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Towards a Poultry House Environment Monitoring System Based on Internet of Things

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Abstract: Aiming at requirements as low cost, low power consumption, large area, multi-parameter, multi-site and high access speed of livestock and poultry house environment monitoring network, the paper proposed a poultry house environmental monitoring system which meets the agricultural Internet of Things architecture. This system can achieve timely monitoring parameters as air temperature, air humidity, soil moisture, CO_2 concentration, light intensity and NH_3 concentration of multi-site online. The paper designed ZigBee sensor nodes to achieve multi-parameter collection as well as embedded coordinator gateway to support access control of remote clients on coordinator gateway. The system prototype collects poultry house environmental information timely and accurately to meet requirements of modern grassland environmental monitoring. *Copyright © 2013 IFSA.*

Keywords: Internet of things, Livestock (poultry) homes, Environmental monitoring, Sensor networks, Embedded gateway.

1. Introduction

The development of agriculture is of important role for national stability. Introduction of high-tech into agriculture is the only way to transform traditional agriculture and improve its production efficiency. Scientific breeding livestock facilities become increasingly important in the agriculture production. Meanwhile, it also breaks through restrictions of traditional livestock from factors as geography, natural environment, climate and others, so it is of great significance [1, 2]. Application of Internet of Things (IoT) in agriculture gradually expands, represented by intelligent chip, embedded system, network and cloud process technologies. Modern livestock and poultry production management includes parts of information access, intelligent information processing as well as expert system. Its research covers multiple fields and shows multidisciplinary character. According to principle of information generation, transmission, processing and application, the IoT can be divided into four layers, namely perception layer, network construction layer, management service layer and comprehensive application layer. The four-layer poultry house environment monitoring system based on IoT places several multi-parameter sensor nodes to accurately access environment information and then merge to gateway via standardization sensor network. The paper addresses poultry house environment monitoring problem with wireless sensor technology, so as to access environmental parameters within house. Then data is transformed and processed to effectively control production environment and

improve livestock productivity. The paper is organized as follows: section 2 designs monitoring system architecture based on IoT; section 3 proposes system implementation method; section 4 concludes our work.

2. Monitoring System Architecture Design

2.1. Network Structure

The network structure of livestock (poultry) house environment monitoring system is shown in Fig. 1. It is designed to meet requirements that IoT-based and low cost with single node multi-parameter collection and multi-site coverage, which can also share high-speed information.

Poultry house environment monitoring system organically integrates wireless sensor network with Internet and 3G network. It is divided into three layers as perception layer, network construction layer and application layer. The perception layer is made up of several sensor nodes, which carries multi-parameter sensor array to access poultry house environment information. Network construction layer is coordinator gateway, including ZigBee coordinator module, 3G module and Ethernet module. The poultry house environment monitoring center in application layer is consisted of SQL database and Web server, which is responsible for data storage and information dissemination. System workflow is as follows: many sensor nodes merge collected data or scene to coordinator gateway. Then the gateway forwards data to distance poultry house environment monitoring center for processing and storage [3]. The server in poultry house monitoring center demonstrates environment evolution process with history data or curve. The users or administrator can query environmental parameters via phone, PC or other intelligent terminals. They can also conduct related control on sensor nodes and coordinator gateway.

Wireless sensor network uses ZigBee protocol, which can be divided into three structures as star, tree and mesh. The star network uses single-hop manner. All terminals directly communicate with coordinator. As the communication distance is limited, it cannot cover a large area. Each node in mesh structure communicates to each other, which covers a larger area. However, increment of communication overhead will lead to decrease of life cycle, which cannot meet system needs for long-time working. Accordingly, the paper designs poultry house environment monitoring network as tree structure and divides nodes in network into three types, namely perception node, routing node and coordinator node. The perception node and routing node have been marked in Fig. 1. The coordinator node is integrated on gateway. The perception node is simplified Reduced Function Device (RFD). There are several perception nodes in the monitoring network to responsible for data collection and transmission. Routing node serves as bridge between sensor nodes and coordinator nodes. In case of long distance between coordinator node and sensor node, it is used to forward data. There is only one coordinator node in the network, which is Full Function Device (FFD) to responsible for construction and control on sensor network. Meanwhile, it collects data from perception nodes.

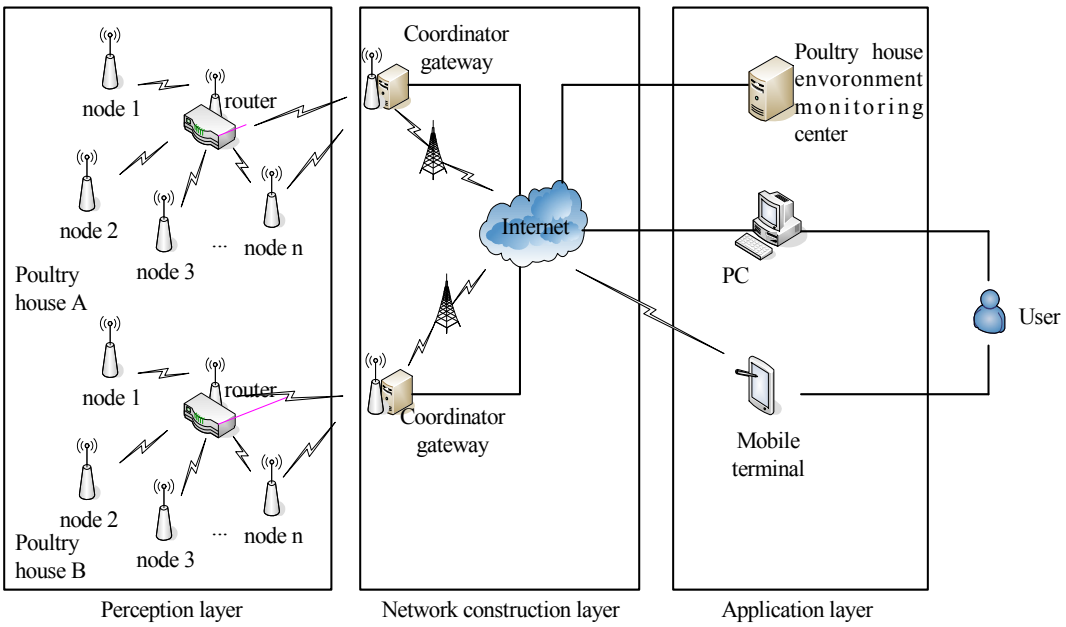

Fig. 1. Poultry house environment monitoring system architecture.

2.2. Hardware Architecture

1) Coordinator gateway.

The constituted structure of coordinator gateway is shown in Fig. 2. It mainly contains ARM micro-controller platform, ZigBee coordinator module, 3G module, Ethernet module and power module. Its main function is to forward data collected from perception nodes to monitoring center.

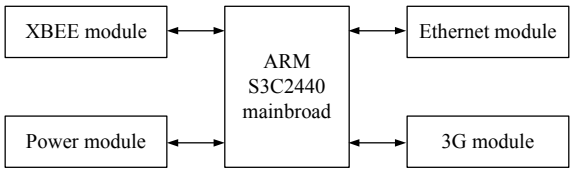

Fig. 2. Coordinator gateway hardware structure.

The micro-controller platform selects chip S3C2440 from Samsung that been extensively used currently. It is based on ARM920TDMI core and embedded MMU unit to achieve multi-task management. The SDRAM and FLASH are expanded externally with larger storage space and stronger data processing capabilities [4]. Embedded operating system uses open-source Linux, which is scalable for multi-function modules and cost controlled. ZigBee coordinator module is designed with XBEE ZNet2.5 low-power module from DIGI in U. S. After hardware setting, the module can work on three modes as coordinator, router and terminal nodes. The routing can be generated automatically to form self-healing network. The 3G module selects EC189 wireless network card from Huawei. It connects to S3C2440 mainboard via USB interface. The downlink rate is 3.1 Mbit/s and uplink rate is about 1.8 Mbit/s. Variety of operating systems are supported. Ethernet module is designed with DM9000 network card chip to adapt to 10/1000 M network. It is also easy to be transplanted to different operating systems.

2) Perception node.

As to poultry house environment monitoring, the most important parameters include temperature, humidity, light as well as NH3 concentration and CO2 concentration. The site image can also help users to acknowledge site information clearly. Therefore, the perception node structure is designed as Fig. 3 shows. It mainly contains micro-controller platform, wireless communication module, intelligent power module, battery monitoring module, status indicator module as well as temperature/humidity sensor, light sensor, NH_3 concentration sensors, CO_2 concentration sensors and camera array. Its main function is to collect environmental parameter information and gather data to coordinator gateway via wireless communication module.

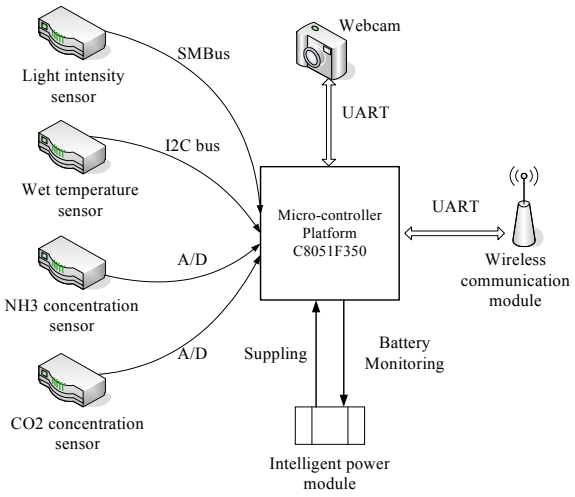

Fig. 3. Perception node hardware structure.

2.3. Software Architecture

According to information flow as data collection, transmission, storage and distribution, the designed system software architecture is shown in Fig. 4 based on system network architecture. Software system consists of three parts, namely monitoring center server program, coordinator gateway program and perception node program. The monitoring center server program is divided into Web server application program, SQL database as well as send receive processing program. Data from perception node is stored in database. Database monitors operation on Web server and trigger corresponding commands. It then control perception nodes through send receive processing program.

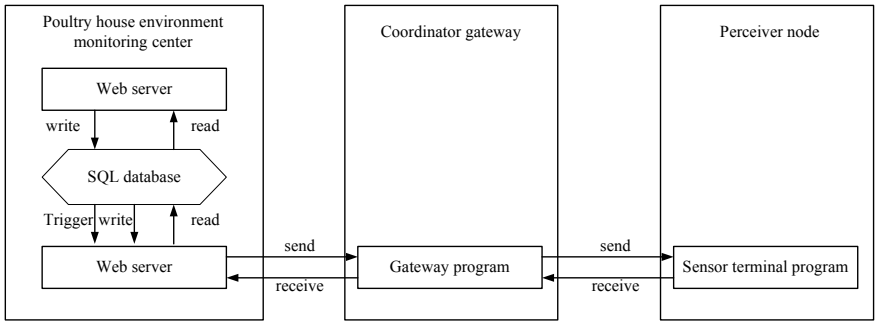

Fig. 4. System software architecture.

1) Monitoring center server.

The monitoring center server is constructed with Tomcat 7.0.10. Tomcat is a lightweight application server. It has advantages that occupy little system resource, good scalability and support load balancing, thus fully meeting system requirements. The server program can be divided into two parts of data storage and control command sending as shown in Fig. 5. Server send receive program store received sensor data and images into database. Web server loads database to provide users with browser services. After user login, they can operate database with commands. Server processing program monitors database operations real-time. Then it configures corresponding commands and distribute to gateway.

2) Perception node software architecture.

Based on hardware structure of perception node, its software architecture is shown in Fig. 6.

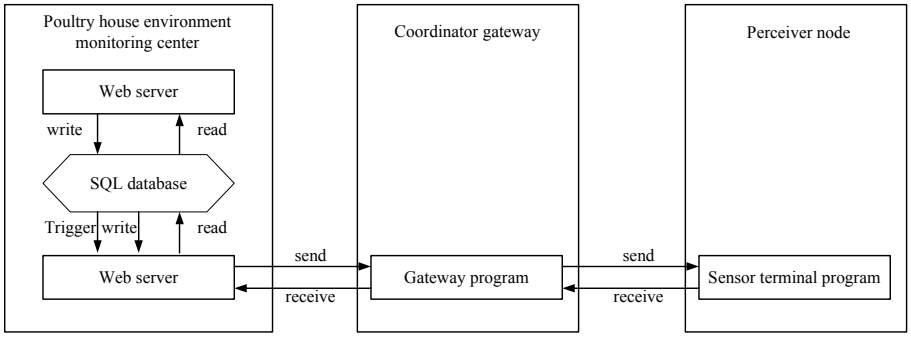

Fig. 5. Server software working flow.

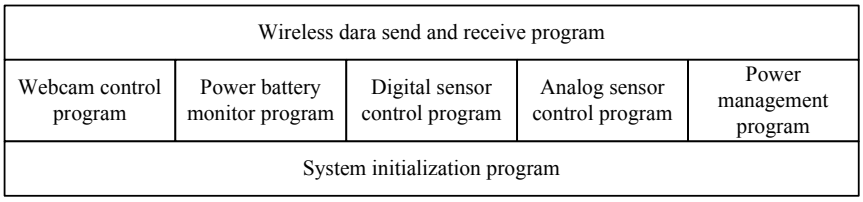

Fig. 6. Perceive node software architecture.

As the sensor array contains two different interface types, namely digital and analog. The control program can be divided into digital sensor control program and analog sensor control program. The functions are as following:

1) System initialization program. The system initialization program on micro-controller platform contains C8051F350 MCU, general system clock, general I/O pins, timers, A/D conversion as well as various initialization settings on communication interfaces.

2) Web camera control program. It implements parameter setting, instruction receive as well as data transmission on serial ports.

3) Battery capacity monitoring program. It conducts real-time monitoring on battery capacity. When the capacity is insufficient, it sends alarm to monitoring center.

4) Power management program. It supplies power to sensor array. With TDM energy saving program, it reduces power consumption of sensor nodes.

5) Digital sensor control program. It completes digital signal finishing from digital temperature and humidity sensor, light intensity sensor.

6) Analog sensor monitoring program. It finishes signals from CO_2 sensor, NH_3 sensor and other analog sensors.

3. System Implementation

Based on determined software development environment and language, the software design idea and implement method of monitoring server, coordinator gateway are described here. Related flows are also provided.

3.1. Hardware Implementation

Hardware design is divided into two parts of coordinator and perception node.

1) Coordinator Gateway.

Hardware diagram of coordinator is shown in Fig. 7. It is used to implement connection among ZigBee network, Internet and 3G mobile communication network. Corresponding functional modules are carried on micro-controller platform.

Considering about functional requirements and post-expansion of coordinator gateway, the paper selects powerful and widely used S3C2440 processor as micro-controller platform. Corresponding devices are expanded. It transplants Linux core and develops appropriate drive program. The chip S3C2440 is based on ARM920TDMI, supporting LCD controller of TFT. It also has MMU unit and fluent external

interfaces to meet embedded application needs. The software is based on Linux system with good stability and security.

2) Perception node.

The perception is designed as Fig. 8 shows. The node takes C8051F350 MCU as core, surrounded by sensor array, XBee wireless communication module, web camera and intelligent power module. The sensor array consists of a series of sensors to measure light, CO2 concentration, air temperature humidity, NH3 concentration as well as cameras. In order to effectively prolong terminal node working time, we designed and implemented sensor TDM program. According to actual test, it can effectively saving energy about 45 %-50 %.

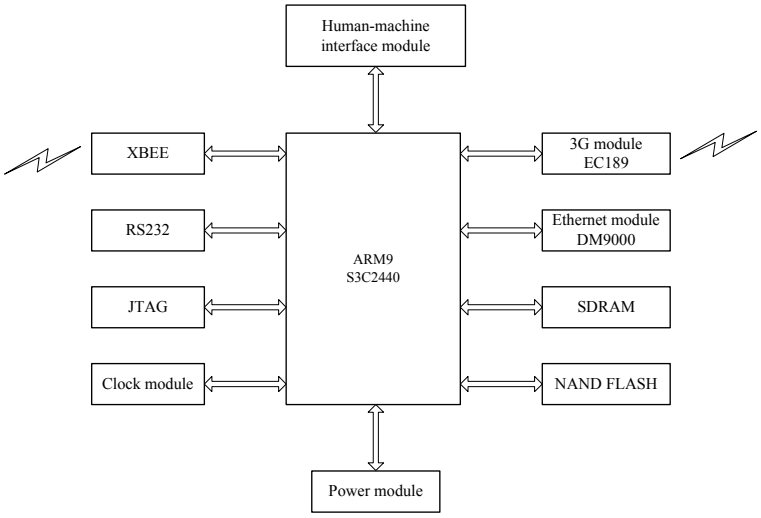

Fig. 7. Perceive node software architecture.

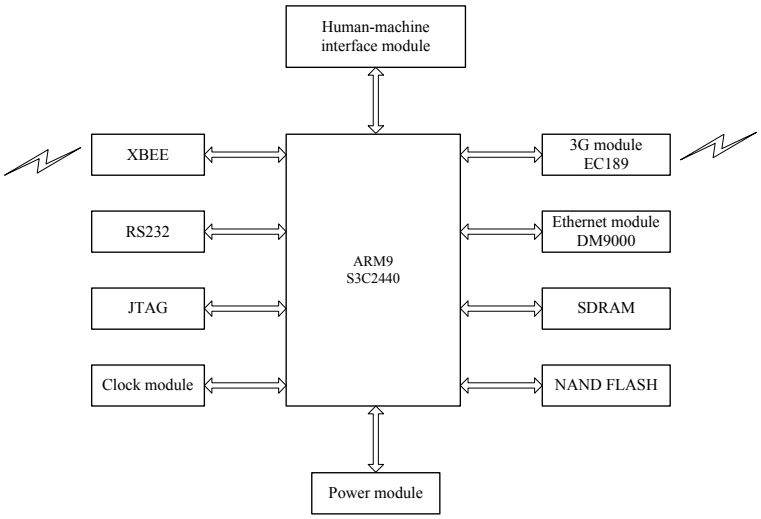

Fig. 8. Sensor node diagram.

3.2. Software Implementation

Due to different platform, the server, gateway and perception node use different development platform. Server application program uses VC++, which is mainstream development tool for Windows programs. There are many resources that can be used [5]. Coordinator gateway program uses Fedora 9.0 operating system to develop embedded application program. Perception node program uses μVision4 IDE windows develop platform of Keil. It integrates editor, project manager as well as various compile tools to support C8051F350 MCU [6].

1. Server software implementation.

The server send receive processing program is designed with Windows socket. Using CSocket class provided by MFC, the coordinator gateway serve as client and environment monitoring center as server.

The functions of server send receive processing program are as follows:

1) Receive data from gateway, process it and store in database for call by Web server.

2) Monitor changes in database. Configure corresponding instructions and send to control test, restart of perception nodes. User sends control instructions to server through network browser. The write operation in database triggers process program in server. After perception node collects, return image data to server for processing and storage.

2. Gateway software implementation.

Gateway software contains send receive program and embedded Web server. Embed Web server is used for wireless sensor network remote maintenance. It facilitates staff to modify gateway IP address, reboot system work or check network status via browser. Send receive processing program is responsible for deal with serial data from WSN and instructions from monitoring center server. So it is divided into two parts of serial and Ethernet, which runs with multiple-thread mode [7]. The work of embedded Web server can also be divided into server configuration and Common Gateway Interface (CGI) program design.

Embedded Web server mainly completes functions as following:

1) Respond real-time HTTP requests from multiple clients and establish connection for each one.

2) Monitor devices in real-time. Configure and record related parameters online.

3) Ensure consistency of device access from different operating system or clients.

Commonly used embedded servers include Apache, Oracle IAS, Tomcat and BOA. Where, BOA is a single task HTTP server. Different from other Web servers, it does not create process for each link access to server, let alone multiple process reusing. It just provides connection service for ongoing HTTP service and open process for CGI. It occupies less system resources, thus be commonly used in embedded design. The paper also implements embedded Web server design with it.

4. Conclusion

Aiming at modernization of poultry monitoring, the paper brought out a poultry environment monitoring system based on IoT. As to system architecture, multiple-site, multiple-parameter and distance information collection was achieved. Access manner of Ethernet and mobile communication network as well as mass data storage and Web server data distribution make wide range data monitoring and sharing reality. In hardware design, modular idea was carried out to design perception node and gateway in network construction layer. The principle of layering was used to perform software module design, including perception node, micro-controller platform of gateway. Related working flows were also given. The future research will focus on environment control to work for loop mechanism from environment information feedback to parameter adjustment, thus effectively regulating environment parameters.

Acknowledgements

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