Design of Greenhouse Control System Using Wireless Sensor Networks

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Abstract

In order to accurately determine the growth of greenhouse crops, the system based on AVR Single Chip microcontroller and wireless sensor networks is developed, it transfers data through the wireless transceiver devices without setting up electric wiring, the system structure is simple. The monitoring and management center can control the temperature and humidity of the greenhouse, measure the carbon dioxide content, and collect the information about intensity of illumination, and so on. In addition, the system adopts multilevel energy memory. It combines energy management with energy transfer, which makes the energy collected by solar energy batteries be used reasonably. Therefore, the self-managing energy supply system is established. The system has advantages of low power consumption, low cost, good robustness, extended flexible. An effective tool is provided for monitoring and analysis decision-making of the greenhouse environment.

Keywords: wireless sensor networks, greenhouse

1.   Introduction

Greenhouse is a kind of place which can change plant growth environment, create the best conditions for plant growth, and avoid influence on plant growth due to outside changing seasons and severe weather [4-5]. For greenhouse measurement and control system, in order to increase crop yield, improve quality, regulate the growth period and improve the economic efficiency, the optimum condition of crop growth is obtained on the basis of taking full use of natural resources by changing greenhouse environment factors such as temperature, humidity, light, CO2 concentration. Greenhouse measurement and control system is a complex system， it needs to various parameters in greenhouse automatic monitoring, information processing, real- time control and online optimization. The development of greenhouse measurement and control system has made considerable progress in the developed countries, and reached the multi-factors comprehensive control level, but if we introduce the foreign existing systems, the price is very expensive and maintenance isn't convenient.

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In recent years, our country have launched many studies in aspects of greenhouse structure and control, and made a lot of achievements, but the greenhouse measurement and control system is mostly based on cable, so it is not only wiring complex, but also unfavorable to improve the system efficiency. With the rapid development of the low cost, low power sensor and wireless communication technology, the conditions that construct wireless greenhouse measurement and control system becomes mature, and it is important to realize agricultural modernization [1, 3]. According to the needs of quickly and accurately acquisition greenhouse environment information, in the paper, we have further studies in aspects of greenhouse environment information collection, treatment, transmission and so on, and we have developed greenhouse measurement and control system based on AVR microcontroller and wireless sensor networks. This system has high practical value to realize information and automation of large-scale greenhouse monitoring and improve work efficiency.

2.   The general structure of the system

The greenhouse measurement and control system compose of the monitoring center, sensor nodes and control equipments. Sensor nodes are deployed in every place of greenhouse, the responsible for periodic acquisition greenhouse environment information and send it to control center. The control center analyze these data which has been obtained, then relevant decisions are made and send control message to greenhouse control equipment, which regulate greenhouse environment parameters to obtain best growth environment for crops. Modern greenhouse has very large size, and which adopt hierarchical system structure. Supposed that greenhouse is rectangular area, the measurement system overall structure is shown in Fig.1.
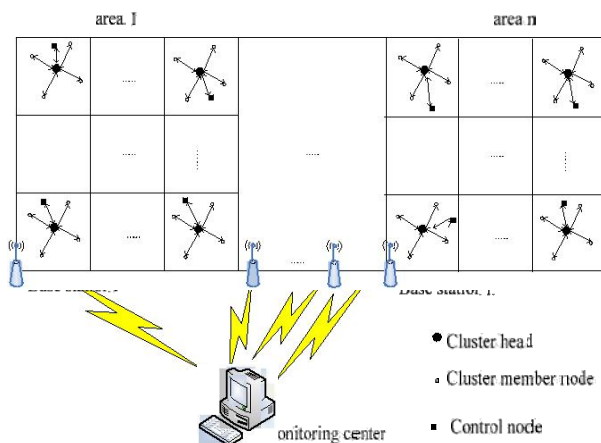

Figure.1.The system structure of Greenhouse WSN measurement and control

In Fig.1, the rectangular greenhouse was divided into several same area of greenhouse, each measurement and control area is managed by a base station, and is divided into many virtual grids which have the same sizes and is non-overlapping. A number of sensor nodes are deployed in virtual grid and make a cluster, each cluster includes a cluster head (sink node) and some cluster member nodes. Cluster head generated from the member nodes through cluster head election algorithm, and cluster member nodes compose of sensor nodes which can collect environmental data and control nodes which can control actuators and adjust environmental parameters. Control node does not participate in cluster head election, it obtain command which the monitoring center send from cluster head node and execute corresponding control operation. The star network composed of Cluster head nodes, sensor nodes and control nodes, it mainly complete data acquisition and control of greenhouse environment. The data which is collected is transmitted directly from sensor nodes to cluster head, the cluster nodes transferred data to the base station by way of multiple hops, at last, the base station transferred each cluster head node data which is packaged to the monitoring center. Base station is relay station between the monitoring center and greenhouse WSN nodes, the network control is realized by managing all the nodes of single greenhouse measurement and control area. The monitoring center is not only total console of more greenhouse network, but also data center of measurement and control system of the greenhouse network , and take charge of control and management of the entire system.

3.   Greenhouse wireless sensor network node design

Greenhouse wireless sensor network measurement and control system consists of two types of nodes, namely, sensor nodes and sink nodes. Sensor node composed of CPU module, wireless communication module, power supply module, sensor module and position switch which can set their physical location information. Sink node contains three modules: CPU module, wireless communication module, continuous power supply module and serial communication module.

A. *Sensor node module design*

Sensor node composed of CPU module, wireless communication module, sensor module, position switch and energy supply module. Its structure is shown in Fig.2. Sensor module is responsible for monitoring area information collection and data transfer, according to the application requirements, and can choose temperature sensor, humidity sensors, light sensor, carbon dioxide concentrations sensor etc. Processor module is responsible for controlling the sensor node operation, storage and processing the data which collected by the node and forwarded by other nodes. Wireless communication module is responsible for wireless communication, exchanging control information and transceiver acquisition data between this node and other nodes. Position setting switch is used to set a sensor node specific physical location in greenhouses. Energy supply module can provide energy which the work need for sensor node, in the paper, we adopt solar self-supply module for node power supply.
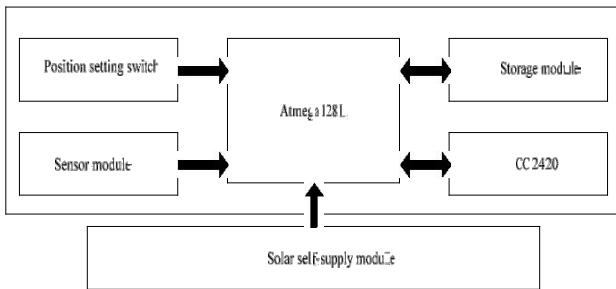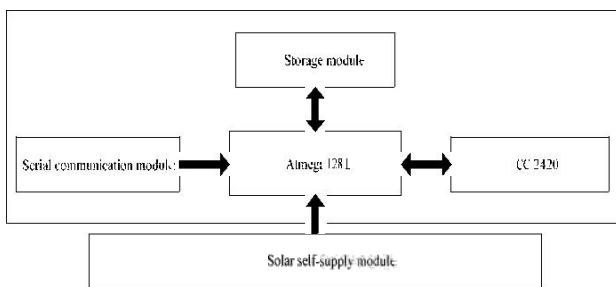

Figure.2 Sensor node structure chart

Figure.3. Sink node structure chart

B. *Sink node module design*

Sink node mainly complete the sensor nodes data gathering and fusion within communication network, and realize ascending and descending communication protocol conversion. It released monitoring task of management nodes, and the data collected is forwarded to the external network through a serial port. It is not only an enhanced sensor node, but also special gateway device which hasn't monitoring function and only has wireless communication interface. Its structure is shown in Fig.3. It composes of a power supply module, storage module, processor module, node communication module and serial interface communication module and so on. Because sink node need process many sensor nodes data, it work longer hours and dormancy time is short, the battery energy can't satisfy sink node energy consumption, so the sink node adopt solar self-supply module for nodes power supply in the paper.

C. *Power supply module*

In order to solve energy supply problem of sensor nodes, we adopted solar energy supply system in the paper, and the structure is shown in Fig. 4. Fig.4 show that power supply module have energy collector, energy storage, backup energy memory, power management and control section. Energy collector composes of solar panels, and it is responsible for transforming solar energy into electrical energy. Energy storage include the main level energy storage, constitute of super capacitance, and is responsible for storing energy which is collected by solar battery and provide energy for

wireless network sensor nodes. Backup energy memory composes of lithium battery, and provide energy source for system in an emergency. Power management and control section is responsible for monitoring status of energy memory which provide power supply according to the energy status, and take solar cell as energy memory supplement energy.
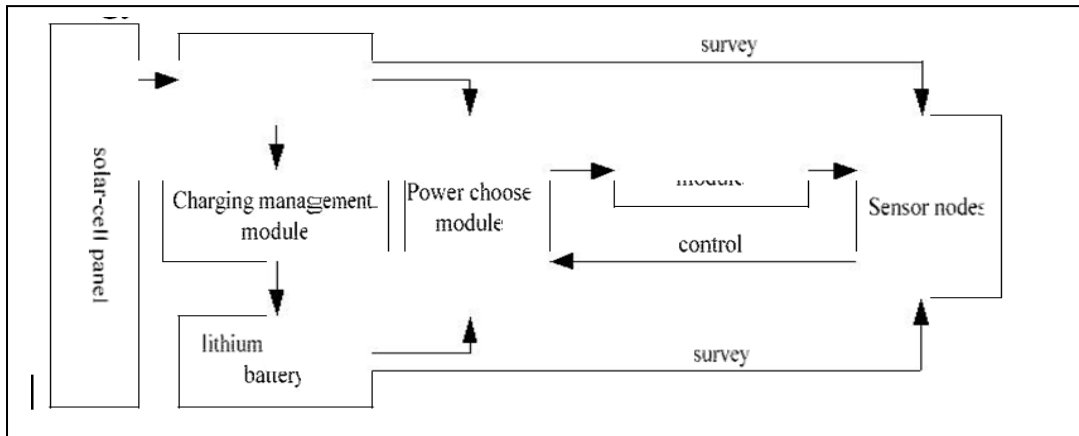

Figure.4. Solar self-supply module structure

d.   The DESIGN OF MONITORING CENTER

The monitoring center control operation of the whole network through the base station of all measurement and control area, and which the main task include sending control command for network, collection and handling monitoring data of each node in network and data is stored into database, historical data is inquired and analyzed. The monitoring center mainly composes of PC and wireless communication module. The hardware structure is shown in Fig. 5.

In Fig.5, the PC is taken as upper computer, CC2430 is taken as a wireless communication module, and the communication between them is realized through serial port. In short, the main function of the monitoring center is described below.

1. *Network management and control function.*

    Such as starting or stopping network operation, configuration network parameters. Network parameters include sensor node data acquisition frequency, the frequency submitting the data to base station, the length of each task time slot, the routing probability vector and so on. The monitoring center can also inquire operation state, environmental data and send control node to control command etc.

2. *Data storage function.*

    The monitoring center need to preserve historical monitoring data for enquiries, this function is realized through the database.

3. *Data analysis and decision support functions.*

    The monitoring data is analyzed by agricultural expert system and establish the most suitable greenhouse environment control strategy.

The base station of measurement and control not only controls all nodes of the district, but also is communication hub between the monitoring center and measurement and control area, mainly providing data forwarding and data buffer function.
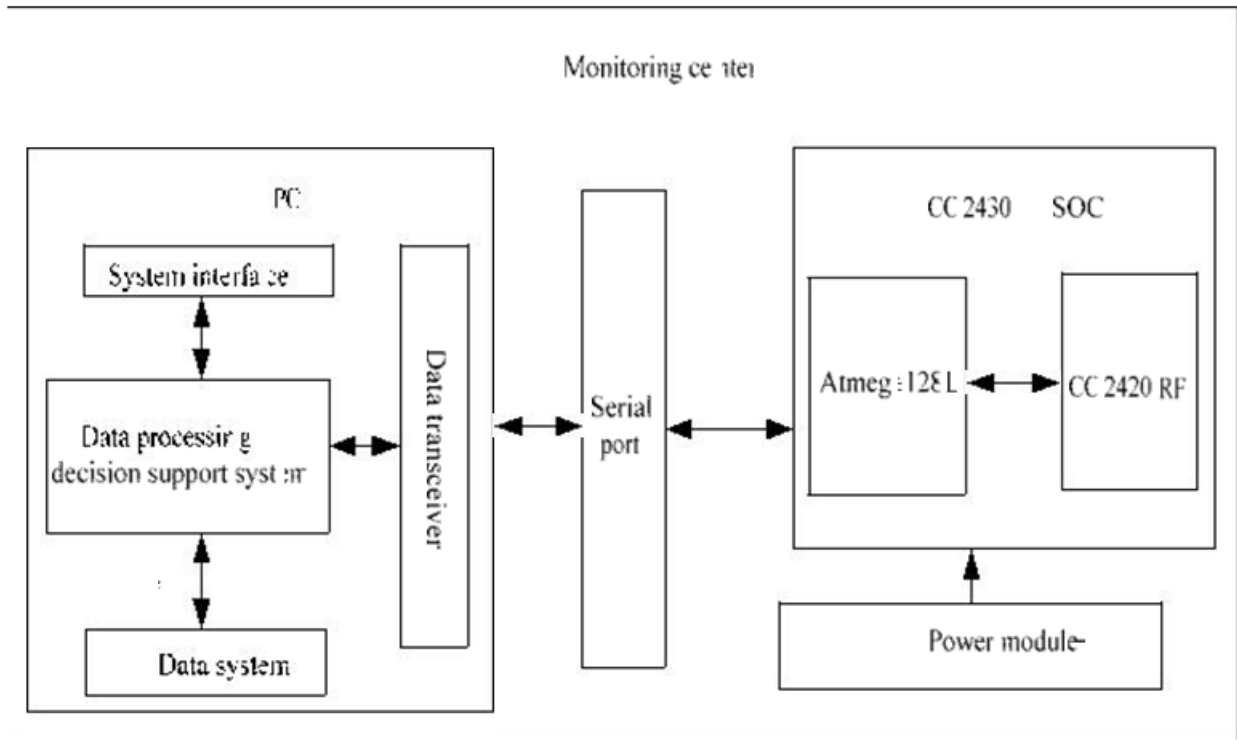
Figure.5.The monitoring center hardware structure

4.   System software

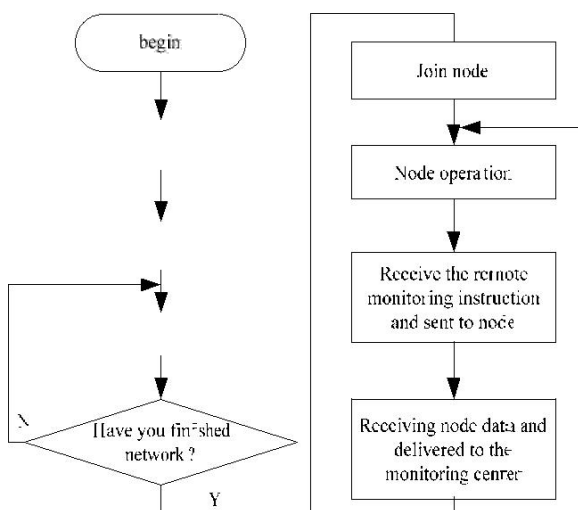### A.   System software design

Figure.6 System software flowchart

Modular design thought is adopted in system software program which mainly composed of data collection system of the greenhouse and wireless control systems. The data acquisition system transfer the data that is wireless sensor node acquisition own surrounding environment information to sink node by wireless network. The data message that is fused

is sent to controller by sink node. Meanwhile, the sink node receives instructions from controller, and forwards instructions to the sensor node. The flow chart of system software is shown in Fig.6.

B. The software design of monitoring center

The monitoring center send the system starts commands in spare time slot (T_{idle}) and receive the network monitoring data of each node in cluster interstate communication (T_{inter}) time slot. If necessary, other management control commands can be sent in spare time slot and routing time slot. In network formation time slot and communications time slot within the cluster, each node is busy with networking in greenhouse, and don't monitor commands of control center, so the management control command for network need not be sent and complete some data processing tasks. We adopt Microsoft access for the monitoring center database. The program flowchart of monitoring center spare time slot is shown in Fig.7
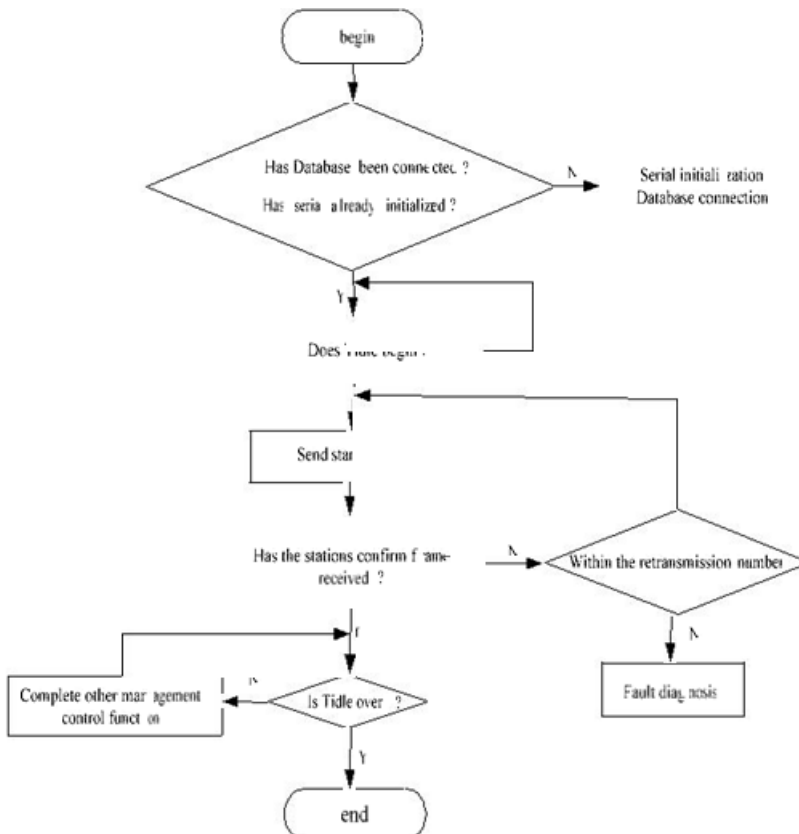
Figure.7.The program flowchart of monitoring center spare time slot

In spare time slot, the monitoring center mainly completes start-up system functions. If the system is the first start, then must connect to database. Then, the monitoring center send starts commands to the base station of all measurement and control area in greenhouse, if not received a confirmation of the base and no more than retransmission times, and the starts commands is resent. If exceed retransmission times, and fault diagnosis module is run. If received confirmation frame that the base station returns and spare time slot is not over, the monitoring center can complete other management control command.

In cluster interstate communication, the main task of monitoring center collect data that greenhouse WSN submitted and store in database. If users have management control requirements, and it may priority executed. The program flowchart of monitoring center cluster interstate communication time slot is shown in Fig.8.
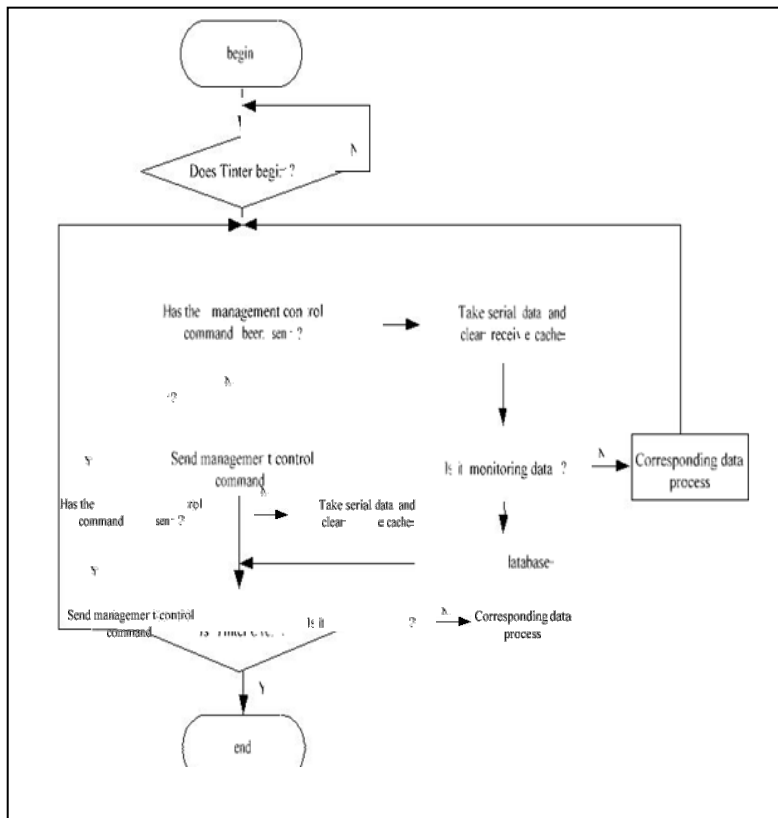
Figure.8 The program flowchart of monitoring center cluster interstate communication time slot

C. The nodes deployed algorithm of measurement and control system based on WSN in Greenhouse

In greenhouse WSN measurement and control system, the sensor nodes deployed in greenhouse periodically collected various environmental data and send it to control center with multiple hops communication manner, and it belongs to the typical centralized data collection network. In Such system, due to the nodes near the base station forward large quantities of data and premature deaths, and the network is divided and even completely paralyzed. The energy consumption hotspot is caused as a result of load distribution imbalance between the nodes, so we take phenomenon as funnel effect [6-7]. This article solve funnel effect of greenhouse WSN measurement and control system through redundancy node technology, using a single measurement and control area of greenhouse as the research object, taking the node's next-hop choose road probability as edge fuzzy weights, and introduce fuzzy graph theory, and the data probability from source cluster head to the destination node cluster head node by m jump is calculated, so we obtain network data load distribution in greenhouse measurement and control area by it, and the redundant nodes deployed algorithm (RNDA) based on cluster load balancing was designed. In order to balance the network load, we adopt three ways in the algorithm, namely, the multi-path routing, redundant nodes deployment and cluster head election. The key of RNDA is that determines each cluster head routing probability.

5. Conclusion

According to the characteristics of modern greenhouse production, the paper introduce wireless sensor network technique to greenhouse wireless detection-control system, and the whole greenhouse system can automatic adjust by combining wireless sensor network technology with greenhouse control technology.

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