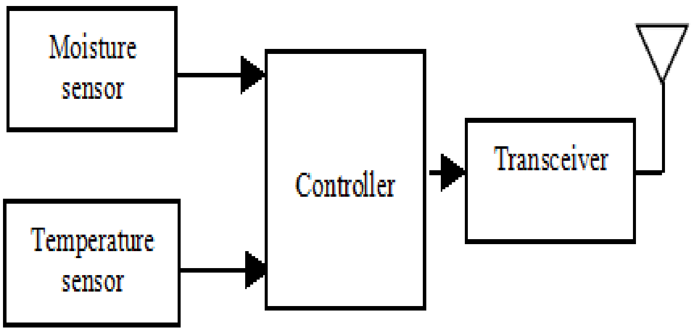


Figure 2. The Block Diagram of Sensor Node

In general, a lower frequency allows a longer transmission range and a stronger capability to penetrate through different materials. Furthermore, radio waves with higher frequencies are easier to scatter. To obtain a long effective transmission communication range with high penetration capability, 433MHz was selected as the communication frequency in this application.

Soil moisture and temperature sensor:

The soil moisture sensor is a high performance accurate sensor. The soil moisture sensor was used as a tool to optimize irrigation and warn plant stress at the dry or wet scale. The EC-5 soil moisture sensor from United States enables precise monitor soil water content. This sensor has been selected from the many commercially available products on the basis of its low cost and low-energy consumption [Bogena *et. al.*, 2007].

The DS18B20 temperature sensor is used that is produced by Dallas Company of the United States, which is one of the single line digital temperature sensors [Zhang *et. al.*, 2005], it has many advantages such as miniaturization, low power consumption, high performance, and strong anti-interference ability and is easy to match microprocessor, the sensor can make temperature directly convert serial digital signal which is processed by processor.

Solenoid valve and pump:

The solenoid valve is an electromechanical valve using liquid or gas. The solenoid valve is controlled by running or stopping electrical current through solenoid to change the state of the valve [Sudha *et. al.*, 2011]. Solenoid valves are the most frequently used control elements in fluidics. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

The pump is used to pump water from the water storage tank to the field. According to the instruction of controller, the pump conduct work so that it could pump the water whenever it is needed.

Base station:

The base station consists of a transceiver, processor, solenoid valve, pump and GPRS module. Here, the basic block diagram is shown in Figure 3. The System selects S3C2410 16/32-bit RISC embedded controller based on ARM920T kernel [Xia *et. al.*, 2004; Xie, 2006]. After getting the value of the soil moisture and the temperature level, the base station compares this value with the threshold value which is already stored in the database. If the measured value is less than the required value, the controller does the necessary actions. The same procedure is repeated for all the nodes.

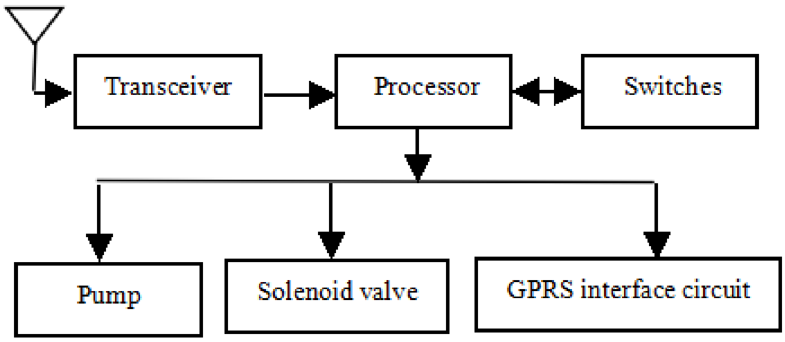


Figure 3. The Block Diagram of Base Station

GPRS module:

GPRS module uses the TC35I module that is launched by Siemens. The module is a new generation wireless communication GPRS module [Bates, 2004]. It brings RS232 communication interface, which can communicates conveniently with PC and single-chip microcomputer. TC35I can realize fast, safely and reliably data and voice transmission, short message service and fax.

4. Experimental Setup

The experiment was carried out in the irrigation test bed of northwest A & F University in yangling, shaanxi province, which is located at northern of yangling shaanxi, east longitude 108°5', north latitude 34°18', the average altitude of elevation is 480 m. The Test area is 100 square meters. During the test, 10 sensor nodes were placed inside the test bed at depth of 20 cm, and 10 sensor nodes were placed at depth of 40 cm. The sensor nodes were programmed to monitor the temperature and moisture of the soil every 30 min. The base station controlled solenoid valve and pump according to the value of the moisture and the temperature level. The remote monitoring center could get the information of irrigation at any time through GPRS communication.

5. Experiment Results

In the system, data sampling interval is set for 30 min in test for 20 WUSN nodes. The collecting data can be transmitted to remote monitoring center through base station. Figure 4 describes the soil temperature at depth 10 cm and 40 cm. We can conclude that the average temperature are 26.3 and 21℃, respectively. The soil moisture is shown in Figure 5. It can be seen that the soil moisture is higher at depth 40 cm.

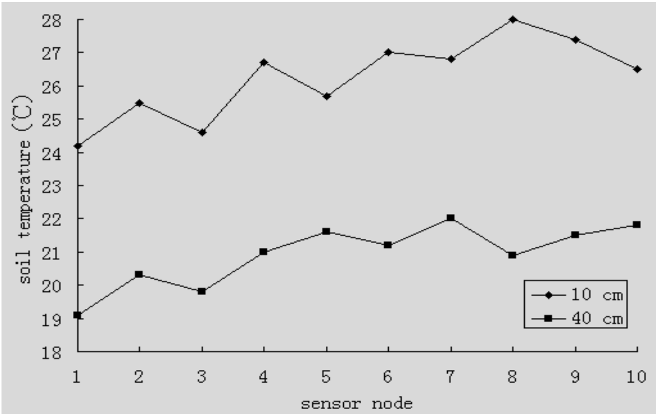


Figure 4. The Soil Temperature

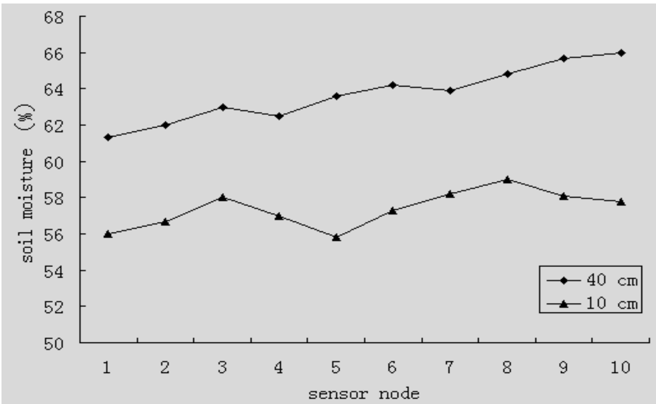
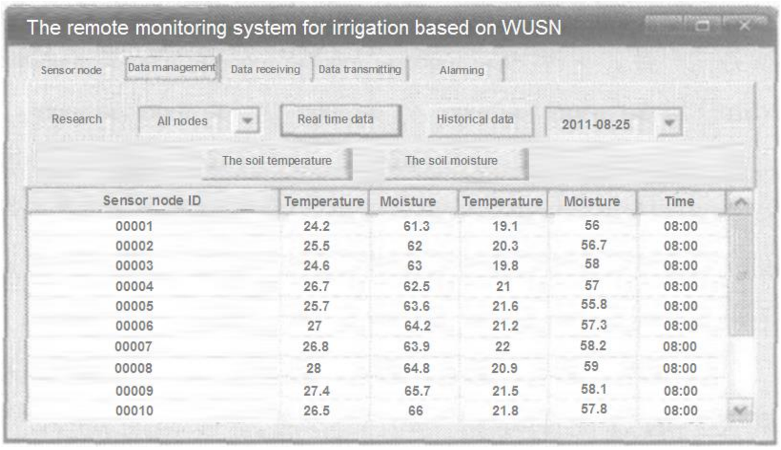


Figure 5. The Soil Moisture

Management software is installed at the remote monitoring center that can realize storage and display of data, statistical analysis, inquiry, alarm and printing, *etc*. Test shows that the remote irrigation system based on WUSN achieves the purpose of water-saving irrigation. Remote monitoring page of the system client and real-time display of monitoring data are shown in Figure 6, the system works well.

Before this technology was introduced, the farmers monitored their irrigation through the traditional way, which is a person visited the field to measure the relevant agronomic parameters with appropriate portable equipment. Now, modern technology has been developed, field information can be collected in real time. As a result, the water requirements of the crops can be estimated without anyone. The farm team could monitor in real time the optimum conditions for irrigation.



Sensor node ID	Temperature	Moisture	Temperature	Moisture	Time
00001	24.2	61.3	19.1	56	08:00
00002	25.5	62	20.3	56.7	08:00
00003	24.6	63	19.8	58	08:00
00004	26.7	62.5	21	57	08:00
00005	25.7	63.6	21.6	55.8	08:00
00006	27	64.2	21.2	57.3	08:00
00007	26.8	63.9	22	58.2	08:00
00008	28	64.8	20.9	59	08:00
00009	27.4	65.7	21.5	58.1	08:00
00010	26.5	66	21.8	57.8	08:00

Figure 6. Management Interface of System Data

6. Conclusions

Irrigation monitoring system is one of aspect the WUSN applications that has important benefits to the farmers. This research is a first step towards modeling based on underground in agriculture. Specifically, it proposed the application of wireless underground sensor networks in agriculture. According to the application requirement of farmland environmental information, wireless underground sensor network technology is researched. The underground sensor node and base station are developed combined with embedded processors, which realized real-time dynamic collection, transmission and store for the farmland soil information parameter.

The paper addresses a fundamental design issue in wireless underground sensor networks. It has designed a closed-loop remote monitoring system of distributed precision irrigation by using WUSN and ARM9 microprocessor and GPRS module.

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