Greenhouse Environment Wireless Monitoring System Based on ZigBee Technology

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Abstract
One sort of greenhouse environment parameter monitoring system based on WSN is designed on account of problems of traditional greenhouse environment parameter monitoring system including complex wiring, high cost, poor monitoring flexibility and the disadvantage of high energy consumption of general wireless sensor network. System hardware mainly consists of CC2530 wireless sensor network transmission module, humiture sensor, carbon dioxide density sensor, etc. It utilizes protocol stack Z-Stack to make system underlying software and develops upper-computer software of greenhouse environment parameter monitoring system on the basis of VB software platform which help realize the real-time acquisition, transmission, storage and browse on greenhouse environment parameters. Experiment results show that utilizing wireless sensor network technology to do monitoring on greenhouse environment parameter simplifies measurement mode of traditional wired greenhouse environment monitoring system, leads monitoring area of the whole system to be more flexible and strengthens its expansion capability.
Key words: ZIGBEE TECHNOLOGY, CC2530 CHIP, TEMPERATURE AND HUMIDITY, CARBON DIOXIDE

1. Introduction

Application requirements of humiture monitoring raise high concerns in many fields. All of grain depot, greenhouse and industrial security monitoring system need to do real-time monitoring on humiture of environment. While most greenhouse monitoring systems still use CAN bus communication to monitor environment and transmit information. Greenhouse environment keeps features of high temperature, high humidity and high corrosion in which communication cable easily becomes aging thus influencing its reliability. In addition, parameter collection points present discrete distribution and strong movement in practical application, resulting in difficult wiring of traditional wired monitoring, increasing construction and maintenance cost and improving operational difficulty [1, 2].

Development of wireless sensor network and long-distance transmission technology provides realization approach for online real-time monitoring of system automation. Since 21st century, people has found and gradually done further research to apply wireless network technology to agriculture in which successful application examples have appeared. However, most applications just utilize the pattern of replacing wired connection with wireless communication. As one important information acquisition technology, wireless sensor network adequately fills gaps of traditional wireless technology such as high cost and being susceptible to disturbance and greatly extends network functions. In 2003 Business Week of America proposed that wireless sensor network technology is one of the four high technologies in 21st century and evaluated that it is one of the 21 technologies being the most influential and potential in the world [3, 4].

In recent years WSN has become one wireless network technology with rapid development. It perceives and monitors the environment region in real time through distributing sensor nodes in the main monitoring area so as to realize the seamless connectivity between people and monitoring area [5]. As a specific achievable form of WSN, ZigBee keeps several notable characteristics including low rate, low energy consumption, ad hoc network and self-repairing. In the meantime, ZigBee operates in the free spectrum 2.4GHz whose effective communication distance is 100m without any power amplifier equipment. This caters for the requirements of greenhouse monitoring system on communication distance [6, 7].

2. Overall Structural Design of System Hardware

2.1. Considerations on System Design

Hardware design of greenhouse environment parameter monitoring system based on wireless sensor network greatly influences working performance of the whole system. From many factors influencing system monitoring, this paper takes the following important ones into consideration in the design of system hardware.

(1) System needs to consider the effective utilization of energy. Meanwhile it has to take real time and accuracy of the monitored environment parameter information into account. For wireless sensor network system, energy consumption is the first being considered because it is the basic safeguard for normal operation of system. Therefore each node needs to periodically acquire and transmit data to guarantee low energy consumption. If interval between acquisition cycles was too long, its real time would become lower and important data would be missing. On the contrary, energy consumption would increase. Therefore at the beginning of the design, both indexes of energy consumption and transmission frequency must be balanced.

(2) During long-time monitoring process of sensor nodes, the following problems may occur, for instance, energy may be used up, breakdown and communication interrupt deriving from physical damage or external environment disturbance, etc. Therefore system monitoring should be protected from these factors as much as possible for the purpose of leading wireless sensor network to keep higher self-organization ability, reliability and fault tolerance.

(3) Because system needs setting in greenhouse for a long time, all hardware in the whole system should be heat-resistant, moisture-proof and sealed well in order to guarantee working life of system and its normal working ability in which the choice of circuit board material and wiring form should take external environment factor into account.

(4) Selection of system hardware has to consider the cost of sensor nodes as wireless sensor network consists of a large number of sensor nodes. While monitoring precision, quality and lifetime of system are ensured, production cost of each single node should be reduced to control the cost of the whole system.

2.2. General Design

Greenhouse monitoring system of this design is mainly composed of sensor nodes, routing nodes, coordinator and subscriber terminal. ZigBee terminal nodes linked with various kinds of sensors distribute on each monitoring point in the greenhouse that are responsible for collecting data and transmit it to routing nodes. Routing nodes take charge of transmitting data to coordinator through ZigBee wireless sensor network and they themselves also communicate with each other so that effective communication distance of system could be considerably extended. Coordinator nodes communicate with subscriber terminal through RS232 serial port, receive commands and upload feedback information. Finally subscriber terminal finishes showing and storing data.

2.3. Design of ZigBee Transceiving Module

Both terminal nodes and control nodes utilize CC2530 as the main control chip in data acquisition of this design. CC2530 internally integrates RF transceiver meeting standard of 2. 4G IEEE802. 15. 4. After ZigBee protocol stack is added on software, ZigBee would realize networking. This chip has built-in 32M crystal oscillator and RC oscillators of 16M and 32.768K. Under different application requirements, corresponding oscillators would be chosen to reduce energy consumption. 32.768K RC oscillator would be utilized under sleep mode. CC2530 also has built-in abundant communication interfaces, for example A/D analog-to-digital conversion interface, SPI interface and UART universal asynchronous transceiver which cater for application requirements of most sensor interfaces. Therefore the application of this chip helps acquisition of system to keep good expansibility. Fig.1 shows us node structure.

2.4. Design of Sensor Module

2.4.1. Temperature Sensor Circuit

This design selects DS18B20 to be temperature sensor which is a kind of single bus data temperature sensor with extensive measurement range and high precision. During communication only one communication line is needed instead of clock line which would communicate with any ordinary IO of CC2530. Its peripheral circuit configuration is very simple as shown in Fig.2 [8].

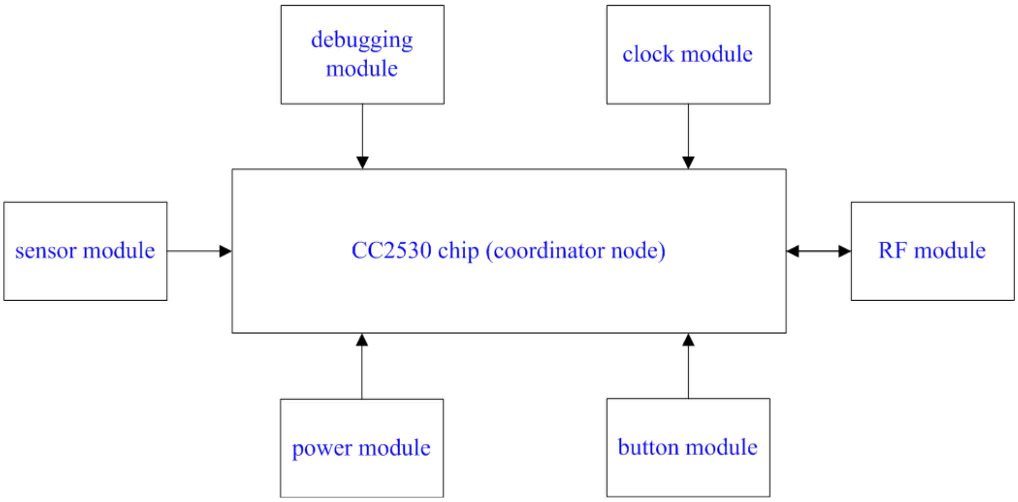

Figure1. Schematic Diagram of Node Hardware Structure

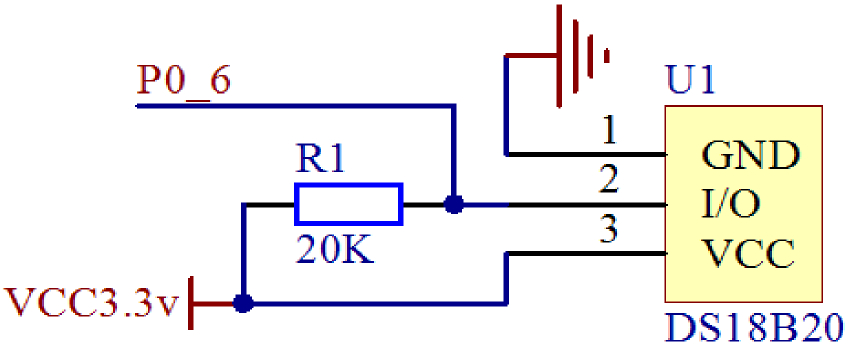

Figure 2. Circuit of Temperature Sensor Acquiring Temperature

2.4.2. Circuit of Temperature Sensor

Utilize HS1101 produced by Humirel Company of France to be humidity acquisition sensor whose measurement range is from 0% to 100% RH. Its error is ± 2% RH and annual drift distance is short. Capacitance of HS1101 presents isotropic change with the changing of air humidity. Put temperature sensitive capacitance into oscillating circuit in which different processing modes show the composition of oscillating circuit. Bridge oscillator consists of operational amplifier, resistance and capacitance which helps rectify, amplify and analog-to-digital convert the produced sinusoidal wave voltage signal to become digital signal. It could also consist of 555 timers. As capacitance value and voltage are inversely proportional, the changing frequency of capacitance converting into voltage signal would be directly received by the computer [9]. This design applies the second method whose working mode is simple and convenient. It also keeps wide range of application. Fig.3 explains that.

2.4.3. Carbon Dioxide Density Acquisition

It is well-known that natural light contains light of various wavelengths. Infrared absorption gas sensor is developed basing the fact that gas absorbs light of different wavelengths in different degrees. Different gases are composed of different kinds and different numbers of elements which determines that the infrared light would be absorbed to varying degrees through different gases thus leading to different kinds of absorption and transmission spectrum. Towards one material, light of some wavelengths may be mostly absorbed, making light intensity become week. While the absorbed light forms an absorption spectrum on the surface of material. The same material would present different absorption degrees on light when it exists in different densities. The higher density, the more light absorbed. They are directly proportional. Therefore detection on gas density also means detecting the spectrum and degree of gas absorbing infrared light.

Do analysis on the spectrum absorbing infrared light thus acquiring a value. This value is converted into corresponding electric signal. Through digital filtering and amplifier circuit, it is finally transmitted to single chip. After being done with temperature compensation, it would be output by single chip system [10]. Detection circuit of carbon dioxide density is seen in Fig.4.

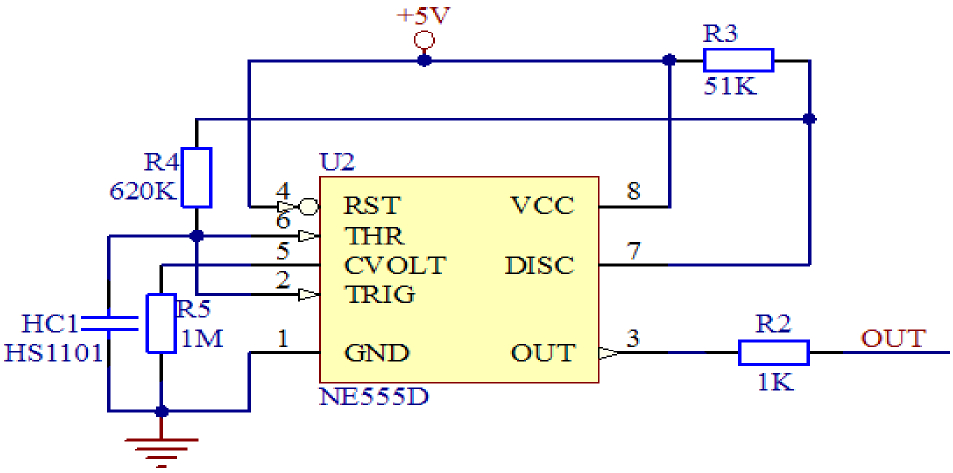

Figure 3. Humidity Measurement Circuit

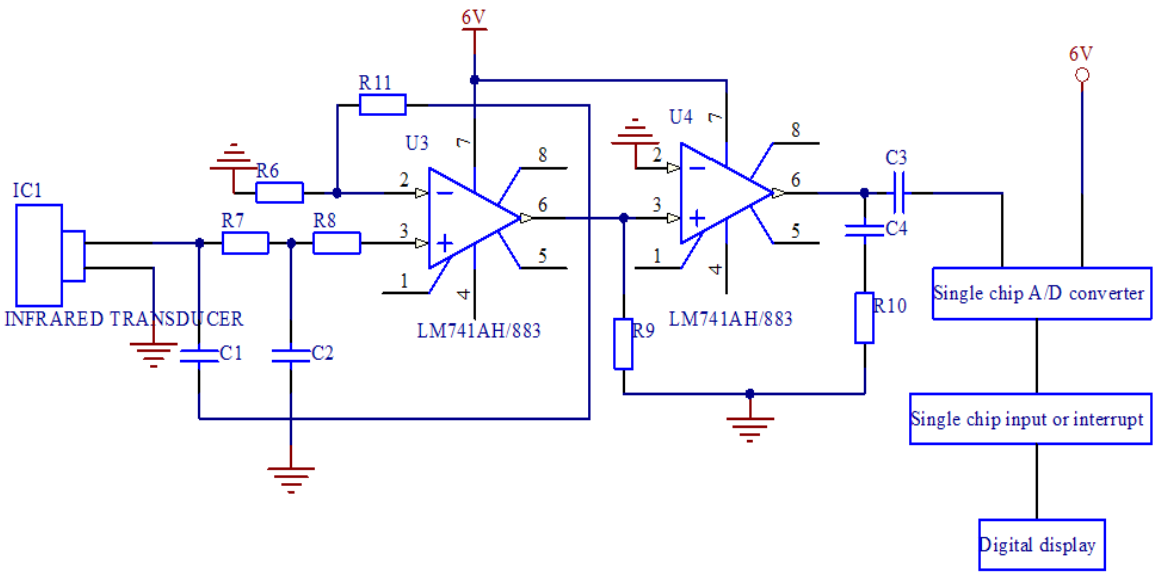

Figure 4. Carbon Dioxide Density Detection Circuit

3. Software Design of Nodes

Software of each node in this system is developed according to Z-Stack-CC2530-2.S.la Protocol Stack of TI Company. During the application, IAR Em-bedded Workbench Development Environment is utilized to do program compilation and debugging on coordinator, routing nodes and terminal nodes. Finally the program is written into CPU chip to realize different functions of each node. Z-Stack has written source codes of some protocols for users. Users only need to put their focus on development application layer which reduces development cycle and input, leading its solution to be more convenient and efficient. Fig.5 shows the procedure of coordinator node software.

Node program applies the task operation mechanism of OSAL (operating system abstraction layer) which centers on multi-task resource allocation and realizes functions of some similar operation systems. When system begins operating, node hardware would be initialized. Subsequently all layers of protocol stack are initialized and node properties are registered. Finally coordinator establishes network and routing nodes apply for accessing network. Each node enters OSAL operation system loop and calls corresponding event handlers based on specific conditions after network is established. Fig.6 is the flow diagram of routing node software.

4. Development of System Upper-computer Software

Upper-computer management software of greenhouse environment parameter monitoring system based on wireless sensor network is developed on account of VB (Visual Basic) Platform which is an event-driven programming language with assist programming interface created by Microsoft Corporation. It uses Graphical User Interface which is GUI for short. Users may create application programs even develop more complex ones through GUI. The main functions of upper-computer management software in this system are receiving information data from sink nodes of wireless sensor network through USB interface simulating serial port, digitally showing density of the acquired carbon dioxide and humiture of air, utilizing real-time dynamic graphs to describe the acquired data so as to observe its changing trends and monitoring memory and replay functions of data in real time.

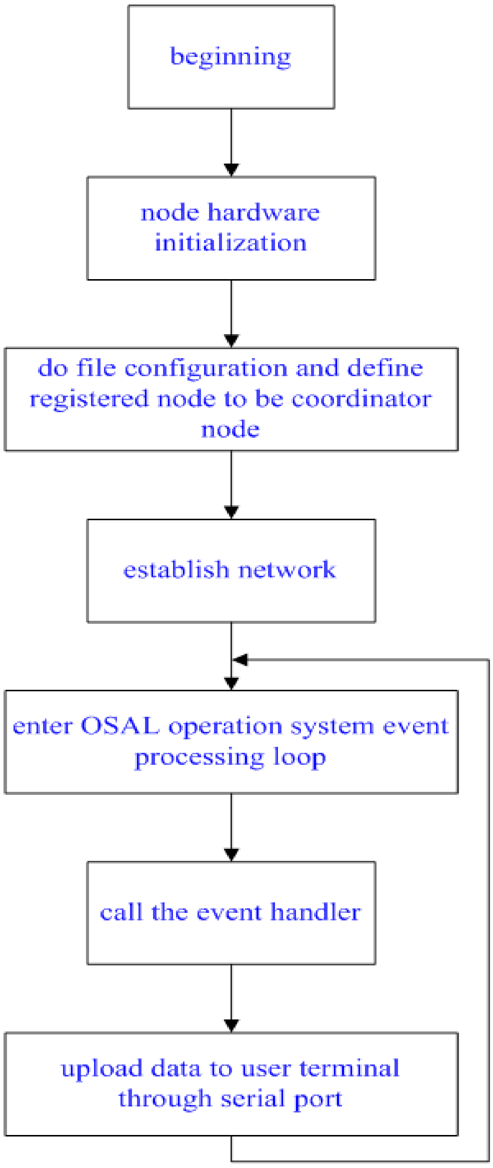

Figure 5. Flow Diagram of Coordinator Node Software

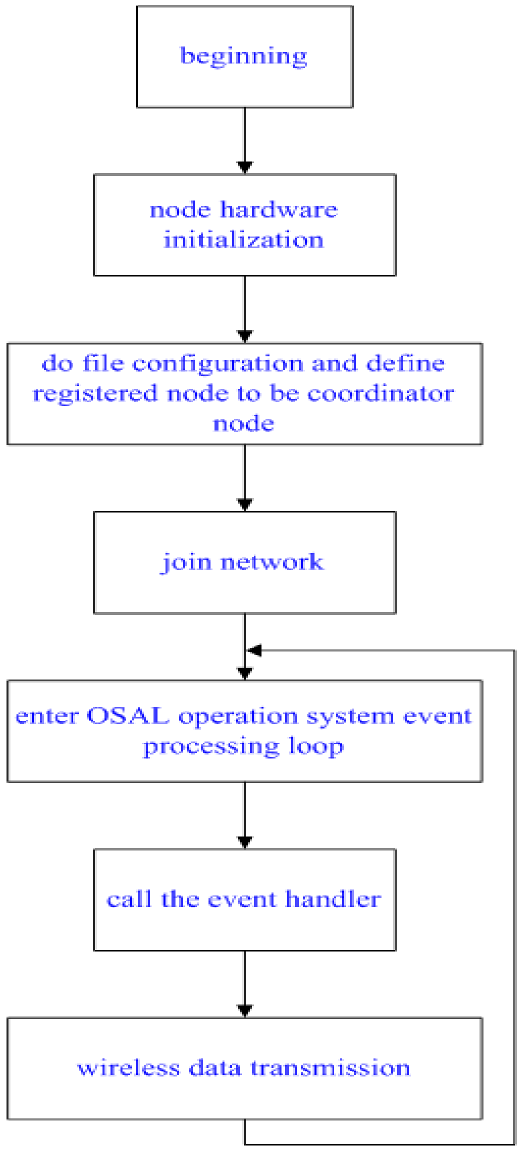

Figure 6. Flow Diagram of Routing Node Software

5. Conclusions

The main purpose of developing greenhouse environment parameter monitoring system is to conveniently, continuously and accurately do real-time monitoring on environmental factors which influence the growth of crops in greenhouse. However, traditional greenhouse environment parameter monitoring keeps problems of complex wiring, low monitoring efficiency, small extension space and high cost. For the sake of solving these problems, this paper designs greenhouse environment parameter monitoring system based on wireless sensor network which combines with CC2530 chip according to requirements of greenhouse environment monitoring, constructs hardware structure and does research on Z-stack Protocol, thus realizing the targets of keeping low cost, low energy consumption, good expansion and high reliability.

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Agricultural Environmental Data Monitoring and Control System Based on Internet of Things

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