Design of a WSN Node for Rice Field based on Hybrid Antenna

Huaqiang Chen
College of Electronic Engineering
South China Agricultural University
Guangzhou 510642, P.R.China
243591735@qq.com

Baoxia Sun
College of Electronic Engineering
South China Agricultural University
510642, P.R.China
sunbaoxia@126.com

Weixing Wang(Correspondence author)
College of Electronic Engineering
South China Agricultural University
Guangdong Engineering Research Center for Monitoring
Agricultural Information
weixing@scau.edu.cn

Jiangpeng Weng, Fenglian Tie
College of Electro+nic Engineering
South China Agricultural University
Guangzhou 510642, P.R.China
vmishiwjpv@163.com, 65517386qq.com

Abstract—Aim at the problems existing in the information monitoring of the farmland environment such as the limited energy, low system stability and large monitoring area, a WSN node for rice field based on hybrid antenna is designed to realize the real-time on-line monitoring for the environmental parameters of rice fields in the network. As for the hardware, the node uses a STM32F103VET6 as a processing core, and a WLK01L39 RF chip is used in wireless communication module, while the sensor module is composed of the air temperature and humidity sensor, light intensity sensor and soil moisture sensor. As for the software, uC/OS-II is applied as an operational system to realize multitask scheduling running. The sensor node applies a mechanism as sleeping and waking up work modes to reduce power consumption. The current consumption of sensor nodes is 0.024mA under the sleeping mode, 32.32mA under the data collection, 26.25mA under data transmission and 21.95mA under the operating mode. The results of a long time networking experiment indicate that the average PLR (Packet Loss Rate) of network is 0.76%. In conclusion, the design of sensor node system is suitable for the real-time and stable monitoring of rice field.

Keywords-Hybrid antenna, rice field, low power consumption, node design

I. INTRODUCTION

In our country, the planting area and production of rice occupy the first position among the main grain crops [1,2,3]. However, some problems have restricted the development of rice industry, such as the low technology content, the backward production technology and small production scale. Wireless sensor network (WSN), which is considered to be one of the most important technologies in the 21st century[4], is a kind of new information acquisition and processing technology that can be applied in the field of agricultural. WSN is a fully-distributed system that typically composed of a large number of sensor nodes with specific functions. The advantages of simple deployment, intensive layout, low cost and no need for on-site maintenance provide convenience for the data acquisition of environmental science researches. Combining with the farmland environment parameter sensor [5], the real-time on-line monitoring of large area farmland environment parameter can be realized, which has great significance to the accelerating of the agricultural informatization in our country and the prediction on the degree of the damage of rice drought and diseases of insect pests. There have been many examples of successful application at home and abroad [6-114].

In accordance with the broad monitoring environment, adequate sunlight and few architectural barriers of rice fields, regarding the air temperature and humidity, the light intensity and the water temperature of the soil as monitoring objectives, this paper designs a node for rice filed based on the hybrid antenna. In order to meet the application requirements of stable real-time on-line monitoring in rice field environment, the wireless sensor network node is designed to realize the energy self-supply.

II. HARDWARE DESIGN OF WIRELESS SENSOR NODES

A. Directional Antenna

In the application of wireless sensor nodes, omnidirectional antenna which has 360 ° horizontal radiation patterns is suitable for the multipoint communication. In the case of a need for sending and receiving information in the whole network, the omnidirectional antenna can guarantee effective reception among nodes and the horizontal movements of wireless node will not influence communication, which make it easy to install and manage. In the designed environmental information real-time monitoring system for rice fields based on WSN, the sensor nodes randomly dispersed in the network monitoring area. Due to the low requirements for its communication distance and direction, the omnidirectional antenna is equipped. The main task of cluster head nodes is to collect data of sensor nodes and realize the reliable communication over a long distance with gathering node, thus, the directional antenna is equipped and its direction is set towards the gateway nodes. Due to the limited length, this paper illustrates the hardware design method of the system with the representative example of the collecting node design.

B. Hardware Structure of Sensor Node

Nodes constitute a complete wireless sensor network in the form of self-organization. The environmental monitoring information of rice field was sent through single hop to the cluster head nodes, from the cluster head nodes to the gateway nodes, then to the monitoring center by the network. In this way, it can achieve the monitoring environment parameters acquisition of rice field [15]. The acquisition node consists of a processor module, a power supply, a solar charging module, a sensor module and a wireless radio frequency module. The WSN node structure is shown in Fig. 1.

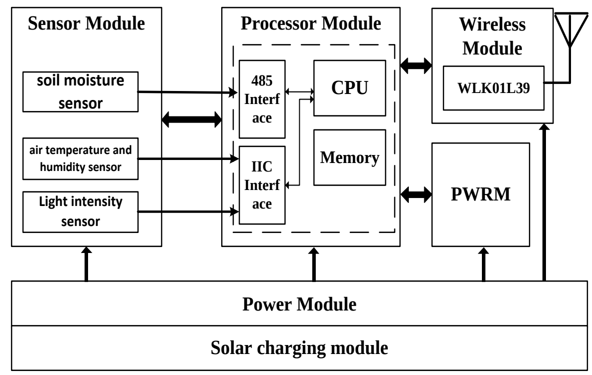

Figure 1. The structural of WSN node

C. Processor Module

In order to meet the design requirements of superior performance and low power consumption, the microprocessor uses STM32F103VET6 produced by ST Microelectronics. It has high command execution efficiency and strong anti-jamming capability. What's more, it supports standby sleep and has the functions of equipment management, task scheduling, data fusion processing, etc.

D. Sensor Module

The sensor module is mainly responsible for the collection of air temperature and humidity, light intensity, and soil temperature and humidity in the rice field. According to the accuracy of the data parameters and the needs of field application , the design uses the HTU21D temperature and humidity sensors, the light intensity sensor BH1750FVI, as well as the soil moisture temperature sensor SMTS-II-485 produced by French Humirel Company.

III. SOFTWARE DESIGN OF WSN NODES

The performance of the wireless sensor network nodes and the stability of the network are directly affected by the software design. Considering the characteristics of the long cycle, strong disturbances and small quantity of data in single transmission, a software system based on the uC/OS-II is designed according to the hardware platform mentioned above . Due to the use of embedded operating system, the design greatly improves the availability of the software to prolong the lifetime of nodes.

A. *Design of Communication Protocol among Nodes*

Limited by the node energy, network computing and processing capacity and other resources, the design of WSN communication protocol is particularly important. The design reduces the cost of energy and data transmission delay by means of routing algorithm, time synchronization algorithm and standby wake-up mechanism, and thus the allocation of WSN resources can be optimized. The routing protocol designed in this paper is improved partly based on the LEACH protocol. This system is aimed at the large rice field so that the design uses the clustering routing algorithm. Cluster head is randomly selected in each round. Data packets of nodes in a cluster are sent to the cluster head and data packets between clusters can be forwarded to the gateway node through multi hop of cluster heads. Cluster head nodes first check their own record after receiving a new packet. If the packet has been forwarded, they will not be forwarded again. In this way, the waste of energy caused by forwarding the same data packets can be avoided. The structure of packets sent to the cluster head by sensor nodes and packets sent to the gateway node by cluster head is shown in Figure. 2.

Data Flag	Cluster Num	Node Num	Sensor 1	Sensor 2	Sensor 3	Battery Voltage	Jump Num	CRC

Figure 2. Sensor node packet structure

B. *Time Synchronization Algorithm Design*

After the gateway nodes obtain the current time and the standby time from the remote server, it will process the information packet of the synchronous time, and then send to the cluster heads and nodes in clusters through broadcast. Each node in clusters receives the synchronous packet, which will be parsed into the current time and the alarm clock time, then set the RTC clock register before entering the low power standby mode. The structure of synchronization time information packet is shown in Figure3.

Syn Flag	Current Time	Alarm Time	CRC

Figure 3. Synchronization time packet structure

C. *Standby Wake-Up Mechanism*

In the network, each node has its local clock. After the system starts, the network will provide a common time stamp for local clocks of all nodes and it will be on standby or be awakened at the right time. By means of this standby mechanism, the whole network can save the cost and reduce the energy consumption.

D. *Application Design*

The version of small embedded real-time system in acquisition nodes is V2.91 uC/OS-II. The system is responsible for preemptive real-time multi tasks scheduling. Tasks communicate with each other through a signal. The whole system is divided into several parts, including initialization task, acquisition task, receiving and forwarding packets task, sending data package task, task of feeding dogs and standby task. The system block diagram of application is shown in Figure4. The processes of the system application in per round are as follows. After initializing the hardware resources, the tasks of collecting, sending, forwarding, standby and waking up are repeated circularly

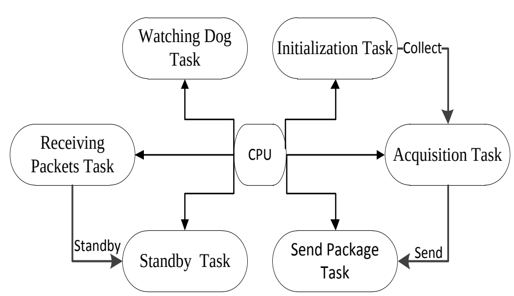

Figure 4. The application system diagram

IV. TEST AND RESULT ANALYSIS

A. Node Hardware Performance Test

The test of node hardware performance mainly refers to the test of low power performance. The working current in the system in different working modes is measured to test the performance of the hardware by using a high precision ammeter accessed to node circuit. After repeated testing, repeatedly recording the power consumption data of sensor nodes and calculating the average value, the test results are shown in Table 1. Results show that the sleep and wake-up mechanism can effectively extend the life cycle of nodes and achieve the requirements of low power consumption.

TABLE I. POWER TEST RESULTS OF SENSOR NODE

Test node	Standby	Data Collect	Data Send	Data Receive
Collectors/mA	0.024	32.32	26.25	21.95

B. Network Packet Loss Rate Test

In the networking test, 10 sensor nodes are divided into two clusters and a gateway node. The sensor nodes collect and send data once every 10min, and then enter the receiving mode after the data packet is sent. Finally, they will enter the sleep state after receiving the synchronization information from the gateway node. The test data of 14d are statistically analyzed and the results are shown in table 2. The results show that the system is stable and reliable, and the average packet loss rate of the network is 0.76%

TABLE II. PLR VALUES OF NETWORK

Cluster Num.	Node Num.	Send Packet Num.	Receive Packet Num.	Packet Loss Rate /%
1	01	2016	2005	0.54
1	02	2016	2001	0.74
1	03	2016	1999	0.84
1	04	2016	1995	1.04
1	05	2016	2004	0.59
2	01	2016	2002	0.69
2	02	2016	1997	0.94
2	03	2016	2001	0.74
2	04	2016	1995	1.04
2	05	2016	2006	0.49

V. CONCLUSIONS

To solve the problems occurred in on-line monitoring in large rice fields such as poor real-time and less system stability, large on-line monitoring fields, a node for rice field based on hybrid antenna is designed and its related performance test is carried out. The results of the test show that:

(1)By means of component selection, hardware circuit design and program design, a sensor node for rice field based on hybrid antenna is developed. The node can realize the stable real-time on-line monitoring towards the data of rice fields.

(2)Sensor nodes have low power consumption in the monitoring process.The current consumption of sensor nodes is 0.024mA under the sleeping mode, 32.32mA under the data collection, 26.25mA under data transmission and 21.95mA under the operating mode. In most of the time, the sensor nodes are in the standby sleep phase during the running time of the system so that the system can work stably in a long term.

(3)In the 14d networking of the labs, due to the close distance between nodes in this test, the average packet loss rate is 0.76%. Network packet loss rate relates closely with node deployment location, antenna height and other factors. During the process of practical monitoring, the network packet loss rate can be reduced by changing the transmission power of the wireless module, adjusting the height of the antenna, increasing the routing node and so on.

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References

[1] Huizhe Chen, Defeng Zhu, The Rice Production and Ecosystem in the World, HYBRID RICE. 05(2003) 4-7.

[2] Zhenhuan Liu, Zhengguo Li, Pengqin Tang, et al. Spatial-temporal changes of rice area and production in China during 1980-2010, Acta Geographica Sinica. 68(5)(2013)680-693.

[3] Hongcheng Zhang, Jinlong Gong, Research Status and Development Discussion on High-Yielding Agronnmy of Mechanized Planting Rice in China, Scientia Agricultura Sinica. 07 (2014) 1273-1289.

[4] Feng Hong , Hongwei Chu , Zongke Jin , Review of Recent Progress on Wireless Sensor Network, Applications,Journal of Computer Research and Development..2010,47:81-87

[5] Xiaojun Qiao, Xin Zhang, Cheng Wang, Application of the wireless sensor networks in agriculture, Transactions of the CSAE.S2 (2005)232-234.

[6] Antai Han, Yong He, Zhiqiang Chen, et al. Design of Distributed Precision Irrigation Control System Based on Wireless Sensor Network for Tea Plantation, Transactions of the Chinese Society for Agricultural Machinery. 09 (2011)173-180.

[7] Jianqing Huang, Weixing Wang, Sheng Jiang, et al. Development and test of aquacultural water quality monitoring system based on wireless sensor network, Transactions of the Chinese Society of Agricultural Engineering. 04(2013) 183-190.

[8] Jin Hu, Hongpan Fan, Haihui Zhang, et al. Design of regulation system of light environment in greenhouse based on wireless sensor network, Transactions of the Chinese Society of Agricultural Engineering.04(2014) 160-167.

[9] Sheng Jiang, Weixing Wang, Daozong Sun, et al. Design of energy self-sufficient wireless sensor network node for orchard information acquisition, Transactions of the Chinese Society of Agricultural Engineering. 09(2012) 153-158.

[10] Heng Zhang , Dongyi Chen , Bing Liu , Research on the Orientation of Antenna in WSN, . Journal of University of Electronic Science and Technology of China, 2010(S1): 85-88.

[11] Jun Liu , Qian Sun , Shaohua Li , et al .Topology Control Algorithm Based on Directional Antennain Wireless AdHoc Networks, Journal of Northeastern University(Natural Science), 2012(09): 1257-1260.

[12] Guangsong Yang , Xu Geng. Engergy-efficient Route Finding Mechanism Based on Directional Antenna in Wireless Sensor Network, Computer Engineering, 2010(22): 91-93.

[13] Xiao Jun, Li Ke, Wang Jianhua.The Research of Communications and Route of Wireless Sensor Network[J]. Computer Knowledge and Technology, 2009. 2008, 2(18): 59-61.

[14] Xiaomin Li, Ying Zang, Xiwen Luo, et al. Design of WSN node with adaptive transmitting power for rice field, Transactions of the Chinese Society of Agricultural Engineering. 07(2014) 140-146.

[15] Baoxia Sun, Weixing Wang, Gang Lei, et al.Real-time Monitoring System for Paddy Environmental Information Based on Wireless Sensor Network, Transactions of the Chinese Society for Agricultural Machinery. 09(2014) 241-246.