A Wireless Sensor Network Prototype for Environmental Monitoring in Greenhouses

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Abstract—**Wireless sensor network technology is very suitable for distributed data collecting and monitoring in tough environments such as greenhouse or cropland. This paper presents a wireless sensor network prototype with two-part framework for greenhouses. In the first part, several sensor nodes were used to measure temperature, light and soil moisture. A sink node with embedded terminal based on ARM processor was installed indoor together for collecting and transferring data wirelessly to a remote PC using short message service. The other part consists of GSM module and the management software based on database running on the remote PC. Some experiments results including sensor data, radio propagation loss and radio range are also expounded in this paper.**

Keywords—Wireless Sensor Network; Environment Monitoring; Greenhouse; SMS

I. INTRODUCTION

Wireless sensor networks (WSN) could advance many scientific pursuits and provide an effective tool for application research as new information technology. Agriculture has just become a typical and significant application field among the wide range of WSN applications. More and more information technologies have been applied for data acquisition in greenhouse production such as different kind of sensors, field bus and wireless communication. In recent years, the apparition of wireless sensor networks has opened new perspectives in the topic of data acquisition. It could provide dynamic, real-time data of a landscape about monitored variables that would enable scientists to measure properties that have not previously been observed continuously.

While the WSN technology itself is still in discussion and development, some research groups and companies have found interest in it and began to work on the deployment and application in agriculture [1]. Most agricultural applications are involved the category of environmental and habitat monitoring. Camalie vineyard currently has an advanced soil moisture monitoring system named Camalie Net [2]. It uses twenty Mica2dot motes produced by Crossbow Inc. to establish the network. These motes were installed in 4.4-acre land to send data of temperature, soil moisture and soil temperature to a central computer once every 10 minutes. As a result, yield per vine in 2005 was doubled in contrast with that of last year. Solar powered wireless acquisition stations (SPWAS) were developed to collect outdoor and indoor climate data of greenhouse in Portugal [3]. These stations were connected in a mesh topology to a base station at a higher level, which supported several communication protocol, data gathering and management. Murat also presented INSIGHT (Internet-Sensor Integration for Habitat Monitoring) system and showed the experiment results in greenhouse [4]. INSIGHT system was an Internet accessible wireless sensor network for environmental monitoring.

The objective of this research is to design, develop and test a wireless sensor network prototype for environmental monitoring in greenhouses. After introducing related work of WSN in agriculture, this paper presents the system architecture in Section II. Section III discusses some experiments results. Finally concluding remarks on the paper are summarized in Section IV.

II. MATERIAL AND METHODS

A. System Architecture

The system could be described as a two-part framework shown in Figure 1. The first part is the sensor mesh network for data acquisition. The environmental parameters including temperature, humidity and soil moisture could be sensed by monitoring network. After acquisition, data is routed to a special sink node, which could gather the data and send them to the other part, remote management center based on GSM network.

B. Monitoring Network

1) Network Hardware

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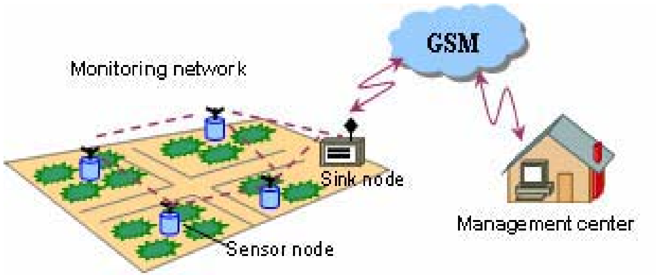

Figure 1 System Architecture

We selected popular products from Crossbow Company in order to make wireless sensor network technology understood sufficiently [5]. The components of network are shown in Table 1, which could be established a demo mesh network.

Table I Network components

Componet		Description
Sensor Node	MICAz	Mote module
	MDA300CA	Data acquisition board
	Echo20	Soil moisture sensor
Sink Node	MIB510	Serial interface board
	Terminal	A single board computer

a) Sensor Node

Each sensor node consists of MICAz mote, MDA300CA data acquisition board and Echo20 soil moisture sensor. The MICAz is a 2.4G, IEEE802.15.4 compliant, mote module used for enabling low-power wireless sensor networks. The MDA300CA is a multi-function data acquisition sensor board for sensing custom parameters. Besides its user interface, MDA300CA also provide on-board temperature and humidity sensors for environment monitoring. MICAz and MDA300CA are connected respectively through 51 pin connector. Decagon Echo20 is a soil moisture sensor that has been tested available for MDA300 board. Echo20 adaptor cable for connection contains three wires, which are connected excitation 2.5, single ended analog channel and GND respectively in MDA 300 board.

b) Sink node

The sink node is composed of a MIB510 board with MICAz and a data terminal. MIB510 provides an RS-232 serial interface for mote programming and data receiving. Here MIB510 is connected with the terminal for data aggregation.

The terminal is a single board computer developed for data displaying and delivering. There are two important reasons that a data terminal is designed in the monitoring network for greenhouse application. The first reason is that we have to view the current environmental parameters while daily management. Another reason is that agricultural facilities are always far from the farm office where the central PC using for data logging and processing is located. It is necessary for the sink node to realize long distance data transmission.

This terminal is designed based on S3C2410, an embedded ARM processor module. S3C2410 supports STN & TFT LCD, touch panel, Compact Flash and some standard communications ports. Siemens MC35i, a GSM module is integrated into the terminal by serial port. The terminal framework is shown as Figure 2.

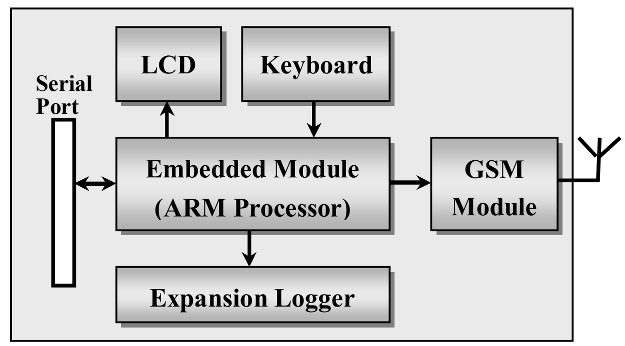

Figure 2 Terminal framework

2) Network Software

MICAz motes could be programmed with TinyOS, an open source, object-oriented, event-driven operating system developed by the UC Berkeley [6]. These sensor nodes were programmed with TinyOS before deployment according to application requirement. Each sensor node was programmed to perform time-triggered sampling of their sensors and data transmission. Every 5 minutes the sensor nodes took a temperature reading, a humidity reading and a soil moisture reading, then transmitted a packet containing the sensor readings to the sink node. The sensor nodes were programmed to be in a sleep state while not sensing or communicating.

C. Management Center

The management center includes a GSM module for receiving data from monitoring network and a central PC for data logging and analysis.

1) Communication Protocol

The SMS (Short Message Service) communication can be utilized for long-distance data delivering. The inexpensive communication method could meet requirements perfectly in our application because of limited data length. Each short message usually supports about 140 bytes at most. Firstly, we define the protocol of data sentence including environmental parameters collected every time. Then the length of each data sentence is computed to determine how many data sentences could be included in each transferring short message in order to reduce communication cost. AT command set is used for receiving and sending short messages. Continued monitoring data could be sent from sink node to management center at regular intervals based on GSM public mobile network.

2) Management Software

The management software running on the central PC is developed based on database in Microsoft Visual C++6.0 IDE. It includes three modules:

a) Data receive

The short message is received from serial port and parsed into different data fields according to custom data protocol.

b) Data log

These data are written into corresponding fields representing environmental parameters in the table of database respectively.

c) Data display

Historical data are read from database to creating different types of charts or curves, which makes it clear and easy for the administrator to comprehend and analyze sensors data monitored by the monitoring network.

III. RESULTS

In order to analyze and optimize system performance, we have conducted some rudimental experiments. This section will show some experiments results.

A. Sensors data

The monitoring network was installed in a greenhouse of our demo farm. Temporal and spatial variations in temperature, humidity and soil moisture are measured continually and sent to the central PC located in farm office. Figure 3 shows 8 hours of temperature data from two nodes. Node 2 is placed in the center and another node named Node 3 is near the window.

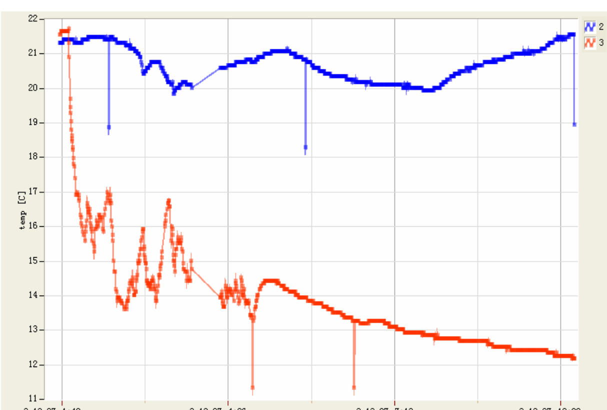

Figure 3 Temperature Readings from Two Nodes over 8 Hours

B. Radio Propagation

Since agricultural application is a non-static environment, the radio connection will change over time. The earth reflection and crop canopy could influence radio wave propagation.

As we known, radio propagation losses follow a complex model including transmission losses, path losses and antenna losses and so on. We could examine radio propagation losses using RSSI (Received Signal Strength Indicator) value, which is built in a radio chip. The RSSI readings are performed in decibels (dB). Figure 4 shows RSSI value over the distance between nodes in antenna height 25cm, 100cm, and 150cm. Received signal strength drops obviously within distance 10m. We also observe reliable and smooth communication between 10m and corresponding maximal radio range.

The proper antenna position is very important for

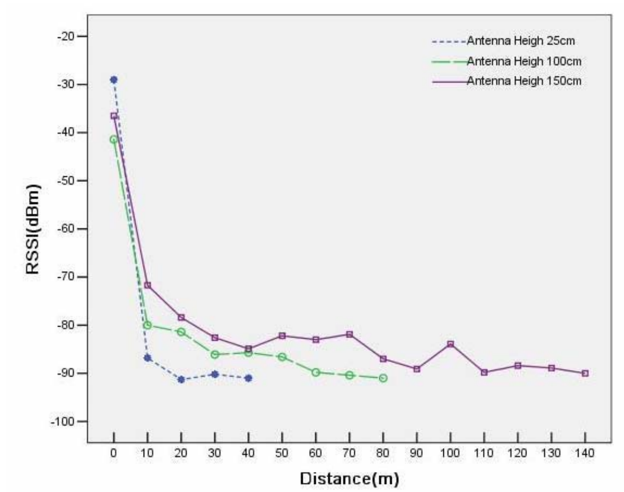

Figure 4 RSSI over distance in different antenna height

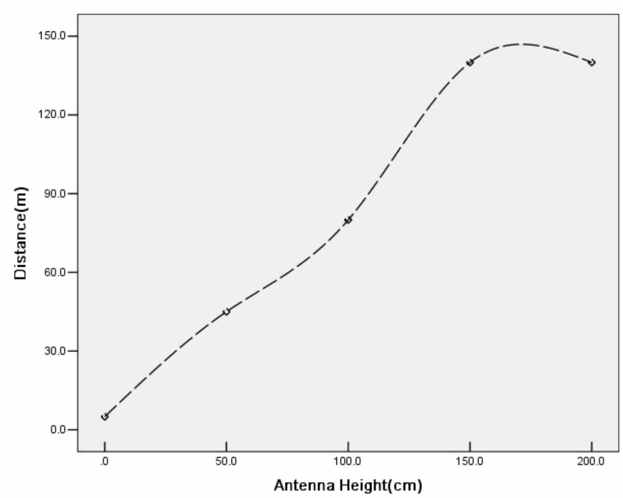

Figure5 Radio Range over Antenna Height

deployment. Figure 5 shows the results of radio range measurements over antenna height in bare field. It is necessary for us to test radio range in specific application.

Polarization losses are included in path losses because of physical misalignment between the transmit antenna and the receive antenna. Radio signal strength is compared in different T&R antenna orientation. The results are shown in Figure 6. Polarization losses occur obviously when antennas are 90 degrees, which cause minimum energy transfer.

These results of radio propagation experiments are helpful to determine the deployment strategy of sensor network.

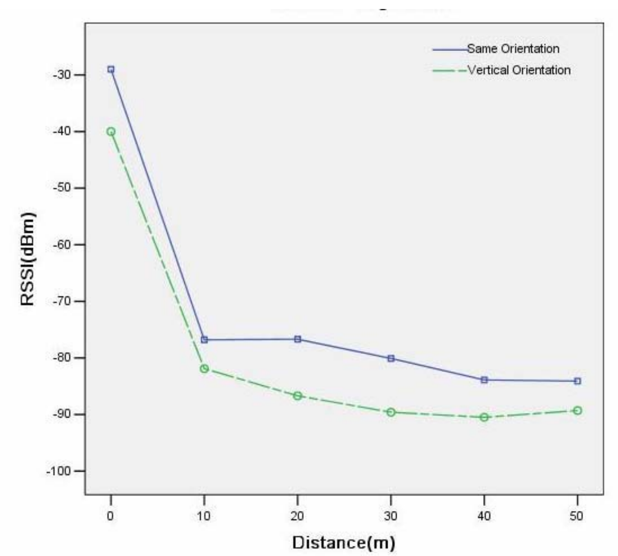

Figure 6 RSSI over distance in different T&R antenna orientation at height 50cm

IV. CONCLUSIONS

This paper reports on an agricultural application study of wireless sensor networks in greenhouses. The network prototype could meet the goal of providing real-time data on environment monitoring and remote querying. The SMS communication is proven an effective and economical solution for long distance transmission of limited data. In terms of application performance, the results of sensor data show the accuracy of continuous phenomenon reporting. In radio propagation experiments, antenna height and orientation significantly affects radio signal strength and radio range.

However, the current solution is expensive for agricultural application because each node is about $400. The sink node seems too complex due to limited compatibility of WSN products. Therefore future work will focus on design optimization and function improvement of the system.

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