Study on Precision Agriculture Monitoring Framework Based on WSN

Xuemei Li [1,2]
1. Institute of Built Environment and Control, Zhongkai Unviersity of Agriculture and Engineering
2. South China University of Technology
Guangzhou, China

Yuyan Deng, Lixing Ding
Institute of Built Environment and Control, Zhongkai Unviersity of Agriculture and Engineering
Guangzhou, China

Abstract— **The wireless sensor networks (WSN) is one of the most significant technologies in the 21st century. In recent years, achievements in micro-sensor technology and low-power electronics make WSN become into realities in applications. This paper describes a real-deployment of WSN based greenhouse management which is designed and implemented to realize modern precision agriculture. The proposed system can monitor the greenhouse environments, control greenhouse equipment, and provide various and convenient services to consumers with hand-held devices such as a PDA living a farming village. This paper discusses the advantages of using management strategy along wireless sensor-actor network technology for such cost-effective and environmental friendly greenhouse management.**

Keywords: wireless sensor networks, Precision Agriculture, monitoring and control system, management

I. INTRODUCTION

There is no doubt that the major factors maintaining the human existence and sustaining life on earth are food and water. While agriculture produces the vast majority of food, it faces many challenges, such as climate change, water shortages, labor shortages due to an aging urbanized population, and increased societal concern about issues such as animal welfare, food safety, and environmental impact. Humanity depends on agriculture and water for survival, so optimal, profitable, and sustainable use of our land and water resources is critical. At the same time, urbanization, developments of industry and overrun of fertilizer and pesticide also bring the river heavy pollution. How to protect, develop and make use of the water resource is an acknowledged problem.

An agricultural greenhouse can be considered as a man-made solution to emulate a suitable ecosystem in order to grow crops rapidly. In modern precision agriculture, greenhouses play an increasingly important role to meet the demand-driven economy. The primary issue of greenhouse is to manage the greenhouse environment optimally in order to comply with the economic and environmental requirements [1]. Although technological advancements offer innovative solutions for specific issues, achieving optimal management of overall greenhouse is generally difficult. Efficient control of the greenhouse environment requires an adaptive, accurate, and cost effective control system.

In the recent years, Wireless sensor networks (WSN), which integrate sensor technology, MEMS technology, wireless communication technology, embedded computing technology and distributed information management technology, has been under rapid development. Thus, it is expected that the WSN will be used commonly in applications in consumer electronics, PC peripherals, home automation, home security, personal healthcare, toys and games, industrial control and monitoring, asset and inventory tracking, intelligent agriculture, and so on [2]. Most of developments and experimental deployments of WSN are inclined to be achieved for citizen in towns. However, there're some researches to share the technology with people in a farming village [3~5]. Paper [3] reported the result of deployment in a vineyard. Considering placing the sensor nodes with fairly high precision, the researchers used a planned network rather than a network with ad-hoc routing. Therefore, WSN based greenhouse control system can be built using wireless sensor-actor network technology [6], which offers local processing and storage capabilities, wireless communication, and comes in highly portable sizes.

The rest of this paper is organized as follows. Section 2 describes the backgrounds and general requirements of the WSN based greenhouse management. Section 3 describes detailed system architecture that solves problems such as low-costs, self-organized, data gathering of water-saving and real-time processing. Finally, the paper concludes with a summary of our work and a statement of future work.

II. REQUIREMENTS OF WSN BASED GREENHOUSE

According to paper [6~8], research on the modern agriculture are becoming increasingly concentrated on monitoring and controlling the entire greenhouse yielding process. During the different growth period of vegetable, the requirements of humidity, temperature and illumination are also different, so we have to monitor the entire growth process. A typical greenhouse climate control system consists of several subsystems: lighting system, cooling system, heating system, carbon dioxide generation system, watering system and fertilization system. These systems will be activated based mainly on the temperature, relative humidity, light, wind speed and direction, and water level inside the greenhouse. The devices used to measure these quantities are referred as sensors. Given that greenhouses are considerably large in size and that a federation of greenhouses are possible, a network of sensors are therefore essential to monitor and govern a greenhouse management system.

The objective of climate control is to protect the crops from external climate that is harmful to the crops and to provide the climate that is favorable for the growth of crops. Since the artificial environment created by the greenhouse often favors the rapid development of pests and weeds, climate control and pest control need to be integrated suitably in order to achieve optimal control.

The requirements in the aspect of WSN based greenhouse system functions can be mainly summarized as the following points:

- Control systems such as climate control and pest control
  - ◇ Hardware – sensors, actors, connectors, interface boards, input and display panels, routers, computers, generators, transformers, etc.
  - ◇ Software – communication, data filter and fusion,
- The sensor node can join the network.
- All the sensor nodes and base station can self-organize the network.
- Data and information management system.
- The server can determine where the abnormal situation such as one index be out of rational range happens, and send an alarming message to the manager by some effective ways.

In addition, there are two performance requirements have to be noticed in the precision greenhouse monitoring system. One is the alarming time must be less than 5 minutes, and the other is the sensor network longevity must be longer than three months, and six months is optimal.

III. Overall Architecture of System Design

Any control system has two main set of components, namely, a sensor or monitoring component to collect data and an actuator component to perform specific actions as a response to the collected data. Now we describe the system architecture, functionality of individual components and how they collaborate together. WSN based greenhouse monitoring and control system consists of WSN, gateways, and a management sub-system. 14 sensor nodes, 1 actuator node, and 2 sink nodes are deployed in greenhouses and operated during severely cold climate condition of heavy snows and coldness last winter, shown in Fig. 1. WLAN APs with directional antennas provide the long range wireless link between WSN and the management sub-system which is about 0.5km far a way from greenhouses. The management subsystem with a DB-server and a web-server manage WSN and provide easy interface to farmers with handheld devices such as a PDA.

A. Node hardware

A-node is an Agriculture sensor node developed to be deployed in a greenhouse and to sense the environment of the greenhouse. The node is embedding a type of low power, low cost, IEEE 802.15.4 compliant wireless microcontroller JN5121 IEEE 802.15.4 compatible transceiver and sensors (ambient light sensor, temperature and humidity sensor) in one PCB to reduce possibilities of defects. A sensor node is equipped with a battery of lithium-ion rechargeable cells and monitors the voltage level of battery for maintenance purpose.

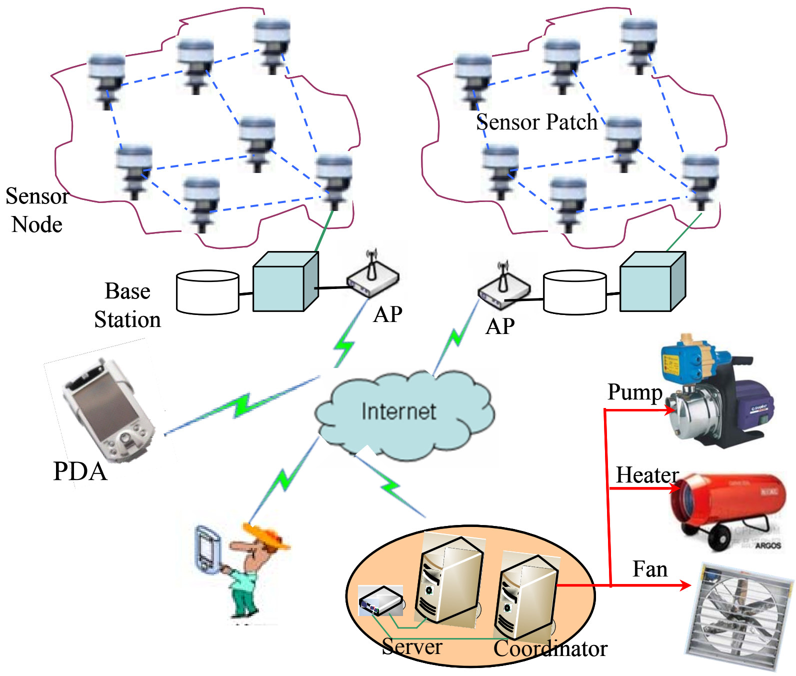

Fig.1 Overall architecture of WSN based greenhouse

The JN5121 Combining an on chip 32-bit RISC core, a fully compliant 2.4GHz IEEE802.15.4 transceiver, provides a versatile low cost solution for wireless sensor networking applications. The high level of integration helps to reduce the overall system cost. In particular, the ROM enables integration of point-to-point and mesh network stack protocols, and the RAM allows support of router and controller functions without the need for additional external memory. The JN5121 uses hardware MAC and highly secure AES encryption accelerators for low power and minimum processor overhead. Integrated sleep oscillator and power saving facilities are provided, giving low system power consumption. The device also incorporates a wide range of digital and analogue peripherals for the user to connect to their application [9].

B. Node Software Implementation

The node software has been developed, considering a node both as a single element, in charge of accomplishing prearranged tasks, and as part of a complex network, in which each component plays a crucial role in the network maintenance. As far as the former aspect is concerned, several TinyOS modules have been implemented, to manage high and low power states, to realize a finite state machine, querying sensors at fixed intervals, and to achieve anti-blocking procedures, allowing to avoid software failures or deadlocks and providing a robust stand alone system. On the other side, the node has to interact with neighbors and to provide adequate connectivity to carry the messages through the network, whatever the destination is. Consequently, additional modules have been developed, in charge of managing STAR MAC and Multihop protocols, according to a cross layer approach. Furthermore, other modules are responsible for handling and forwarding messages, coming from other nodes or gateway itself. As a result, a full interaction between the final user and the WSN is guaranteed.

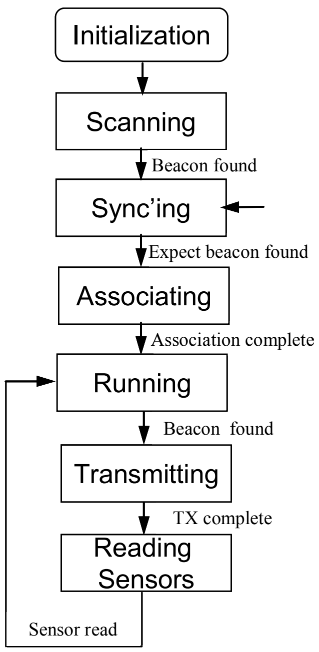

Fig.2 The flow chart of node software

C. Gateway & Management sub-system

The gateway transforms data over RS-232 from a sink to data over TCP/IP to server and vise versa. The gateway is implemented on a Pentium-M 1.6GHz based industrial PC. The gateway is connected to AP via WLAN link or wired ethernet link. The AP is connected to the management sub-system in the distance of 0.5km via WLAN link.

The management sub-system has a DB server, an application server, and a web-server. The application server receives data from WSN and stores them in the DB server and provides the way to configure the WSNs. The schedule of sensing is configured by the application server. The whole sensing data are stored in the DB server and can be accessed by users (PC or PDA) via the web-server.

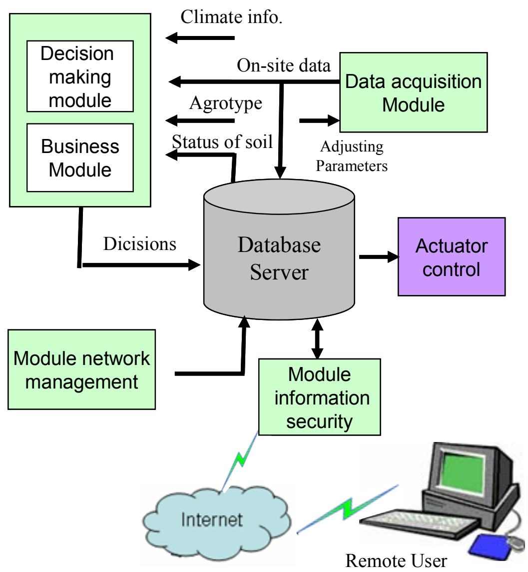

Fig.3 Software Architecture of WSN based greenhouse management

WSN based greenhouse management is composed of six modules: WSNs data acquisition module, WSNs management module, business module, decision-making module and information issuance module. Fig.3 shows the basic framework, information flows and collaborating relations. WSNs data acquisition module is the data source of the whole software, which includes information apperceiving, data package, multi-hop routing, clock spring, message management, conflict management, and so on

D. Remote User Interface

The remote server stores, processes and presents the information gathered by the WSN. Data are not only sensing (measures, battery level) but also control and management messages (synchronization, node-reset). Final user might check the system status by means of a graphical user interface (GUI) accessible via web1. After the log-in phase, the user is able to select the proper pilot site. For each site the deployed WSN together with the gateway is schematically represented through an interactive map. In addition to this, for each node the related sensors are shown to display individual or aggregate time diagrams with a adjustable time interval for the observation. The system monitoring could be performed both at a high level with a user friendly GUI and at a low level by means of message logging.

IV. CONCLUSIONS

In this paper, we proposed real-deployment of WSN based greenhouse management which is designed and implemented to realize modern precision agriculture. Characteristics of sensor node such as low energy wastage, short communication range and self-organized combine with the need for predictable operation guide us the application architecture and services. From the sensor node hardware to the management system, the whole system architecture is explained. Users can tailor the motes operation to a variety of experimental setups, which will allow scientists to reliably collect data from locations previously unaccessible on a micro-measurement scale. Such a system can be easily installed and maintained. After several months' test, the system has been working normally and shows its competent abilities on modern precision agriculture.

ACKNOWLEDGMENT

This work is supported by Guangdong Sci. & Tech. Plan with No. 2007B080701002.

REFERENCES

[1] N. Wang, N.Q. Zhang, M.H. Wang, Wireless sensors in agriculture and food industry-Rencent development and future perspective, Computers and Electronics in Agriculture, Vol. 50, No.1, pp. 1-14, January 2006.

[2] Jose A. Gutierrez, Ed. Callaway, and Raymond. Barrett, Low-Rate Wireless Personal Area Networks: enabling wireless sensors with IEEE 802.15.4, IEEE Press, 2004

[3] R. Beckwith. D. Teibel, and P. Bowen Jones, Report from the Field: Results from an Agricultrual Wireless Sensor Network, proceedings of 29th IEEE LCN'04, Tampa, Florida, November 15-17, 2004

[4] A. Baggio, Wireless sensor networks in precision agriculture, proceedings of REALWSN'05, Stockholm, Jun 20-21, 2005

[5] K. Langendoen, A. Baggio, O. Visser, Murphy Loves Potatoes: Experiences from a Pilot Sensor Network Deployment in Precision Agriculture, 14th Int. Workshop on Parallel and Distributed Real-Time Systems (WPDRTS), Rhodes, Greece, April, 2006

[6]V. Lakshmi Narasimhan, Alex A. Arvind, and Ken Bever, Greenhouse Asset Management Using Wireless Sensor-Actor Networks, Proceeding of Int. Conf. on Mobile Ubiquitous Computing, Systems, Services and Technologies, pp:9~14, 2007

[7] H.Q. Luo, X. Zhang, E. Liu, X.J. Qiao, Y.H. Zhang, "The Design of Wireless Sensor in Greenhouse Environment Measurement". Sensor World, Vol. 12, No.5, pp. 45-48, 2006.

[8]Wang Yang, Huang Liusheng, Wu Junmin, Xu Hongli, Wireless Sensor Networks for Intensive Irrigated Agriculture, Proceeding of Int. Conf. on Consumer Communications and Networking, pp: 197-201, Jan. 2007

[9] Datasheet: JN5121.