

A Study of Agricultural Meteorological Monitoring System Based on Wireless Sensor Networks

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Abstract

In order to keep the sustainable development of agricultural industry, monitoring the four basic essential elements' changes, which are temperature, humidity, light intensity, carbon dioxide, and applying the corresponding solution is really necessary. An agriculture meteorological monitoring system with ZigBee wireless sensor networks (WSNs) and wireless communication technology is designed in this paper. Sensor nodes are distributed in the measurement area and form a self-organizing network. The sink collects information which transmitted from sensor nodes and then, sends the information to the server. Server will summarize the information, then taking analysis and processing. At the end, the server will give some corresponding warning and forecast. The cost of this system is low and could improve the accuracy and timeliness in agricultural meteorological monitoring.

Key Words: ZigBee, WSNs, Agricultural Meteorological Monitoring

1. Introduction

Crops growth and yield is often affected by some meteorological factors [1]. Therefore, it is necessary to strengthen the essential elements monitoring in agricultural industry. Essential elements contain temperature, humidity, light intensity and carbon dioxide. With the development of wireless sensor networks [2-6] and requirements of agricultural meteorological monitoring, an agricultural meteorological monitoring system with wireless sensor networks is designed to realize the intelligent agriculture monitoring. The system can predict environmental trends and the corresponding impact on agriculture. By collecting the information like this, people can take appropriate measures to ensure stable and high yield of crops. The system could improve accuracy and timeliness in agricultural meteorological monitoring.

Cluster network is selected since it has simple construction, with multi-function and good fault-tolerance. When one or more nodes are damaged, the network could form a self-organizing network again and still functional.

The system combines ZigBee wireless sensor networks with wireless communication technology, sends parameters to mobile phone users through GSM network. The system not only can provide monitoring and warning, but also can give another way to provide intelligent

prediction so that the user can be able to do the remote monitoring. The architecture of system is illustrated in Figure 1.

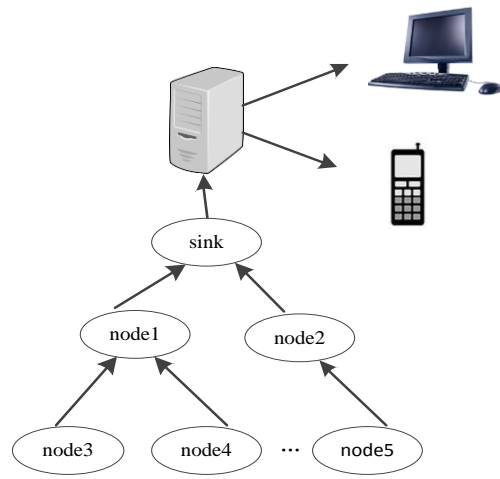


Figure 1. Architecture of Agricultural Meteorological Monitoring System

The system provides two kinds of monitoring schemes. The first scenario designed a software application to display the monitoring interface on computer. The sink collects information which transmitted from sensor nodes and then sends the information to the server. User could check each node's situation through the software. The second scenario uses mobile phone text to transmit the warning. Computer will summarize the information, then taking analysis and processing. Once it is beyond the threshold, the system will send mobile phone text to inform the user.

2. Design and Implementation

In our system, the nodes can collect temperature, humidity and light intensity information. We use DHT11 to collect temperature and humidity information and ON9658F collect light intensity information. CC2430 is used as the processor module and communication module of the nodes and provides the power that the system need through the battery. The structure of nodes is illustrated in Figure 2.

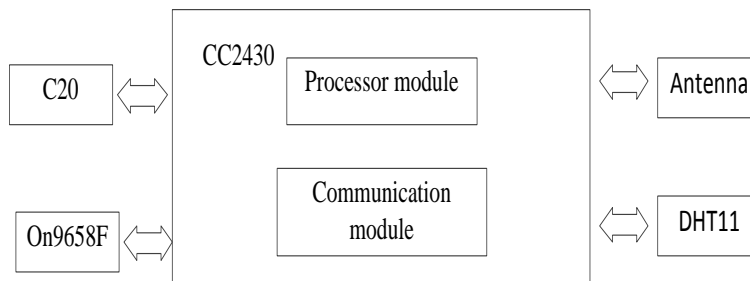


Figure 2. The Structure of Nodes

2.1. Some Work in Hardware

(1) The processor

The CC2430 is a true System-on-Chip (SoC) solution specifically tailored for IEEE 802.15.4 and ZigBee™ applications. The CC2430 combines the excellent performance of the leading CC2420 RF transceiver with an industry-standard enhanced 8051 MCU, 32/64/128 KB flash memory, 8 KB RAM and many other powerful features [7]. The CC2430 has high performance, low power and have well anti-noise performance. We can use few external components to build ZigBee nodes.

The sensor nodes were composed of CC2430 and other external circuits such as crystal oscillator, bias resistance and coupling capacitance. Barron circuit is used as the node's antenna part, Barron circuit were composed of discrete inductors and capacitance. Using two capacitance and a crystal oscillator which in 32MHz to make up the clock circuit. Three lights are designed to indicate the working status of the node power supply status, networking status and communication status. The schematic diagram of CC2430 is illustrated in Figure 3.

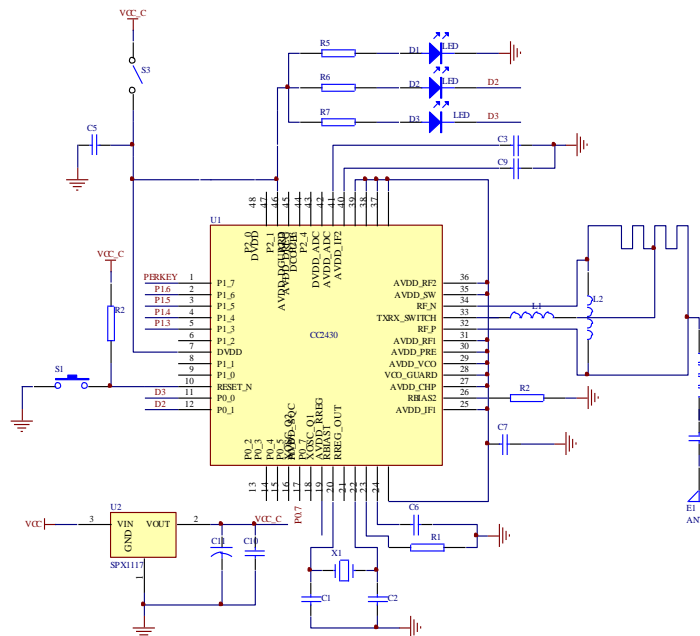


Figure 3. The Schematic Diagram of CC2430

(2) Light sensor part

On9658F is used here to collect light intensity information. The On9658F is a photoelectrical integrated optical sensor, with double sensitive receiver, and add visible light pass and N-IR cut optical filters. It is highly sensitive to visible light, and varies linearly with illumination changing [8]. The On9658F is widely used in digital product and industry device. We know the voltage is proportional to current, and the current is varies linearly with illumination changing. So the voltage also with illumination is changing. We use the transformation of voltage to calculate the value of light intensity. The schematic diagram of On9658F is illustrated in Figure 4.

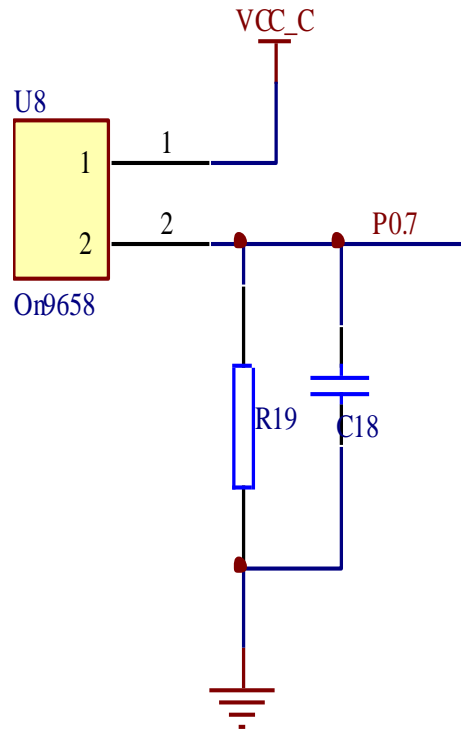


Figure 4. The Schematic Diagram of On9658F

In CC2430, the ADC supports up to 14-bit analog-to-digital conversion. ADC is used to process voltage value which was send by On9658F. In the end, the actual light intensity value was calculated.

(3) Temperature and Humidity Sensor

DHT11 temperature and humidity sensor is a complexed temperature and humidity sensor which contains a calibrated digital signal output. Its professional digital module technology ensures the high reliability and excellent long-term stability[9]. DHT11 was widely used for its small size, low power dissipation and strong anti-interference. DHT11 includes a resistive element and a NTC wet and temperature measuring devices to collect temperature and humidity information.

DHT11 uses 1-Wire Bus technology. In other words, DHT11 only need one cable to finish data transmission and sensor control. After power it on, DHT11 need 1s to complete the initialization. At the same time, DHT11 will collect and record temperature and humidity data. This time, the pins of DHT11 is at the state of input. When we give DHT11 a low level signals that is greater than 18ms, DHT11 will get into the output state. Then, DHT11 sends 80 us high level to the processor and processor responds with 80 us high level to DHT11, signing the preparation is ready. After that, data will be transmitted from the DHT11 to the processor and DHT11 will get into another turn of data transmission

In this system, DHT11 is used to collect temperature and humidity information. The first pins is connected with working voltage, second pins connects with data communication and fourth pins connects with grounding. The schematic diagram of DHT11 is illustrated in Figure 5.

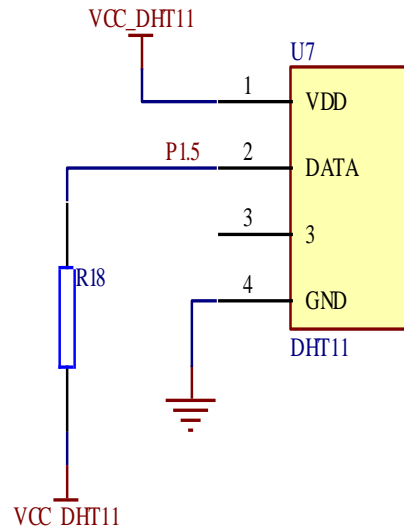


Figure 5. The Schematic Diagram of DHT11

(4) Carbon Dioxide Sensor

In this system, C20 is used to collect carbon dioxide information. C20 is made by a company called GSS. C20 was used in system for its small size and strong anti-interference. It could be well used in agriculture meteorological monitoring. The second pins is used to send data and third pins used to receive data. The schematic diagram of C20 is illustrated in Figure 6.

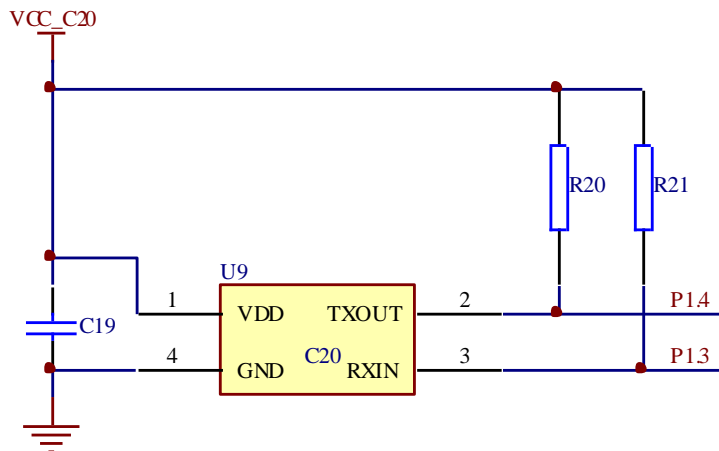


Figure 6. The Schematic Diagram of C20

2.2. Some Work in Procedure

The system adopted cluster network. Routing nodes and common nodes are set according to certain proportion. Each node has different task.

(1) The procedure design of sink

The task of the sink is completing the form of the network, searching for a new node, collecting node data from the net and sending them to the server. The procedure design of sink is illustrated in Figure 7.

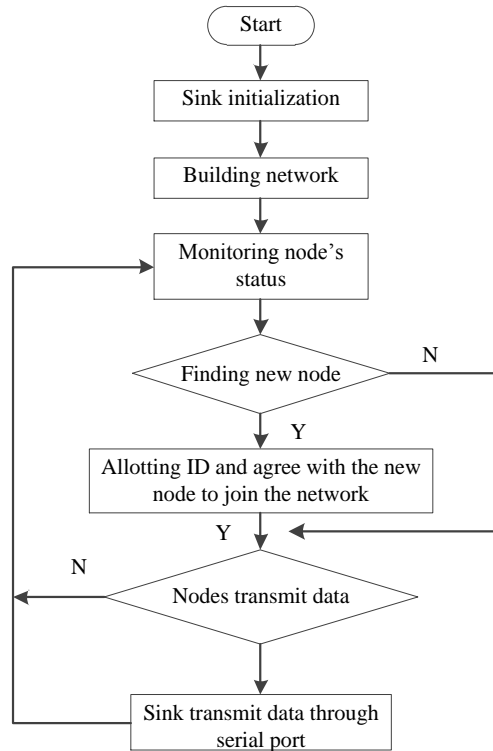


Figure 7. The Procedure Design of Sink

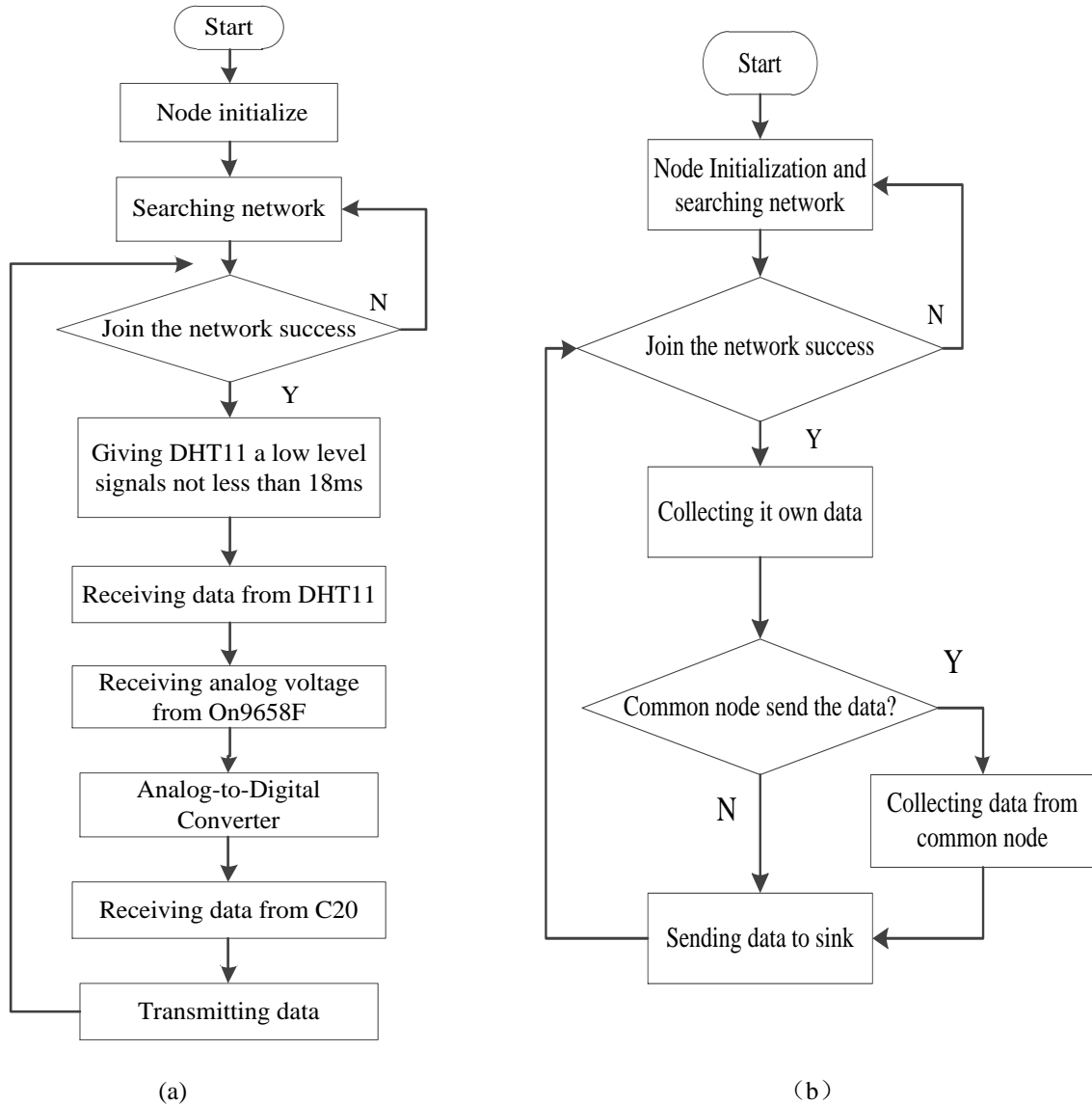
At the beginning, sink need to have an initialization. After initialization, the sink will monitor the nodes' status. If the sink find a new node, after checking whether it is connected, if not, it will allot ID and agree with the new node to join in the network. After that, the nodes will transmit data to the sink. In the end, the sink will transmit data through serial port.

(2)The procedure design of common nodes and routing nodes

In this system, cluster network is applied. So, routing nodes and common nodes will be set according to a certain proportion. In order to prevent a node can't transmit the data when its routing node have a blockage or damage, the terminal nodes will contain the search function. If a routing node is damaged or stop working, its common nodes will search a new routing node.

The design procedure of common node is illustrated in Figure 8(a). The nodes will start with an initialization. After the initialization is done, the node will search the network and send a request to join in the network. Then, the node will give a low level signal no less than 18ms to DHT11. After this, DHT11 will transfer into output state and send signal to CC2430. After accepting the data from DHT11, the node will receive voltage from On9658F and save the data after an analog-to-digital operation. In the end, Node will transmit data which it received and get into the next round of cycle.

For routing nodes in WSNs, it has similar process with common nodes. The difference is that it not only collects its own data but also collects other common node's data. At last, the nodes send the data to the sink. The design procedure of routing node is illustrated in Figure 8(b).



**Figure 8. (a) The Design Procedure of Common Node
(b) The Design Procedure of Common Node Routing Node**

2.3. Some Work in Software

In this system, a software application is designed as the final display interface. The software displays the data from the database. SQL Server is applied here to store the information which collected from the serial port. The software provides the following functions: (1) Dynamic displaying the temperature. (2) Showing data which from the database. (3) Statistical computing functions. (4) The software Settings function. (5) Controlling the status of collection. (6) Showing the status of collection. The software interface is illustrated in Figure 9.

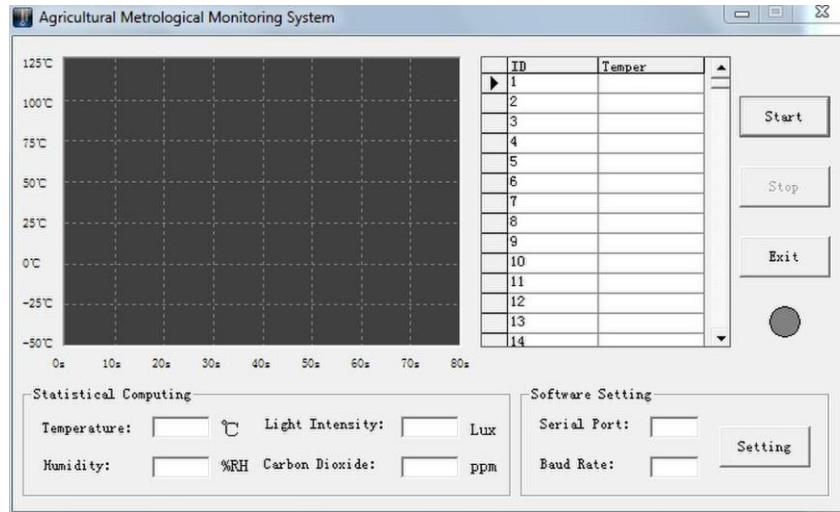


Figure 9. The Software Interface

In the system, computer will summarize the information, then taking analysis and processing. Once beyond the threshold, the system will use mobile phone text to tell the user. The software design is illustrated in Figure 10.

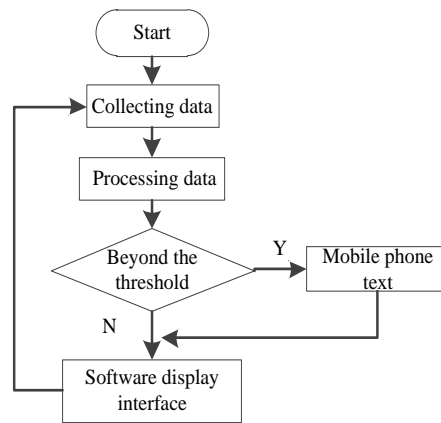


Figure 10. The Software Design

3. Experiment and Results

We deployed some nodes to validate the effectiveness of this system. The area of the test site is approximately 100 square meters. Set the sink as the center of the circle, 10 nodes (contain two routing nodes) are set around it. The distance between the each nodes is about 10 meters. After 20 hours, the experimenters found that the data packet transmitted stably and packet loss probability was low. The packet loss probability of nodes was between 2.07% and 7.08%.The packet loss probability of nodes is illustrated in Figure 11.

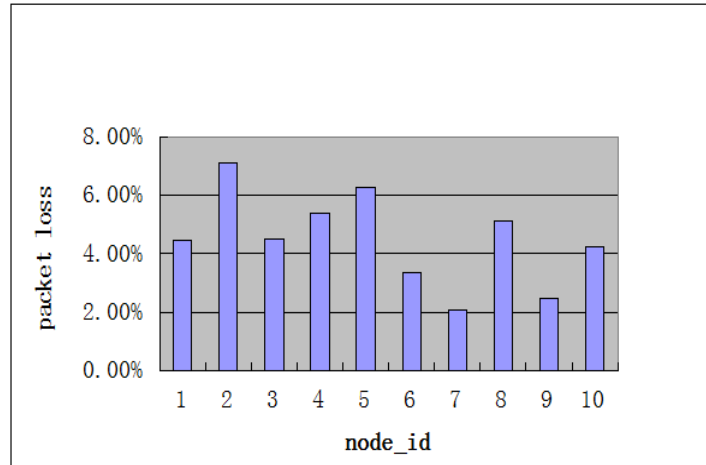


Figure 11. The Packet Loss Probability of Nodes

4. Discussion

In this system, CC2430 is used as the processor module and communication module of the nodes. The experimenters developed the nodes in the farmland and used DHT11 to collect temperature and humidity information, On9658F is used to collect light intensity information and C20 is used to collect carbon dioxide information. Collected information will be sent to the routing nodes first. And then, will be sent to the sink. At last, the information will be sent to the server. If the server received the information, SQL Server will store the information which collected from the serial port. The software could show the data from the database. In this design, accurately data can be acquired with low cost. Applying WSNs to the meteorological monitoring is an inevitable trend. With the development of micro-electronics, computer and wireless communication technique, WSNs will have much more application prospects. The agricultural meteorological monitoring system based on wireless sensor networks will be applied widely.

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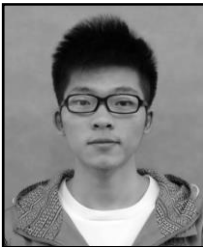
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