A Crop Monitoring System Based on Wireless Sensor Network

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Abstract

This paper proposed an agricultural application of wireless sensor network. The main work is to implement two types of nodes and building sensor network. The hardware platform is constituted by data process unit, radio module, sensor control matrix, data storage flash, power supply unit, analog interfaces and extended digital interfaces. The software system adopts TinyOS which is composed of system kernel, device drivers and applications. Energy-saving algorithm is implemented in the software system. The monitoring network adopts two networking protocols. The Collection Tree Protocol is a tree-based collection protocol which consists in collecting the data generated in the network into a base station. The dissemination is the complementary operation to collection. The goal of a dissemination protocol is to reliably deliver a piece of control and synchronization instructions to every node in the network. The experimental results show us that the monitoring system is feasible for applications in precision agriculture.

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Selection and/or peer-review under responsibility of the Intelligent Information Technology Application Research Association.

Keywords: Wireless sensor network; TinyOS; sensor node design; internet of things; Precision agriculture

1. Introduction

The agriculture is in the transition from traditional agriculture to modern agriculture currently. Internet of things (IOT) for agriculture will play greater role for the promotion of agriculture informationize, including the construction of agriculture information network, the development of agricultural information technology and the agricultural use of information resources. The application of intelliSense, identification technology and pervasive computing, ubiquitous network integration applications of IOT will promote the development of smart agriculture and precision agriculture.

The crop monitoring system has its practical significance as a large-scale application of agriculture IOT [1]. As the global climate changing, not only a wide range of research and study of the crop growth is needed, the small scale environment for the growth of crops needs to be understood. The growth pattern and environmental parameters of crop growth provides scientific guidance and countermeasures for
agricultural production. An environmental parameter model of different regions of crop growth pattern of different environments can be established to improve the overall efficiency of agriculture.

The platform for the crop monitoring system implements two types of nodes and accomplishes the system networking. The environmental parameter acquisition platform collects meteorological and soil information such as temperature, humidity, wind, air, rainfall, soil ph and so on [6]. The image capture platform obtains crop growth images. The growth of crops and growing conditions can be observed directly. A large number of nodes form the agricultural condition monitoring sensor network, and then access to the internet.

The rest of this paper is organized as follows. In section II the design of hardware platform are introduced. In section III the architecture of scalar sensor node is proposed. Then the design of image sensor node is proposed in section IV. In section V the system software is introduced. Section VI presents the experimental results. Finally, we conclude the paper.

2. The design of hardware platform

2.1. Requirements

In the first place, the main wheat producing areas of China covers a wide field. The coverage of the same cropland must be representative. Secondy, the sensor platform need to be of universal property and referential for different crop of different areas. The platform nodes should establish low power consumption and adapt for the long time-unattended use in the field. The nodes need to be of low-cost and work stably and reliably in a variety of outdoor conditions.

2.2. Design Target

The design targets include platform targets and wireless sensor network targets. The platform is of wireless application and low-power consumption. The sensor network accomplishes two-way data transition and data acquisition.

- The monitoring nodes adopt wireless communication. The communication band is 433MHz/2.4GHz. The communication distance is about 1km. The data rate is 250kbps. The nodes support the integration of GPRS/CDMA terminals for the extended applications.
- The sensor platform accomplishes universal application. The platform provides rich interfaces for the collection of digital data, analog data and pulse data. The analog data is voltage or current. The input range is 0-3.3V or 4mA-20mA.
- The platform is low power consumption. This is a general requirement. The platform is powered by 3.3V, 5V and 12V. The sensors are switched regularly and dynamically. The cycle length and frequency can be regulated to adjust the sensors’ suspend mode.
- The sensor network meets the requirements of two-way communication. The moisture growth of the seedlings collected is sent to the host server with CTP protocol. The server distributes control instructions and synchronization instructions.
- There are so many nodes and so much data in the sensor network. Data security is taken into consideration both the data storage and transmission. The data flash for data cache is integrated in the platform. Not only the nodes but also the gateway accomplish data backup to ensure data security.
- The agricultural monitoring network is low-cost, stable and reliable. The nodes can adapt to complex outdoor conditions. The key component is a SoC of intellectual property. The communication technology and software system is developed by me.
3. The architecture of scalar sensor node

The crop monitoring network system is mainly composed of seven parts [2]. The data process unit processes all the information and manipulates all the peripheral devices [3]. The RF module transmits the messages collected by sensors. The sensor control matrix is in charge of sensors switching to accomplish low power consumption. The flash is data cache to ensure data security. The platform is powered by DC source or solar battery through a Multi-level voltage in 3.3V, 5V and 12V. The environment parameter is voltage or current signal. The extended digital interface is prepared for digital sensors that adopt digital protocol. The architecture of the platform is shown in Figure 1.

![Figure 1 The architecture of hardware platform](image)

3.1. Data Process Unit

This unit is mainly composed of ATmega128A. This MCU is a High-performance low-power 8-bit Microcontroller. The architecture is advanced RISC. The In-System Self-programmable Flash program memory is 128K Bytes. The In-System programming interface is SPI compatible. It also has 8-channel, 10-bit ADC and dual programmable serial USARTs. Its operating voltage is 2.7-5.5V. There are also some periphery circuits such as crystal oscillator circuit and reset circuit. All the data or field-environment signals acquired by the sensor will be processed by the MCU. ATmega128 also controls devices on the platform. The crystal clock is 7.3728MHz. The basic peripheral circuits include reset circuits, clock circuits and signal lights.

3.2. RF Module

This unit is mainly composed of CC1101. CC1101 is a low-cost sub-1 GHz transceiver designed for very low-power wireless applications. The circuit is mainly intended for the ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency bands at 315, 433, 868, and 915 MHz. The main operating parameters and the 64-byte transmit/receive FIFOs of CC1101 can be controlled via an SPI interface. CC1101 has high sensitivity and low current consumption. The received power reaches to -166 dBm at 0.6kBaud, 433MHz. The current consumption is 14.7mA in RX, 1.2kBaud, 868MHz. CC1101 has a variety of modulation such as 2-FSK, GFSK, 4-FSK or MSK to assure the transmission quality.
3.3. Sensor Control Matrix

Different sensors work and different environmental parameters need to be collected. The sensors are switched regularly and dynamically. The cycle length and frequency can be regulated to adjust the sensors’ suspend mode. A transistor amplifier circuit drives the relay switch. The switching circuit is shown in Figure 2.

![Figure 2 The circuit of sensor control matrix](image)

3.4. Data Storage Unit

This unit is composed of AT45DB041D. It is a serial-interface flash memory. The memory is organized as 2048 pages. The device operates from a single power supply for both program and read operations. The AT45DB041D is enabled through the chip select pin and accessed via a three-wire interface consisting of the Serial Input, Serial Output, and the Serial Clock.

3.5. Power Supply Unit

The platform is powered by DC source or solar battery. Different modules or chips need multi-level voltages. The DC source is 12V. Though LM2575-5V, it outputs 5V. Though AS1117-3.3, it outputs 3.3V. The 3.3V is provided for MCU, RF module and data storage flash.

3.6. Analog Interfaces

The environmental parameters gathered by the special sensors are mostly meteorological and soil information. The range of the input voltage is 0V-3.3V. The range of the input current is 4mA-20mA. Take the accuracy and input range of the ADC into consideration, the match of voltage and current is accomplished. The input voltage range is 0-3.3V. In order to improve the utilization of ADC channel, each ADC port is voltage and current compatible. When the input signal is voltage, the switch Q1 is disconnected. The signal is sent to the ADC directly. When the signal is current, the Q1 is closed. The current turns to voltage after a 150 Ω resistor. The pulse signal is connected to the interrupt port of the MCU. According to the counter, we can figure out the rainfall. The analog interface is shown in Figure 3.
3.7. Extended Digital Interfaces

The extended digital interface is prepared for digital sensors that adopt digital protocol. Some extended digital interfaces are reserved.

4. The design of image sensor node

This kind of nodes is made up of an independent intellectual property SoC THLK2405 and CMOS image sensor OV7640. An image processing module is integrated in the SoC THLK2405. The image subsystem is mainly comprised of three parts: the control circuit of image sensor, data acquisition circuit and compressor circuit. The OV7640 provides full-frame sub-sampled or windowed 8-bit images in a word range of formats; it is controlled by Serial Camera Control Bus interface. OV7640 has an image array capable of operating at up to 30 frames per second (fps) with complete user control over image quality, formatting and output data transfer. All required image processing functions, including exposure control, gamma, white balance, color saturation, hue control and more, are also programmable through the SCCB interface. Figure 4 shows the front and reverse sides of the image node.

5. System software

5.1 The architecture of operating system

The operating system in use can be divided into two parts: the system kernel and applications. The system kernel provides some basic functions such as process management, task scheduling and system initialization. The kernel also drives hardware resources such as processor, radio modules and sensors. The device drivers that provide interfaces for the call of applications are packaged. It also provides a common wireless communication protocol stack, which provides a variety of options for the interaction between nodes. The system kernel and interfaces provided for users present flexible choices for secondary development. While the application control the system logically by calling the system hardware resources provided by the kernel interface and transmission protocols. The tasks of the system software include
environment information collection, information transmitting and the controlling of information collection parameters [5]. The system functions realize and accomplish energy conservation.

5.2. Software control flow

The control flow of source node is shown as Figure 4. The control flow of sink node is shown in Figure 5.

Figure 5 The control flow of source node

Figure 6 The control flow of sink node
5.3. Low power consumption

The nodes is always in a state of low-power listening. Normally the nodes are under low-power state while listening to the message leading [4]. The wireless module is opened and waits for message transmission after the preamble is received. If no message is received within the specified time, there is no need to send their own messages, the nodes turn back to low-power state and continue to monitor. Usually the sensor is in a quiet state until the timer triggers them. The sink nodes distributing instructions to change the source nodes’ sampling period and preheating time depend on the monitor’s real-time requirement and the type of sensors. The sampling frequency is adjusted dynamically to accomplish low-power consumption.

6. Experimental results

The crop monitoring network is deployed in Beijing, Henan and Shandong Province etc. We have gathered Temperature and humidity data and crop growth images. Figure 7 shows the temperature changing curve within 24 hours detected from four observation points. The four curves change consistently and reasonably. The acquisition data reflects the real temperature trend appropriately. Figure 7 shows an image captured the crop growth. We can observe the crop intuitively and distinctly. The image helps experts to make easy and accurate judgments in time. This two figures show the correctness and feasibility of the monitoring system.

7. Conclusion

This paper presents a crop monitoring system based on wireless sensor network. IOT has important significance in promoting agricultural informationization. Two types of nodes are implemented and the system networking is accomplished. The architecture of scalar sensor node and image sensor node and the system software are introduced. The experimental results show that this monitoring system works
correctly and reliably. The design objectives are basically realized and the design requirements are met. Some of the tasks for future experiments and researches: Further increase the stability and reliability of the work. Adapt to complex environmental changes. Improve the performance of low-power consumption.

Acknowledgement

This work was supported by Special Scientific Research Funds for Commonweal Section (200903010), National S&T Major Project (2009ZX03006-004) and Doctoral Fund of Ministry of Education of China (20070003098).

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