The Realization of Precision Agriculture Monitoring System Based on Wireless Sensor Network

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***Abstract*-Based on the analysis of the development of agricultural mechanization, the trend of agricultural service system reform, agricultural environment protection and the development of information technology, it is possible to realize the precision agriculture. This paper designs the agricultural environmental monitoring system based on the wireless sensor network (WSN). The system can real-timely monitor agriculture environmental information, such as the temperature, humidity, and light intensity. This paper introduces the theory of the monitoring system, and discusses the aspect of hardware and software design of the composed modules, network topology, network communication protocol and the present challenges. Experiments show that the node can achieve agricultural environmental information collection and transmission. The system has the feature of compact in frame, light in weight, steady in performance and facilitated in operation. It greatly improves the agricultural production efficiency and automatic level drastically.**

Index Terms-precision agriculture, environment monitoring, data acquisition, the network protocol

I. INTRODUCTION

In the agricultural information developments, the information collection technology is indispensable to agricultural scientific research administration. The low-cost and high-intelligent equipments are used in the fields to improve the traditional agriculture. Precision agriculture is a management philosophy or approach to the farm and is not a definable prescriptive system. It identifies the critical factors where the yield is limited by controllable factors, and determines intrinsic spatial variability [1]. It is essentially more precise farm management made possible by modern technology. The variations occurring in crop or soil properties within a field are noted, mapped and then management actions are taken as a consequence of continued assessment of the spatial variability within that field. Conventional agriculture is practiced for uniform application of fertilizer, herbicide, insecticides, fungicides and irrigation, without considering spatial variability. To alleviate the ill-effects of over and under usage of inputs, the new concept of precision agriculture has emerged [2]. Site specific management to spatial variability of farm is developed to maximize crop production and to minimize environmental pollution and degradation. It leads to sustainable development. Spatially variable crop production to a large extent is technology-driven. The new tools applicable to precision agriculture are the advances in electronics and computers such as RS, GPS and GIS. The technology covers three aspects such as data collection, analysis or processing of recorded information and recommendations based on available information.

In the coming years, it is expected that the Wireless Sensor Network (WSN) will be used commonly in applications in consumer electronics, personal healthcare, toys and games, industrial control and monitoring, agriculture, etc. Considering the site of the sensor nodes with fairly high precision, the researchers use a planned network rather than a network with ad-hoc routing. WSN provides route diversity and multiple transmissions [3]. The authors demonstrate some of the value that a wireless sensor network might deliver to an agricultural setting. The total cost of ownership of a wireless network is lower than a wired network. The authors described a precision agriculture architecture based on WSN. They deployed a large-scale sensor network and acquired valuable experiences. The paper is very useful references for WSN applications in the intelligent agriculture field. However, they have a little bit weak points. They can gather the environmental information, but they are weak to control the environment of the field. The contributions of this paper are summarized as follows. The system architecture of the agriculture system is presented from the sensor node hardware in the bottom to management sub-system in the top and is evaluated in the real-deployment. The way to control the environment using the feedback from the gathered information is described in the paper. The paper gives the experiences of a real deployment in fields and the ideas to improve the system.

II. THE DESIGN OF THE AGRICULTURE SYSTEM BASED ON WIRELESS SENSOR NETWORKS

The architecture of the precision agriculture system based on wireless sensor networks consists of the environmental monitoring nodes, base stations, communications systems, Internet access and the structure of monitoring hardware and software system. From Fig.1, it proposes a novel network structure which increase system scalability [4]. According to different functions, a large number of the different sensors can be placed in the field and constructed a self-organized network to monitor the value change including temperature, humidity, atmosphere, precipitation and soil PH value, etc. The collection data is send to the sink by wireless mode. The control center can send the control information to any node in

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the network. Likewise, the remote data could be transmitted to the control center with the sink. The system adopts the cluster topology and hierarchical routing protocols. All sensor nodes are divided to some cluster. Each cluster is equivalent to a relatively fixed self-organizing network. The nodes are divided into the common node and cluster-head node. The common nodes will collect the data which transmitted to the cluster-head node. The data is stored to the database. Expert decision support system processes and analyzes the data at the same time.

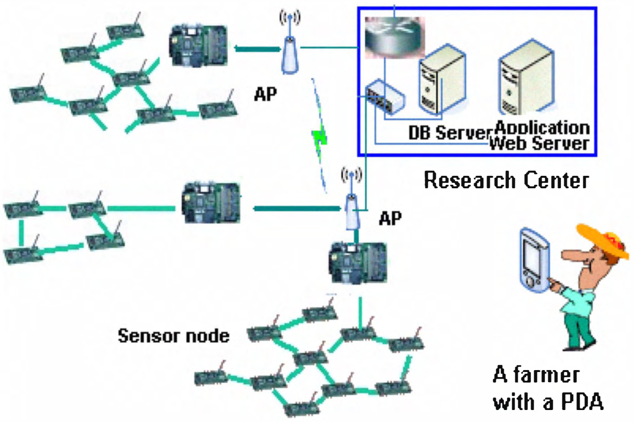

Fig.1 The system architecture

A. The Hardware Design of Sensor Nodes

Sensor node is the basic platform of wireless sensor networks. The sensor is made up of four parts, sensor node module, the processing module, wireless communication module and the power module. Sensor module is responsible for collecting temperature, humidity, light intensity and other parameters and data conversion module. The processor module controls the operation of the sensor nodes, stores and processes the collected data. Wireless communication module communicates with other nodes, exchanges control information and sends and receive data. The power modular provides the energy to the sensor module, processing module and wireless communication module. The hardware structure of the node is shown in Fig.2.

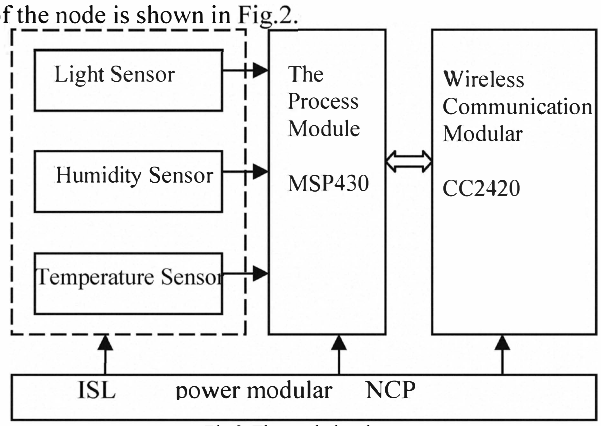

Fig.2 The node hardware structure

B. The Hardware Design of Cluster-head Nodes

The cluster-head node acquires the environment information itself. It receives signals from other sensor nodes, integrates and stores the data automatically [5]. In Fig.3, the hardware of the cluster-head node can be divided into moisture sensor, A/D converter module, wireless communication module, LCD modules, and data storage and power supplies. The cluster-head nodes sends sensor signal to the signal processing circuit .After A/D conversion, the data will be transmitted to microprocessor and sorted [6]. If the cluster-head node sends the query to the nodes in the self-organized network, the relative node will return the data to the cluster-head node. The cluster-head node receives the data of each node which will be automatically stored in regular USB devices, and it can display relevant information in the LCD screen.

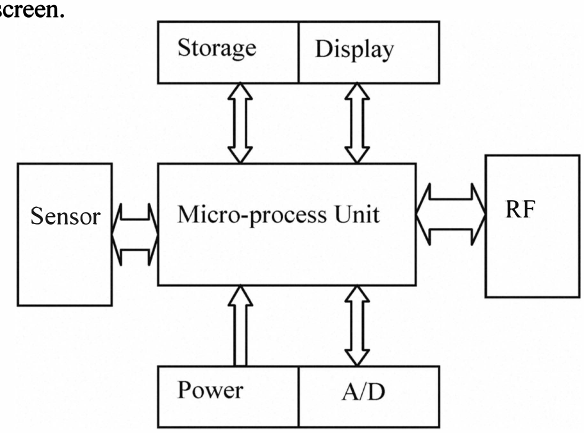

Fig.3 The structure of the cluster-head node

C. Remote Control System

Remote control system completes the real-time information processing through the Internet network access systems, remote monitoring center and the interface display control management system. The system have the real-time information processing functions ,such as a display measured parameters, data reporting, curve display, graph generation, data storage, fault statistics and statements, reports and printing[7]. System can achieve network connectivity with TCP/IP and communicate between the terminal node and central station. The data analysis and evaluation in system provides quality assessment for the agricultural environment.

III. THE DESIGN OF SYSTEM SOFTWARE

A. The Software Architecture

The software architecture of sensor node is divided into embedded OS kernel layer and API layer. Embedded module provides tasks, power management and communication protocol [7]. The kernel also provides a low-level node driver of all hardware devices. API layer provides sensor acquisition module and RF communication module. The software architecture of sensor node is shown in Fig.4. Task debugging module controls the control flow throughout the operating system, which is mainly responsible for the initialization of the wireless sensor and the maintenance of the operating status. The power management module supports processor, RF transceiver, sensors and other parts of the state control of energy consumption [8]. Energy management is able to ensure that nodes wake up at the right time, run in the low-power mode and maximize the use of energy.

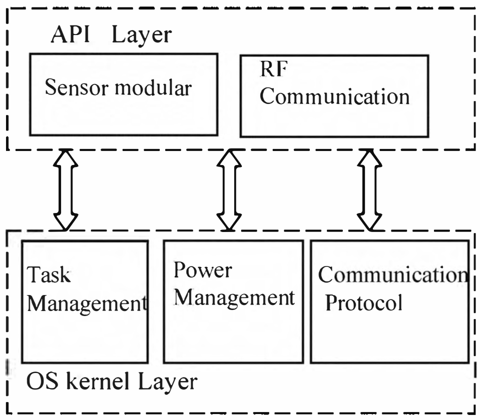

Fig 4. The software architecture of the sensor node

B. The Function of WSN Protocol

Wireless network communication protocol provides the wireless communication standards between the cluster-head nodes and nodes [9]. It achieves registration, sleep the node, data acquisition, device controller, parameter settings and debugging.

1) Registration. When the nodes work on, the node registers MAC to the cluster-head node and accesses to the network subnet number. It is assigned to a child node ID.

2) The Node Sleep. The cluster-head node sends a data packet to notify the next node sleep time.

3) Data Collection. According to testing requirements, the cluster-head node assigns the task of data collection, such as temperature, humidity, light intensity and gas concentration.

4) Equipment Control. The cluster-head node analyzes the data and makes decision. The packet of control instructions is sent to the node.

5) Parameter Settings. The cluster-head node sends the modified equipment parameters to the child nodes.

6) Debugging. It is the equipment development and debugging functions.

C. Wireless Sensor Network Protocol Stack

Software component is the gateway and sensor nodes. The function of gateway software is processing and management data from sensor nodes [10]. It mainly consists of the serial port communications software, RF communications software, command software and task management software. The operating system is TinyOS. The software of sensor node is to receive the instruction from the cluster-head node and send the data to the sensor gateway [11]. In Fig.5, the wireless sensor network protocol stack consists of the physical layer, medium access control layer, network layer and other components. Application interface provide a simple software interface including the application sub-layer and device object, so the application layer achieves the management of the equipment.

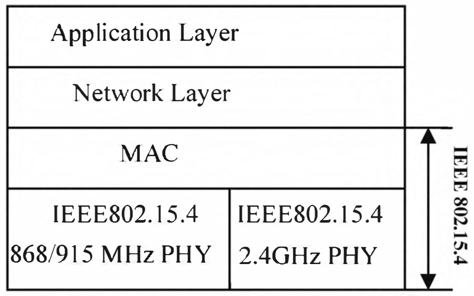

Fig.5 The protocol stack architecture

The function of the child node is relatively simple. It does not require complex data processing. The interface peripherals are relatively small. Node data transfer flow is shown in Fig.6.

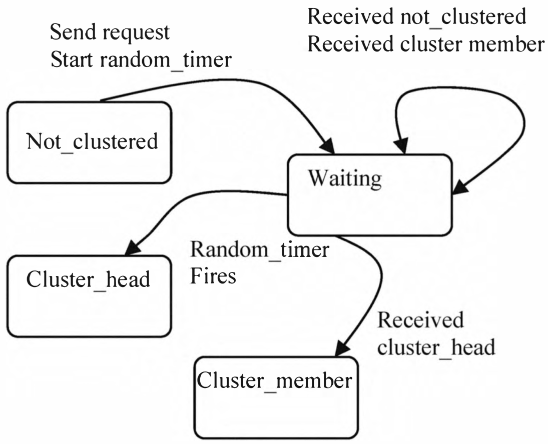

Fig.6 The node data transfer flow

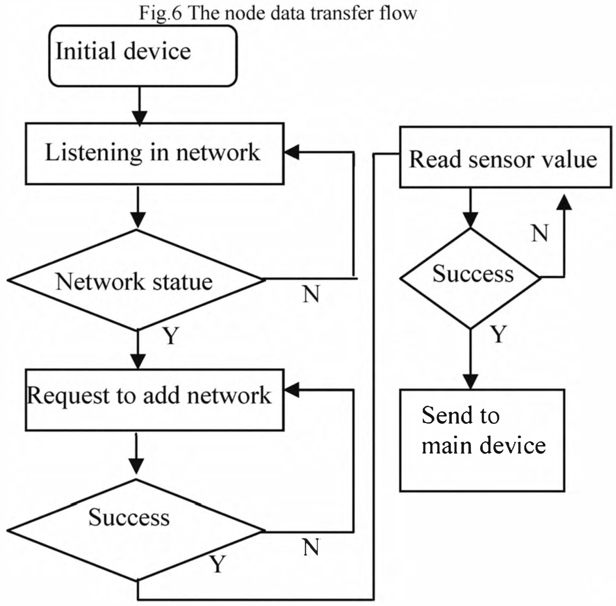

Fig.7 Flowchart diagram of host device control

Cluster-head node is the center of the entire system, all cluster-member nodes in the cluster nodes work smoothly under the management of cluster-head node. After the cluster-head node completes the network connection, it receives the data from each node and sends data via serial port to the embedded module [12]. The processed data is sent to a remote control center through the network in Fig.7.

IV. Prospect and Challenge

In the agricultural monitoring system, all nodes always work under the adverse environmental condition, so they are different from the design of the traditional sensor network. Due to a larger monitoring area of agricultural production, the sensor network has a large number of nodes while it ensures the cost of the network. The nodes will be scattered in various regions to achieve a comprehensive monitoring on agricultural field. Because the sensor node energy is limited, the possibility of node failure is very large. The monitoring system must solve the reliability problem. The lifetime of WSN depends on the failure of the sensor node. In short, the agricultural monitoring system must solve the following problem:

A. The Large-scale High-density Network Structure

The requirement of monitoring material movement in geographical space is intrinsic motivation of the sensor networks. Compared with the traditional mode base on radar or satellite, WSN has some unique technical advantages on a distributed multi-dimensional and multi-angle information processing [13]. It can significantly improve the signal noise ratio, reduce the possible exploration in the region, and eliminate shadows and blind spots. The network nodes must be a large-scale, high-density deployment method to keep monitoring the area coverage and connectivity [14]. A large number of nodes in the network will inevitably increase the cost which will affect the network in the practical application. The premise of agriculture application is to design an available and economic deployment mechanism for WSN.

B. Data Processing and Node Energy

Communication is the maximal energy consumption. Each node has data independent processing ability. It reduces network transmission cost by processing and extracting the original data. A well-designed network networking, data transfer and data integration algorithms are important to the lifetime of the network.

C. The Network Redundancy and Tolerance

The validity and accuracy of data in agricultural monitoring system is very important. The optimization of node distribution is studied to reduce the energy consumption and ensure the effective information acquisition in wireless sensor network. Network fault tolerance includes node failure detection and failure recovery. Node failure needs to locate. If each node has the portable GPS devices, it will inevitably increase the cost of the entire network. How to balance between the costs of network configuration and node failure detection is a problem to be solved. Node failure recovery adopts the replacement of the general failure of redundant nodes, but it needs to design the number and the location of redundant nodes.

V. Conclusion

This paper has described the design and implementation of a novel wireless sensor network for monitoring agricultural environment and evaluated the reactivity, robustness and longevity of the network in the field. Compared with the traditional agriculture, the system greatly improves agricultural production efficiency. In future, agriculture will face formidable challenges to provide adequate nutrition for people. Therefore, it is the right time to take decisions, how to increase agricultural productivity, as the developing countries have the lowest productivity for most of the food crops. It is obvious that the latest tools of science and technology are applied for sustainable and equitable distribution of natural resources. The new technology may be able to harness several possibilities in managing the farm sector precisely. Future work will focus on addressing the limitations of the current prototype in robustness of packet delivery and network longevity, and in guaranteeing network response to events of interest. We also plan to generalize our event-condition-action framework for programming reactive sensor networks.

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