Advance Journal of Food Science and Technology 11(10): 643-650, 2016
DOI:10.19026/ajfst.11.2755
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: July 2, 2015 Accepted: August 30, 2015 Published: August 05, 2016

Research Article

Internet of Things_Based Real_Time Farmland Environment Monitoring

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Abstract: The aim of the study is to design the farm environmental monitoring system based on the Internet of Things (IoT) and to solve the problems of large area, too many monitoring points and long lasting time period in traditional farmland environment monitoring. Consisting of sensing layer, transport layer and application layer, the system developed the wireless sensor network node cored with Free scale MC9S12XS128 microprocessor and the hardware circuit with solar energy self-powered module, agreed the communication protocol between the application layer and the sensing layer, compiled the bottom monitoring and communication software of the coordinator and router as well as the management software for the application layer and tested the communication reliability between the application layer and sensing layer of singular point and multiple points. The test results showed that the IoT-based farmland environment monitoring could operate stably and it was safe and reliable, providing references for scientific cultivation and management.

Keywords: Internet of things (Iot), monitoring, Wireless sensor network (Wsn)

INTRODUCTION

Farmland is a kind of natural resources which cannot increase and therefore how to improve farmland production efficiency, economic benefits and environmental benefits based on the limited farmland resources by using advanced scientific and technological means has become a major issue that is bound to be solved in China (Chen and Guo, 2013; Li, 2009). The combination of information technology and agricultural technology provides a way to solve the problem. As a newly-emerging agricultural information technology, the Internet of things (IoT) can effectively make full use of agricultural information resources, which makes agricultural resources allocation more reasonable and effective (Hu, 2012; Zhu *et al*., 2011). Thus, in view of the current farmland environment monitoring characteristics of large area, too many monitoring points and long lasting time period, we designed the IoT-based farmland environment monitoring system, which developed the MC9S12XS 128-based IoT node hardware platform as well as corresponding software system, in which the measuring and controlling nodes were installed all over the farmland. Wsn was used to transmit the collected data to the server, which was used to analyze the collected data (Medaglia and Serbanat, 2010).

Researchers can remotely monitor farmland in real time at the master control room and make the right decisions based on the information collected to meet the requirements of the precision agriculture-automation, economization and accuracy.

SYSTEM ARCHITECTURE OF IOT

IoT-based farmland environment monitoring system achieved the remote monitoring and management of the farmland through installing sensor nodes within the farmland monitoring area, which could collect the environment data within the effective monitoring area and send the data to the coordinator node (Jiao *et al*., 2014), where the data was uploaded to the remote terminal through GPRS\Internet public network.

The system consisted of the sensing layer which was composed of Wsn, data transmission layer and application layer. Each layer had separate functions and the layers were connected to each other using software interface (Jiao *et al*., 2014b). Sensing layer was responsible for the collection of environment information as well as the control of irrigation, consisting of coordinator and router; responsible for the transmission of all kinds of data, the transmission layer was composed of ZigBee module, GPRS and Internet; the application layer was responsible for data storage, statistics, analysis, graphical display and carried out the decision-making and automatic control according to the farmland information, mainly including database and background data processing software. The system schematic plan was as shown in Fig. 1.

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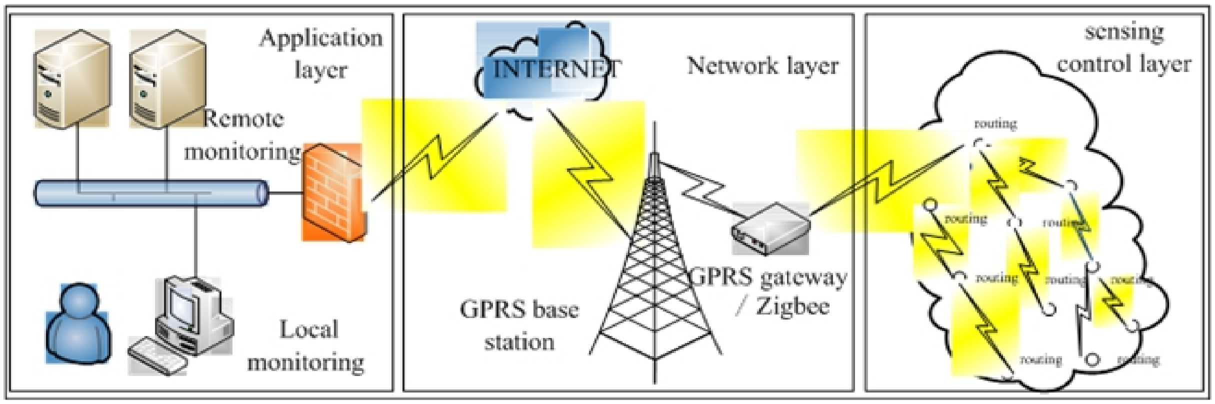

Fig. 1: Schematic plan of IoT system

NODE DESIGN OF WIRELESS SENSOR NETWORK

The Wsn of IoT system was mainly composed of routing nodes and coordinator nodes, which had the function of information collection and data transmission.

In Wsn, all nodes existed in the form of isomorphism, which conducted communication and data receiving and sending through the multi-hopping features as well as the ZigBee communication protocol. In the meantime, the coordinator node was also functioned as the Wsn network administrator (Zhang *et al*., 2007), which was not only responsible for the initialization of ZigBee sensor network, but also responsible for receiving all environmental data transmitted from all routing nodes. After processing according to different requirements, these data were sent to the far end server.

Hardware circuit design of the node: The hardware of Wsn routing and the coordinator nodes were mainly composed of the processor module, sensing control module, wireless communication module and photovoltaic modules and the coordinator had one more GPRS module than the router (Fig. 2).

MC9S12XS128 of Free scale Semiconductor Company was selected as the microprocessor of the nodes to collect and store data, process the data transmitted from other nodes, as well as ensure data security and task management. Serial port 1 of MC9S12XS128 was expanded to 5-way serial port using GM8125 serial port expansion chip; the serial port 0 was connected with the Zigbee module to conduct command receiving and sensing data transmission; sub serial port 1 was connected to the serial LCD screen to show the current collected information of the node and sub serial port 2 was connected to GPS module to receive the geographical information of the node, while the coordinator was connected to GPRS module using sub serial port 4 to achieve the communication with remote server.

Sensor control module was responsible for the collection of air temperature and humidity, soil temperature and humidity and illumination information of the farmland within monitoring area, in which soil temperature and humidity sensor was the PH-SWR-100W produced by the Wuhan Xinpuhui Technology Co. Ltd. and air temperature and humidity transmitter was the AQ3020Y from Guangzhou Lexiang Electronics Co. Ltd., photosynthetic active radiation the SY-HGY photosynthetic active radiation meter of Shijiazhuang Shiya Technology Co. Ltd. As for the control part, the HK4100F-DC5V-SHG relay driven by NPN audion 8050 was used to control the water valve.

Responsible for the communication between nodes, the exchange of control messages and the receiving and sending of collected data, the wireless module was the AQZ2000 wireless transparent transmission module of Hangzhou Qiujie Technology Co., Ltd. GPRS was the HC-GPRS/232/T module of Nanjing Woloog Company and the erected GPRS unvarnished transmission dedicated server was used, so there was no need for users to apply for fixed IP to have access to IP services.

Photovoltaic power supply module used 7824 to make the output of voltage generated from the photovoltaic panels stabilize at 24V and comparator LM339 and audion TIP42 and other components were used to compose the lead-acid battery charging circuit, providing stable, reliable and non-polluted electric energy for the Wsn nodes (Fig. 3).

In addition, the clock circuit of the node was used to control the operating frequency of the whole system; JTAG was used as program debug and download interface; reset circuit was used to restore the broken-down system or program default and other unforeseen circumstances. The pictures of used router and coordinator were as shown in Fig. 4 and 5.

Software design of nodes in Wsn nodes: In Wsn, the nodes had the functions of environment data collection and irrigation control and the router and coordinator could achieve Ad-Hoc Network, in which coordinator

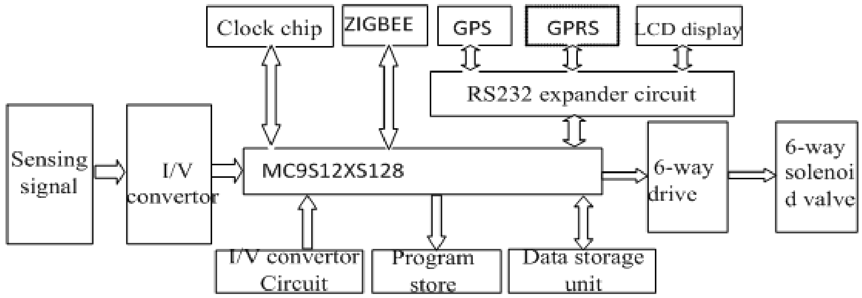

Fig. 2: Schematic diagram of the coordinator and routing node structure

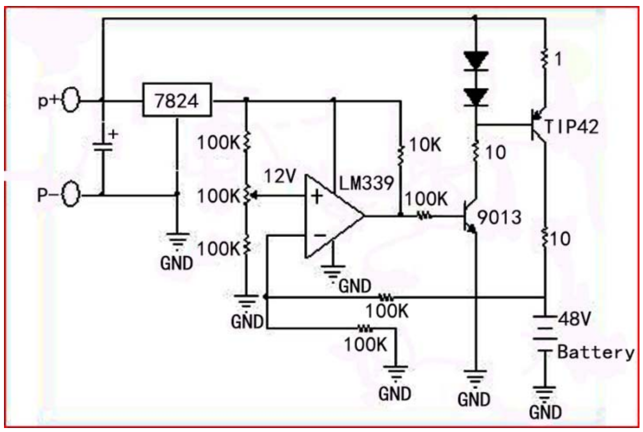

Fig. 3: Photovoltaic charging circuit

Fig. 4: Router

Fig. 5: Coordinator

was the core node. At the beginning of Wsn setting up, coordinator joined the network first and after powering on, the routing node sent out the connection information to connect with the coordinator or other adjacent routers to join the network one by one (Bao *et al*., 2007; Zhou, 2011).

The remote server and nodes in Wsn achieved data exchange through GPRS or ZigBee module and after the information collecting node finished the senor data collection, processing and format coding, the data were required to send to the server safely, quickly, completely and accurately to process these data and make them display and store in the computer.

Heartbeat packet "CONNECT" and heartbeat period were set up at the initialization configuration stage of the GPRS module of the server and coordinator. After connecting the GPRS modules of the server and coordinator and powering on, when the GPRS joined in the network successfully, the server and coordinator could periodically receive "CONNECT" heartbeat to sense whether the other side was on line or not.

The Zigbee module was used for the communication between Wsnmidnodes and its initialized set PAN ID was 66 77, Baud rate of 9600 and set the channel was 11.240 5MHz.

In Wsn, there were various kinds of transmission information, including networking information, addressing command information, monitoring command information and controlling command information and feedback information and all information was differed from router and coordinator. In order to ensure the system have no information interference during the operational process, the software system internal agreement was designed, which mainly included "addressing", "monitoring" and "electromagnetic valve controlling". Therefore, the remote server needed to send commands to a certain order, namely first to "addrssing" to acquire the network address of each node and then "monitoring" or "controlling" function command according to the network address.

Design of communication protocol: The protocol information included prefix, node number, network address, function words and parity bit. Prefix was used to distinguish coordinator and router as well as the data transmission direction; node number and network address were to distinguish different nodes; function work to distinguish instruction function; parity bit represented whether the information transmission was right or wrong. The processing results of these control commands would also be showed on the LCD screen of the coordinator.

"Wsn addressing frame" and "Wsn addressing response frame": The server sent out " Wsn addressing frame" aiming to acquire the network address of Wsn coordinator or routing node in Wsn and coordinator or routing node send back network address Corresponding.

Addressing frame sent by the server to Wsn coordinator or router: addressing frame header+node ID +length+function code+frame end.

Addressing response frame sent by the Wsn coordinator or router to the server: Addressing response frame header+00+00+00+net work high byte address+network low byte address+frame end.

Addressing frame header: 0xf1.

Node number: 0-0xff, Wsn coordinator numbered 0, 0 Non Wsn routing numbered non-0, no repetition of node numbers.

Function number: 0XAA, indicating the completion of addressing function.

Length: the number of bytes of the frame.

Frame end: The algebraic sum of the bytes of the frame.

Addressing response frame header: 0xfd

Network address: A 16 network address of the addressed nodes in Wsn network, different nodes with different addresses.

"Monitoring frame" and "monitoring response frame" The aim for the server sending "Monitoring frame" was to command Wsn coordinator or routing node to monitor the environment information and Wsn coordinator or routing node send back the monitoring results.

Monitoring frame sent from the server to the Wsn coordinator or router: Monitoring frame header+ number+Wsn high byte address+Wsn low byte address +function code+frame end.

Monitoring response frame sent from the Wsn coordinator or routing to the server: Monitoring frame header+00+00+00+function word+Wsn high byte address+Wsn low byte address+monitoring information+frame end.

Monitoring and monitoring response frame header: 0xfd.

Function word: 0x31, indicating monitoring function.

Monitored response information: totally 5 kinds of environment information in the order of soil temperature, soil humidity, air temperature, air humidity and photosynthetic active radiation.

The definitions of other items of this frame were the same as those of the "addressing frame".

"Control frame" and "control response frame": The aim for the server sending "Control frame" is to command the Wsn coordinator or routing node to control the solenoid valve start or to stop irrigation and in the meantime, the Wsn coordinator or routing node sent back the controlling results to the server.

Controlling frame sent from the server to the coordinator or router: Controlling frame header+ number+Wsn high byte address+Wsn low byte address +function number+electromagnetic valve opening and closing sequence number+frame end.

Controlling response frame sent from the Wsn coordinator or router to the server: Controlling response frame header+number+00+00+function number+0xAA+frame end.

Controlling and controlling response frame header: 0xfd.

Function number: 0x32, indicating the control of solenoid valve.

Electromagnetic valve opening and closing sequence number:

D5 bytes: 0/1 respectively represents the electromagnetic valve 1 closed/open.

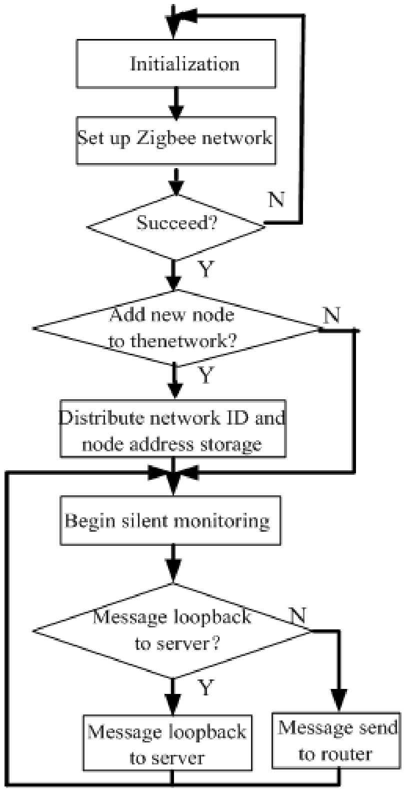

Fig. 6: Program flow chart of coordinator

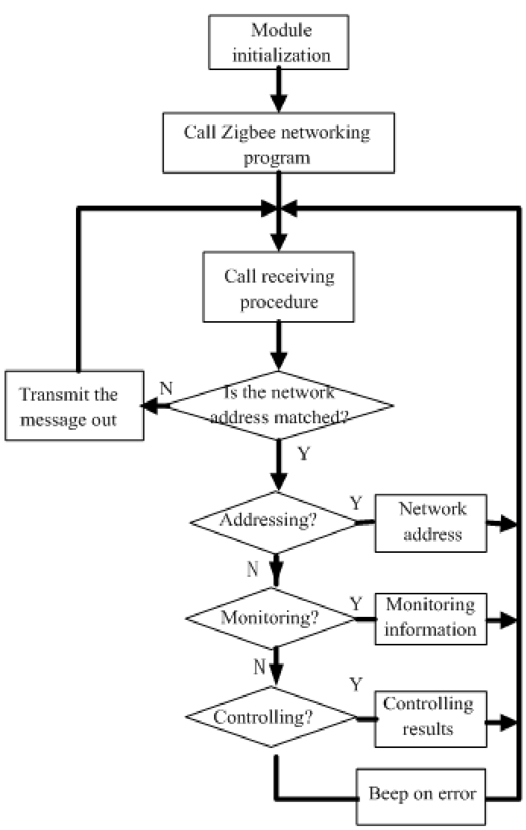

Fig. 7: Program flow chart of router

D4 bytes: 0/1 respectively represents the electromagnetic valve 2 closed/open.

D3 bytes: 0/1 respectively represents the electromagnetic valve 3 closed/open.

D2 bytes: 0/1 respectively represents the electromagnetic valve 4 closed/open.

D1 bytes: 0/1 respectively represents the electromagnetic valve 5 closed/open.

D0 bytes: 0/1 said solenoid valve 6 closed/open respectively.

Software design for coordinator and router: As the composed nodes for Wsn, both the router and coordinator had the function of environment information collection, but performed different functions in Wsn. Mainly responsible for the establishment, management, maintenance of network, the coordinator received the various monitoring and controlling commands from the remote server through GPRS and then compared the network address in the commands with the address of the local node.

If consistent, it indicated that the command was for the coordinator and the command would be carried out and the results would send back to the server through GPRS; if not, it indicated that the command was for the other routing nodes and the coordinator would transmit the command out through ZigBee and the executive results of these controlling command would show on the LCD of coordinator.

The router preformed the real-time receiving of the transmitted command from the coordinator or other routers through ZigBee module. If the network address of the transmitted command was inconsistent with the local network address, then it indicated that the command was sent to other routing nodes and it would send out the command; if consistent, it indicated the command was for this node and the router would analyze the command type. If the command was "addressing", it would send back the network address through ZigBee and if it was "monitoring" command, the router would send back the monitoring environment information, if the "controlling" command, the router would send back the controlling results. The work process of coordinator and router software was shown in Fig. 6 and 7, respectively.

EXPERIMENTAL DESIGN AND VERIFICATION

Testing environment: The farmland environment information monitoring system was installed at the Agricultural and Crafts Garden of the Anhui Agricultural University, where there planted the Israel tomato 5148, which was irrigated using the double-barreled trickle irrigation method. There totally installed 10 routers and 1 coordinators to carry out the

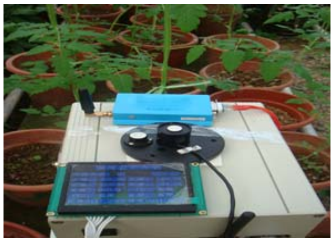

Fig. 8: Coordinator in the experimental field

Fig. 9: Router in the experimental field

Table 1: Statistics of receiving and transmitting packets

	Single-node		Multi-nodes	
Distance (m)	Number of receiving packets	Success rate (%)	Number of receiving packets	Success rate (%)
40	360	100	360	100
60	360	100	360	100
80	360	100	360	100
100	360	100	356	98.88
120	360	100	358	99.44
140	360	100	358	99.44
160	355	98.6	354	98.33
180	351	97.5	350	97.22
200	346	96.11	345	95.83
220	339	94.16	337	93.61
240	331	91.94	330	91.66
260	321	89.1	319	88.61

environment information collection and the server was placed at the research laboratory of the Anhui Agricultural University. The nodes were used to collect the air and soil temperature, relative humidity and solar radiation. The locations of the equipped routers and coordinators in the garden were as shown in Fig. 8 and 9. Each node installed with four soil temperature and humidity sensors, which were 8 cm above the ground and a air temperature and humidity sensor.

When it monitored that the soil moisture was lower than the set threshold, the control system would open the electromagnetic valve and after 15 min (set according to the crops and soil), it would close the electromagnetic valve and waited for water infiltration. After 5 min, it would monitor whether the soil humidity was lower than the set threshold, if so, it would open the electromagnetic valve again.

Network testing: In order to test whether the network worked, whether the communication distance met the requirements and whether the communication protocol was effective in anti interference, single node network testing and multi-nodes network testing were carried out.

The single node network testing used the testing software in the server to send a monitoring command to 10 routes from 0-10 at random, while the multi-nodes network testing used the testing software sending the monitoring command to the 10 routers from 0-10 one by one. From 40 m, the distance between the nodes increased by every 20 m until the distance between 2 nodes reached 260 m. The analysis of multiple test results showed that the average time interval from the host computer sending out command to receiving data was 1.5s, the reason of which was the sending and receiving module of GPRS was joined up through serial ports and serial read-write speed was relatively slow.

Moreover, the data needed to pass through the GPRS server of Woloog Company. Therefore, in order to ensure the Wsn communication quality, the command sending and receiving time interval in the server of the test was set at 10s and the number of received and sent data package of 1 h (totally 360 commands were sent from the server) was recorded. The test results were as shown in Table 1.

In Table 1, in single-node testing, when the distance between the routing node and coordinator was less than 140 m, the success rates of the data packets sending was 100%, indicating that GPRS module and ZigBee module worked stably and reliably; however, when the distance went over 140 m, with the increase of the distance between the router and the coordinator, the success rates of data packets receiving decreased, indicating that the communication protocol worked normally and had the efficiency of anti-interference, while the ZigBee wireless signal was affected by the distance of communication.

In multi-nodes testing, when the distance was no more than 140 m, the success rates were over 99%, while when the distance increased over 140 m, the success rates were lower than those of the single-node testing, indicating that when the communication distance was the same, the increase of data transmission pressure to the coordinator would cause data packets loss.

Environment information acquisition test: The environment data collection results from August 13, 2014 to August 26, 2014 were as shown in Fig. 10. From the picture, we could see that the air and soil temperature showed little change, while the air humidity fluctuated around 60. And the value of the photosynthetic active radiation was reduced to 30 times, which was also performed stably. There was fluctuations of soil humidity, in particular at 8-13:09:04; 8-15:04:11; 8-20:09:39; 8-22:18:02; 8-24:19:32, which was due to the open of trickle irrigation and the soil humidity variation, was well-

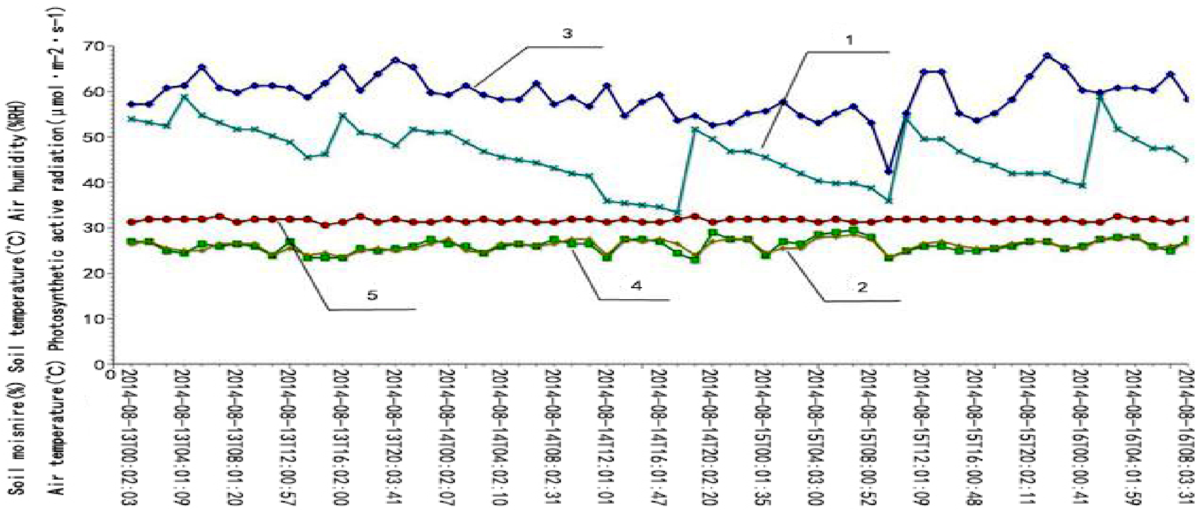

Fig. 10: Real-time monitoring curve; 1: Soil moisture curve; 2: Soil temperature curve; 3: Air humidity curve; 4: Air temperature curve; 5: Photosynthetic active radiation curve

presented. With the involvement of solenoid valve, the moisture content of the whole irrigation area could maintain at a certain range, which could be set flexibly according to the demand for water in various stages of plant growth, which was also one of the characteristics of this system. From the observed data, the soil moisture content monitoring of the system was accurate and reliable.

CONCLUSION AND DISCUSSION

Precision agriculture is trend of world agricultural development and farmland environment monitoring is the key to supporting precision agricultural technology. The IoT-based environment monitoring system satisfies the requirements of the precision agriculture on fast, accurate and continuous measurement. Therefore, in this study we developed the IoT-based environment monitoring system, set out the system structure, developed the nodes hardware circuit and software circuit in Wsn and designed the network performance tests and environment information collection scheme. The test results showed that the soil moisture content monitoring of the system was stable and reliable, which could provide technological support for the development of a more accurate automatic measurement and control system.

ACKNOWLEDGMENT

The project was supported by the International Cooperation Project of Anhui Science and Technology Department (1403062031), also support by the Natural Science Research Foundation and Quality project of Education Department of Anhui province (KJ2014 A074, 2014 jyxm091, 2014 tszy 090) and the Fund to Introduce and Stabilize Talents of Anhui Agricultural University, respectively.

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