Research and Implementation of Agricultural Environment Monitoring based on Internet of Things

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***Abstract*—The research of this paper emphases on the following contents: according to the investigation of field condition monitoring system in practical application scene, based on EPC framework, systematic network framework is designed and perception layer of ZigBee sensing node is also designed. The sensing node should real-timely collect multiple important environment information which is related to agricultural production and perform controllable image acquisition on crop form. Then, various data are sent to Web server through gateway by means of wireless communication module to design Web server at application layer. Experimental tests show that the system prototype can accurately collect the field environment information. In addition, the data can be stored in agricultural environment monitoring center server. Remote user on internet can access server, coordinator and gateway through web browser, control the whole system, browse and download data. This system basically realizes low-energy-consumption as well as extensible design target and it can satisfy modern agricultural environment monitoring requirement.**

Keywords-Things; agricultural environment; monitoring platform; sensor nodes; ZigBee

I. INTRODUCTION

With the development of agricultural things technology, overall field environment monitoring technology which combines sensing technology and things has been rapidly developed. Currently, most wireless environment monitoring networks are based on trunking communication system, GSM short message and CDMA/GPRS technology, etc. They have disadvantages including high cost of network construction, low access rate in public network, complex operation, small network covering range and difficult information sharing. They influence popularity and promotion of field environment monitoring network on modern agricultural production to some extent.

Foreign scholars are early to study agricultural things and field environment monitoring. Represented by European and American nations, they collect more information technology and large-scaled agricultural production. At present, on agricultural information network construction, agricultural information technology development, agricultural information resources utilization, etc, they apply 5S technologies, environment monitoring system, meteorological and pests monitoring warning system, etc, to perform fine management as well as control of crop production, save human resources, improve resources utilization rate and acquire great achievements. Many domestic research institutions and universities have done a lot of work on studying agricultural things and achieved some developments. Some companies have corresponding products. Although these products can realize accurate collection of data, they have some disadvantages: for single perception node, they have problems such as single function, short work time, working environment limitation, etc; For network architecture, they only complete data monitoring task in one production base and they are difficult to realize network coverage in provincial or even in national scope; for information publishing and sharing, monitoring data can only be browsed by host and data sharing ability needs to be further improved.

This paper is based on the requirements of low cost, low power, large area, multi-parameter, multi-location and high access rates in field environment monitoring network to study an agricultural things framework-based field environment monitoring system. It can realize air temperature, humidity, soil moisture, CO2 density, light intensity, ph values in water environment in multiple locations and multi-parameter real-time online monitoring of crop growth pattern. The main studies in this paper include (1) Designing a physical structure in field environment monitoring system corresponding to agricultural PSC framework which supports ZigBee network, 3G mobile communication network and TCP/IP network connection. (2) Designing ZigBee perception node in perception layer can realize synthetic collection of multi parameters. (3) Designing embedded coordinator gateway based on ARM9 microprocessor platform and embedded Web server supports accessing control of remote client on coordinator gateway; (4) Designing agricultural environment monitoring center server which has data storage and control function supports users' web page browsing and data downloading.

II. PHYSICAL STRUCTURE IN AGRICULTURAL ENVIRONMENT MONITORING SYSTEM

A. Requirement Analysis

The field environment monitoring system of things has the following features:

- It needs advance on performance which can realize monitoring of multi-parameter in multiple locations.
- Multiple locations refer that perception nodes can be arranged in many needed monitoring areas and perform data collection in united coordination.
- Multi-parameter refers that single node can acquire many environmental parameters at the same time so as to fully understand field information of agriculture.
- Information sharing should satisfy information accessing requirements of agricultural experts, agricultural

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technicians and common farmers in any place and at any time to guide and implement agricultural production with scientific strategies.

- Structural design requires low cost, high efficiency, effective stability and extensibility.
- Cost is an important factor to restrict popularity and promotion of agricultural environmental system. Efficient data processing ability and working stability are preconditions for system to be broadly applied. System should apply modular design to promote system to be updated. In many application situations, it can be performed simple installation to satisfy different requirements.
- On operability, users' threshold should be reduced since working farmers do not have enough knowledge.
- Each step should be simple and feasible to improve the users' systematic enthusiasm from installation, management and maintenance to users' utilization.

B. Network Architecture

The agricultural environment monitoring system organically integrates wireless server network, internet and 3G network. The whole system consists of three parts: perception layer, network construction layer and application layer. Perception layer is made up by several perception nodes and boards multi-parameter sensing array to acquire field information. Network construction layer equipment is the coordinator gateway which contains ZigBee coordinator module, 3G module and Ethernet module. The agricultural environment monitoring center in application layer is made up by SQL database and Web server to be responsible for data storage and information publishing. The systematic working process is that most perception nodes accumulate collected data or locale images to coordinator gateway. The coordinator gateway transmits data to remote agricultural environment monitoring center to store. Agricultural environment monitoring center server displays environment evolution in historical data or curve form. Users and managers can access and inquire environmental parameters through cell-phone, PC or other intelligent terminals and control perception nodes as well as coordinator gateway.

Wireless sensor network adopts ZigBee protocol and designs field environment monitoring network as tree structure and divides nodes in network into three types: perception nodes, route nodes and coordinator nodes. Perception nodes and route nodes are marked in figure one. Coordinator nodes are integrated on coordinator gateway. Perception nodes are reduced function device and there are several perception nodes in environment monitoring network which is responsible for parameter collection and transmission. Route node is the bridge between sensor node and coordinator node. When coordinator node is far from sensor node, it is responsible for transmitting data. There is only one coordinator node and it is the full function device, FFD, which is responsible for constructing and controlling sensor network. Meanwhile, it collects data from perception nodes.

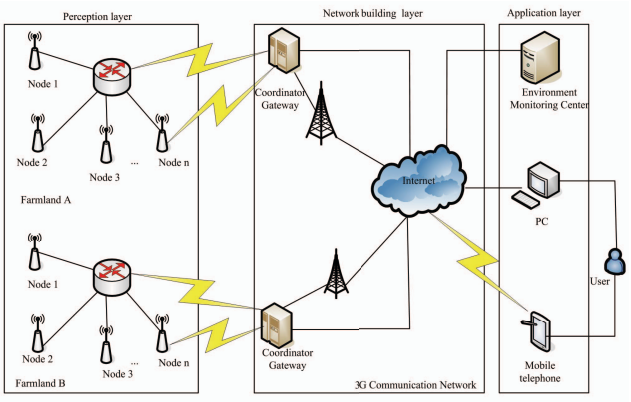

Figure 1. Network topology of environment monitoring system

C. Perception Nodes Deployment

For the agricultural production, the most important environmental parameters contain environmental temperature/humidity, light intensity, soil nutrient, water quality and CO2 density. Meanwhile, locale image can help users to understand field locale information in a more visual way. Therefore, perception nodes which are designed in this paper are shown in figure 2. They are made up of micro controller platform, wireless communication module, intelligent power module, monitoring module of battery electric quantity, status indication module and the sensor array of air temperature/humidity sensor, light sensor, CO2 density sensor, soil humidity sensor, pH value sensor and camera. Its main function is to collect environmental parameters information and accumulate data into coordinator gateway through wireless communication module.

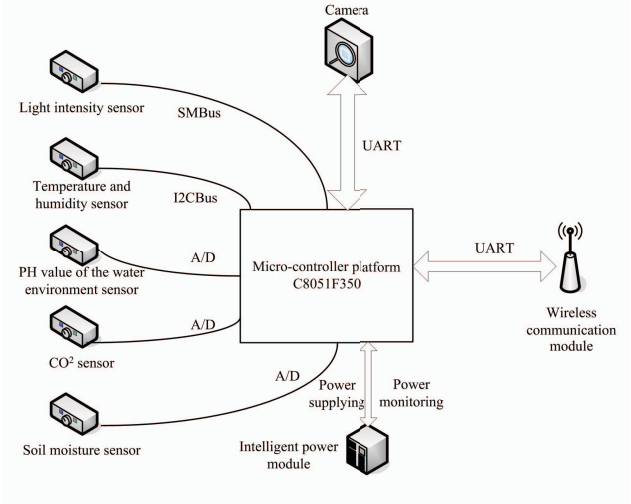

Figure 2. Physical structure of the sensor nodes

When perception nodes are performing field operations, they can combine between solar power and storage battery to solve electricity supply problems. When perception nodes are used in agricultural production of facility, it can also be used in city power supply. The design of intelligent power module can satisfy power requirements of systematic

arrangement in different situations. Because of design cost consideration, most sensor modules in perception nodes are usually applied common IC design, which is easy to be realized with low cost

III. Analysis on Key Modules of System and Their Relations

The system consists of two subsystems: the client system and monitoring platform. The client system is operated on locale instrument to receive the collected data from locale instrument. Then, it processes and packs data to send data to monitoring platform through network. It consists of four functional modules of data collection, data transmission, parameter setting and control. Monitoring platform is operated on monitoring server to receive all data from all locale instruments, to analyze, process data and display all processed results to all monitoring staff in different forms. It consists of nine functional modules of data transmission, data management, integrated query, basic information management, geological information system, control, environmental pre-warning, video monitoring and SMS short message. The system architecture is shown as figure 3.

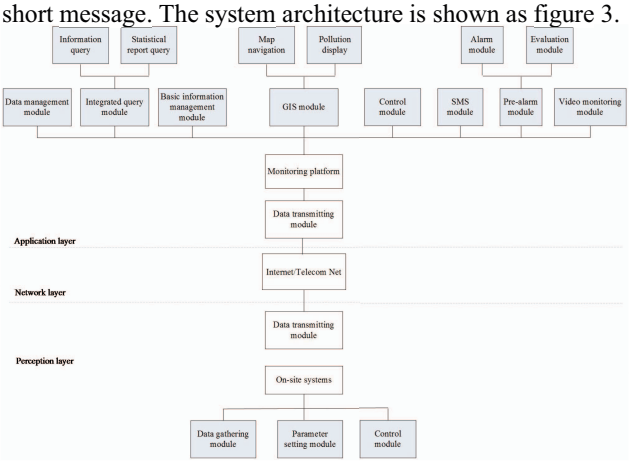

Figure 3. Software architecture of the monitoring system

A. Locale Instrument System Module Functions and Relations

1) Function of Locale System Module

- Data transmission module is responsible for establishing Socket connection with monitoring platform to receive control command from monitoring platform and send monitoring platform collected data.
- Control module is used to analyze, operate and control command.
- Parameter setting module is used to set configuration information of locale instrument.
- Data collection module is used to send collection command to acquisition instruments and receive data from acquisition instruments.

2) Relations of Locale System Modules

Data transmission module transmits acquired control command to control module. Control module analyzes and executes command to send configuration information command to parameter setting module or send collection command to data acquisition modules. After data collection module receives collected command of control module, it collects data and sends collected data to data transmission module. The relationship between locale instrument systematic modules is shown as figure 4.

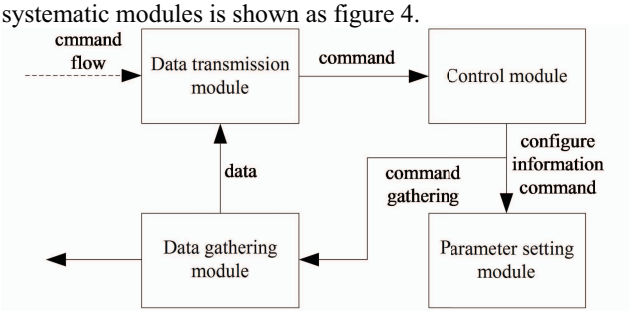

Figure 4. Relation among the system modules of machine

B. Monitoring Platform Module Functions and Relations

1) Function of Monitoring Platform Module

- Data transmission module is used to establish Socket connection with locale instrument to receive uploaded data of locale instrument and send control command to locale instrument.
- Data management module is responsible for read-write operation of database to complete data addition, deletion, modification and query.
- Basic information management module manages basic information of monitoring points as well as users.
- Integrated query is responsible for data query, users' information query and monitoring information query.
- Environmental pre-warning module makes use of data mining technology to analyze and process data, judge whether data are over standard or not, predict data change tendency and evaluate environmental quality.
- Geological information system module displays geological information of monitoring point and displays warning, pre-warning and evaluation information of environmental pre-warning module.
- SMS short message module is used to send data in short message form.
- Camera monitoring module is used for camera scanning, video recording, cloud-mirror control and front-end parameters setting in monitoring fields.
- Control module is used to transfer various control command.

2) Relations Among Monitoring Platform Modules

Data transmission module receives data package which is uploaded from locale instrument to analyze the data package. Then, it sends data to data manage module to be stored. Environmental pre-warning module makes use of data management module to read and process data. Then, it will display processed results on GIS and it will be sent through SMS short message module to realize warning and pre-warning of over-standard monitoring points on pollution index. Video monitoring module will operate from data transmission module to acquire video information of monitoring local situation, complete video scanning, video

recording, etc, in locale monitoring situation. The monitoring platform modules relations are shown as figure 5.

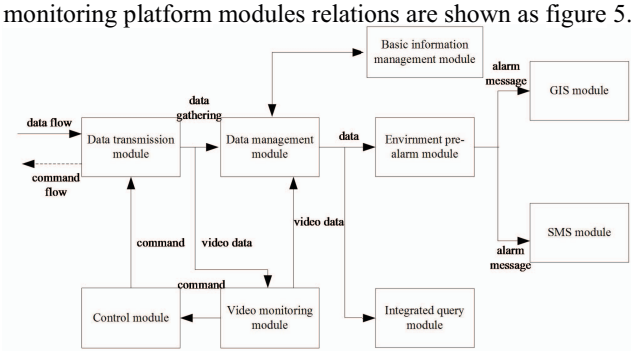

Figure 5. Relation among the modules of monitoring platform

IV. SOFTWARE REALIZATION AND TESTING

A. Program Design

Transceiver processing program of the server adopts Windows sockets design. Windows socket are opened network programming access which can complete data transmission function in network. There are three kinds of common sockets: One of them is stream socket (SOCK_STREAM) which provides connection-oriented and reliable data transmission service. The second one is datagram socket （SOCK_DGRAM）which provides non-connection service. The third one is raw socket （SOCK_RAW. Its difference from two previous ones is that raw socket can read IP data package whose kernel is not processed. However, stream socket can only read data of TCP protocol while datagram socket only reads data of UDP protocol. Since the system should have high accuracy of data, stream socket is finally selected. CSocket type from MFC is applied and coordinator gateway is taken as client. agricultural environment monitoring center is taken as server.

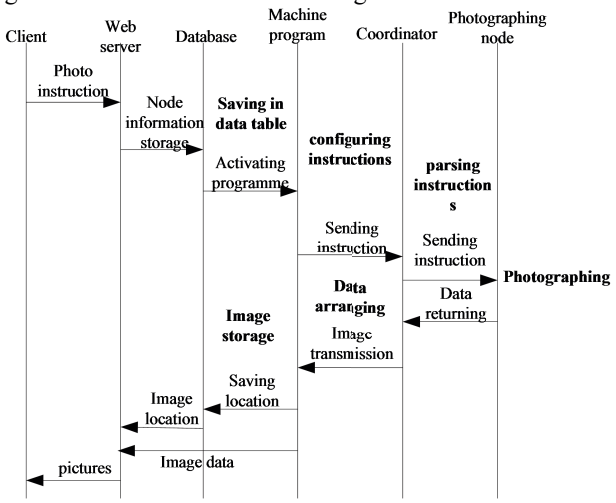

Figure 6. Signaling flow of photographing process

Transceiver program functions of server are followings: (1) Receiving data from gateway, process and store to database to apply for Web server; (2) Monitoring the database change and allocate corresponding instructions to control photo taking, testing and restart of perception nodes. The photo signaling graph is shown as figure 6. Users send photo instructions to server through network browser. Write-operation of database triggers server-end to transverse processing programs. After it sends down users' instructions and perceives nodes photos, it returns image data to server to process and store.

B. Function Test

1) Monitoring Information Gathering and Processing

Monitoring point information management contains addition, editing and deletion of source information in monitoring points:

Adding monitoring information refers to fill parameter information in different cubic blocks in windows. Then, to singly hit button of adding point source information, which is shown as figure 5-15. In basic information management blocks of pollution point-source, basic information of pollution point source is filled in. In pre-controlled parameters information management blocks, international and pre-controlled parameters refer to nationally allowed emission standard and local governments' allowed emission standard. In pre-warning information management blocks, supervision grade, defining time and list are set whether they operate pre-warning and warning. Defining time refers to time interval of pre-warning and list sets supervisors' cell-phone number in monitoring points.

Editing monitoring information, the point-source codes of text box fill in point-source codes to singly hit source-point information editing button. If query monitoring points exist, its information can be edited in windows. Then, to singly hit store button to quit to completing the information editing of monitoring points, which is shown as figure 7.

Deleting monitoring point information is based on monitoring number or name to perform query. After they are discovered, singly hitting delete button deletes related data.

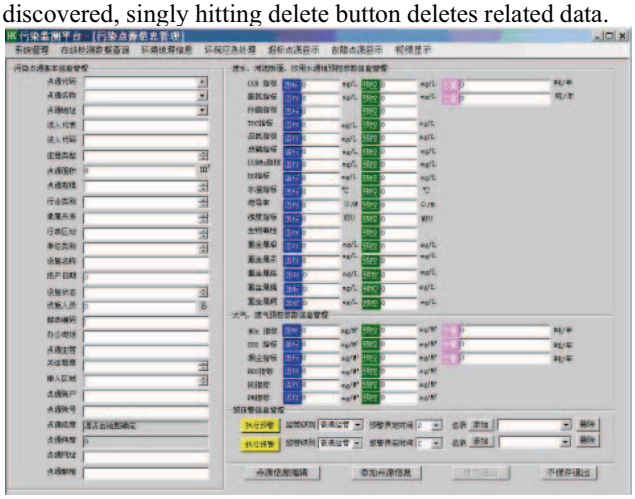

Figure 7. Original information data edition

2) Power Testing of Perception Nodes

In experimental environment, the perception node of improved projects are performed power testing. When testing condition is room temperature of 26 ℃ , constant operation time in system will maintain 24 hours. In contrast to All-ON server without adopting projects in this paper, our projects can effectively save power. Power testing results contrast is shown as figure 8 and longitudinal axis is power.

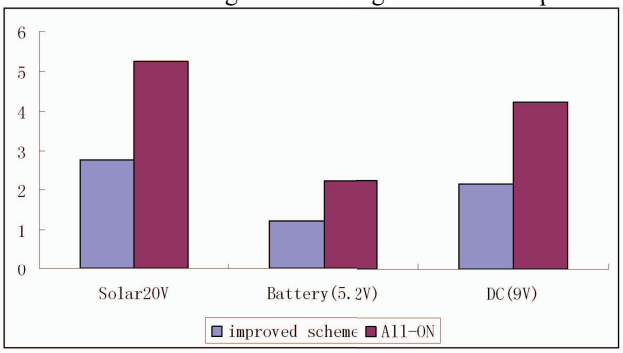

Figure 8. Energy consumption testing results

Power testing results between improved projects and ALL-ON project are shown as table 1. From test results, the project in this paper can save 45%~ 50% electric powers in contrast to ALL-ON project. Under limited electric power supply condition, working time of perception nodes can extend one time as much as ALL-ON project. It is significant to broad apply field environment monitoring system.

Table 1. Contrast of the energy consumption

	Improved scheme	*ALL-ON*
Solar energy(20V)	2.81	5.26
Battery(5.2V)	1.25	2.36
City electricity(9V,1000MA)	2.21	4.43

V. CONCLUSIONS

This paper studies development situation of national agricultural things and agricultural environment monitoring technology. Based on domestic relevant technologies in agricultural things field, a set of low-cost, efficient and information sharing field environment monitoring systems which are broadly applied in different geological conditions are designed. On hardware design, this paper adopts the modular idea to design perception layer nodes and networked construction layer gateway. It explains various selected sensor modules, wireless communication module, networked accessing module, micro-controller platform selection and electrical characteristics. It also introduces circuit connection and pin distribution in detail. The hardware design reflects design concept of systematic low-cost, modular, broad access, etc. For software design, this paper is based on layer idea to perform program design on various functional modules. By system testing, it proves that our agricultural environment monitoring system which is designed and realized in this paper can satisfy the requirements. The air temperature/humidity, CO2 density, light intensity, soil humidity, ph value in water environment and present images can accurately reflect field environment. Agricultural environment monitoring center server can store data for a long time to realize information sharing. So the scheme has realistic significance to study agricultural informatization and application research for agricultural things.

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