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Environmental Monitoring System in Solar Greenhouse based on STM32 and GPRS

Dening Zhang*[a], Delong Zhang[b]

[a] College of Mechanic and Electronic Engineering, Agricultural University of Hebei, Baoding 071001, Hebei, China
[b] College of Automotive Engineering, Weifang University of Science & Technology, Shouguang, 262700, Shandong, China
78750682@qq.com

An environmental monitoring system is designed to deal with the problems in current solar greenhouse, which mainly composed of concentrator (data exchange terminal) and sampler (sampling terminals). Information of environmental parameter acquired by different sensors in sampling terminals were transmitted to the concentrator by the radio frequency module, a storage circuit was designed in concentrator using secure digital card, which can meet the need for mass data storage, data come from all monitoring points were stored into SD card, Gateway hardware platform were structured based on STM32F103 microprocessor and SIM900A in the data exchange terminal, environment parameter data were sent to the server of monitoring center via GPRS network finally, the system solve the shortcomings of GSM communication using GPRS technology to transmit data, STM32 processor with low power consumption, low price, high processing speed and high performance improve the performance of this system, The preliminary experimentation proved that it can get the environmental parameters data within the error rang, this system has advantages such as simple structure, more greater data processing capabilities, better real-time, high reliability and easy to install and operate.

1. Introduction

Precision agriculture requires the acquisition, transmission and processing of large amounts of data from farm fields. It is the basic premise to implement and promote the precision agriculture to collect the environment information real-timely and accurately. Mohammad Hossein Anisi et al. (2014) reported the precision agriculture, Mare Srbinovska et al. (2014) reported the precision agriculture deployed in a pepper vegetable greenhouse.

The existing environment monitoring system in solar greenhouse is usually realized using wireless sensor networks, Aqeel-ur-Rehman et al. (2014) reported wireless sensors and applications in agriculture, Antonio-Javier Garcia-Sanchez et al. (2011) reported wireless sensors used to data-monitoring over distributed crops, and Daudi S. Simbeye et al. (2014) reported wireless sensors used to aquaculture monitoring and control. ZigBee work on 2.4GHz is known for its easy to network, low power consumption, Raul Morais et al. (2008) and M. Azaza et al. (2016) reported ZigBee for data acquisition, Dae-Heon Park et al. (2011) used wireless sensor network (WSN) based on ZigBee technology to acquire environmental parameter, Raul Ionel et al. (2015) used GPRS technology to complete the remote data transmission of environmental parameters. However there are three problems to be solved, First, ZigBee work on 2.4GHz used to short distance communication, less than 100 meters generally, more routers are needed for long-distance data transmission. Second, if there are more collectors and we want to get more environmental parameters, so large volumes of data will be processed by the CPU of the concentrator that the 8-bit processor can not meet the requirements, third, it can't achieve large data storage using EEPROM, so a nonvolatile memory with large capacity is needed in concentrator.

In view of the above questions, a new wireless environment monitoring system of solar greenhouse is developed based STM32, wireless radio frequency technology and GPRS, a carrier signal with 433 MHz is used instead of 2.4 GHz, transmission distance can be increased to 3 km, so the structure of this system is greatly simplified. The thesis adopts microcontroller of STM32F103 as the center of this system according to

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the application requirements, the high-performance ARM® Cortex™-M3 32-bit RISC core operating at a 72 MHz frequency, and chooses SD card as storage devices that can store large capacity data.

2. Overall structure and working principle of system

This system consists of sensors, collector, concentrator, power supply module, remote monitoring center, etc, Environmental parameters data were collected by sensor array installed on the collector, and were sent to the concentrator by the wireless RF module, large amount of data come from each collector were stored into the SD card first, then were sent to the remote monitoring terminal for further analysis via the GPRS network, On the other hand the command from the server were sent to the concentrator through the GPRS network, sent to the corresponding collector Structure diagram of the monitoring system is shown in Figure 1.

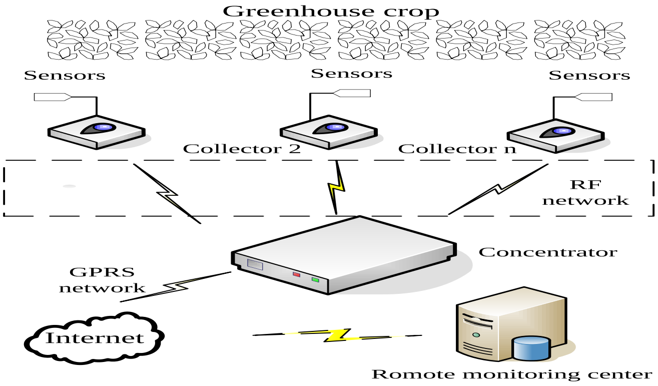

Figure 1: The structure diagram of the overall system

2.1 Collector terminals

Collector terminals finish the function of collecting information and routing forwarding. It consists of sensor array, wireless radio frequency (RF) module and processor. The sensor array consists of SHT71 used to measure the temperature and relative humidity of atmosphere, ISL29010 used to measure the luminosity, H550 used to measure the concentration of CO2, SLST1-5 used to measure the temperature of soil, and FDS100 used to measure the of soil moisture, only FDS100 provided an analogue output signal, others provided digital output, which was confirmed (Guo et al., 2011). STC12C2052AD as a processor control the data acquisition and transfers of environment parameters. The working process of the collector is: first, sensors collect information of environment parameters, second, data are sent to the controller and finally data are sent to the concentrator through wireless radio frequency module. The structure diagram of one collector is shown in Figure 2.

2.2 Concentrator

Concentrator as a localization management platform which finishes the centralized processing of information needs to have a faster processing speed, strong function of the information management and rich peripheral hardware interface resources. It receives the data from each collector terminal, then saves data into the SD card, finally sends the data to the remote monitoring center through the GPRS network and internet, so it is the control center of this system. Concentrator consists of STM32F103RCT6 processor, SIM900A communication module and Wireless RF module, the structure diagram of concentrator is shown in Figure 3.

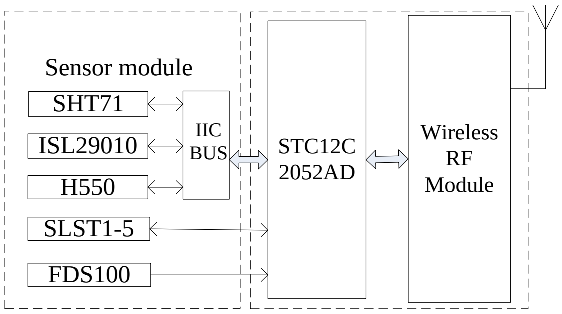

Figure 2: The structure diagram of collector terminal

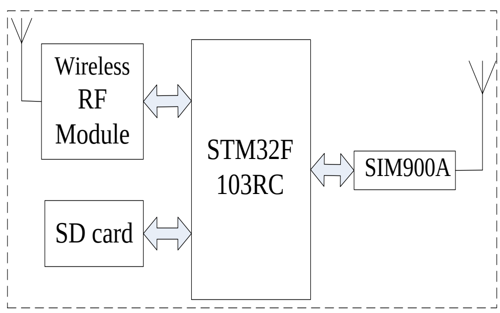

Figure 3: The structure diagram of concentrator

2.3 The selects of the devices

It consists of microprocessors, sensors, RF module, GPRS module, memory in this system.

(1)Micro-controller

Two different micro controllers were used in this system.

A.STM32F103RCT6

The STM32F103RC performance line microcontroller incorporates the high-performance ARM® Cortex™-M3 32-bit RISC core operating at a 72 MHz frequency, high-speed embedded memories, and an extensive range of enhanced I/Os. The STM32F103RC offers four general-purpose 16- bit timers plus two PWM timers, as well as standard and advanced communication interfaces: one SDIO, five USARTs. The STM32F103RC high-density performance line microcontroller operates, supply range from 2.0 to 3.6 V with low-power applications.

B.STC12C2052AD

STC12C2052AD was selected as the microcontroller in collector terminal. It is 8-bit microcomputer with 2 KB Flash, 2 KB EEPROM, 256 bytes on-chip Data RAM, 8-channel A/D converter, one USART, one 4-pin hardware SPI Interface. It has a wide operating range 3.4 to 5.5V.

(2) Sensors net

A. Temperature and humidity sensor

SHT71 is chose in this system. It adopts two line digital output interface, can be connected directly with microcontroller with a simple circuit. It can work with a wide working voltage range from 2.2 V to 5.5 V DC.

B. Illumination sensor

The ISL29010 is an integrated light sensor with IIC interface. It has an internal signed 15-bit integrating type ADC which can be configured at four different range to dynamically accommodate various lighting conditions. In normal operation, power consumption is typically 250μA. Furthermore, a power-down mode can reduce power consumption to 1μA, It's working voltage range from 2.5V to 3.3V.

C. Carbon dioxide concentration sensor

H550 is a digital CO_2 sensor with IIC interface used to collect concentration data of carbon dioxide in this system. The measurement accuracy is ±30 ppm, and power consumption is 15 mA.

D. Soil temperature sensor

SLST1-5 is used to collect temperature data of soil, it supports the 1-Wire interface, the measuring range is -55 °C ~ +125 °C.

E. Soil moisture sensor

FDS100 is soil moisture sensor based on Time-Domain Reflectometry (FDR), It adopts analog output interface, measurement range of 0 ~ 100% RH, the out range of analog voltage from 0 to 1.875V.

(3) GPRS module

SIM900A is a core module of data transmission provided by SIMCOM Wireless Solutions Co., Ltd, it provides GPRS data transfer function, the built-in TCP/IP protocol stack make it easy to use the TCP/IP protocol easily. It provides two types of operation mode: Data transparent mode and the AT command mode, According to the characteristics of this system, we select data transparent mode to realize remote data transmission, once the connection is established under Transparent Mode, the module will be in data mode. All data received from serial port will be treated as data packet to be transferred later, as well all data received from remote server will be sent to serial port directly. The working voltage of SIM900A is 3.2 V to 4.8 V. This system takes the PC as a server, which connected to the Internet, the IP of PC must be a public network IP address, GPRS module as the client, the mcu control the GPRS module to send a TCP connection request to the server via AT commands, a dynamic IP address will be assigned to the SIM card inside of the module, then the data collected by sensors are sent to the PC through the IP address. Finally we store data into the database for further analysis.

After the processor is powered on, the GPRS module is started by AT command, searches network and connects to the Internet next, and the field real-time data are collected and sent by GPRS network.

Preparations for GPRS module includes the following steps:

(1) Send the AT command to query the GPRS module and mobile network signal is working correctly.

(2) Send the AT command to set the communication mode to CMNET, communication protocol to TCP/IP.

(3) Send the AT command to set SIM900A work in Data transparent mode.

(4) Send AT commands to establish a TCP connection between the GPRS module and server, set the IP address and port number.

(4)Wireless RF Module

The type of Wireless RF Module is KYL-1020L. It has the features of DC 5V power supply, less than 500 mw output power, works in industrial scientific medical frequency band, can be set to sleep mode by the Pin8.

(5)Memory module

Secure Digital card (SD card) is selected to store data in this system. It is a flash-based memory card that is specifically designed to meet the security, capacity, performance and environmental requirements inherent in newly emerging audio and video consumer electronic devices. The SD card communication is based on an advanced nine-pin interface designed to operate in a low voltage range. The SanDisk SD card offers an alternate communication protocol, which is based on the Serial Peripheral Interface (SPI) standard, and it provides up to 1024 million bytes of memory using flash memory chips, which was designed especially for mass storage. We select SDSDJ-32 for data storage, it has 32M Bytes of data storage. The use of SD card not only enhance the storage capacity of the system, and also improve the scalability of the system, we can realize the expansion of the storage capacity without modifying the circuit.

3. Hardware

Hardware circuit in this system is mainly composed of concentrator and sampler. Environmental parameters are collected and transmitted through radio frequency to the concentrator. The concentrator is intermediary device between terminal and the compute, it is the center of the centralized and decentralized information, it can achieve the dispersion and concentration of information, realize a long-distance data transmission.

3.1 The collector circuit

Collector circuit consists of sensor array (temperature and humidity sensor, illumination sensor, carbon dioxide concentration sensor, soil temperature sensor and soil moisture sensor), wireless RF module, MCU and power supply module. SHT71 needs only two I/O port, that is, DATA and SCK, a pull-up resistors of 4.7 KΩ is needed for the pin of SCK and DATA, P1.1 and P1.0 of Microcontroller are connected respective to pin SCK and DATA of STH71. Communication interface of ISL29010 and H550 are both used IIC bus, their SCL and SDA are connected respective to P1.2 and P1.3 of MCU, SLST1-5 is connected to P1.4 of MCU. P1.7 of Microcontroller is connected to output pin of FDS100, P3.0 and P3.1 are connected respective to TXD and RXD of KYL-1020L module, and the collector circuit is shown in Figure 4.

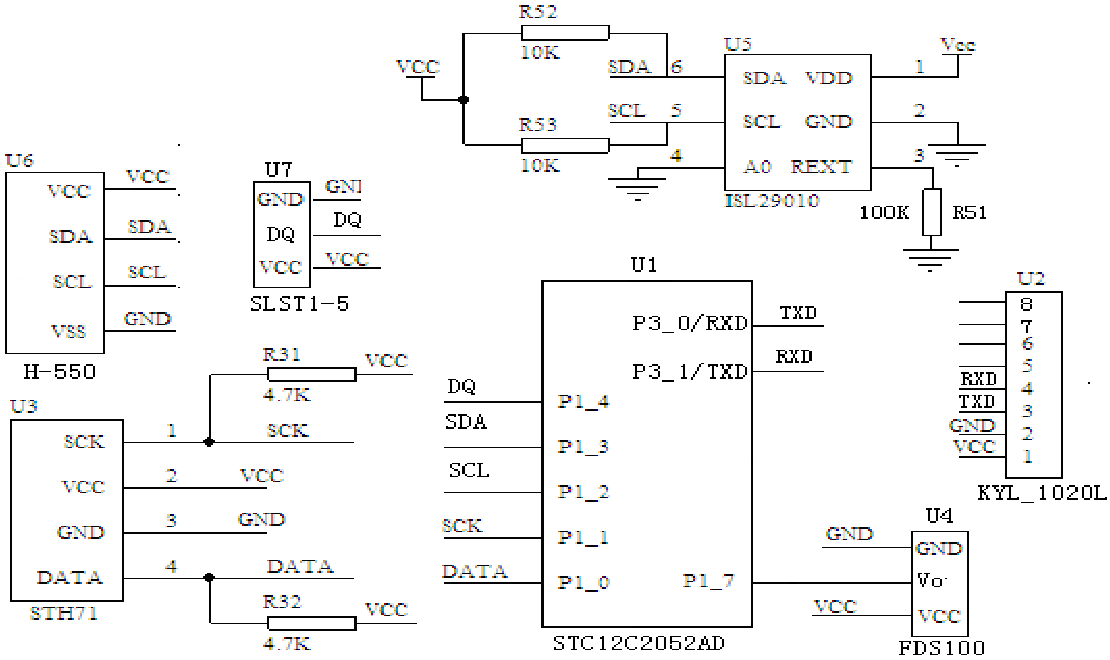

Figure 4: Terminal node circuit

3.2 The concentrator circuit

Gao Junxiang and Du Haiqing (2011) reported S3C2440 based on ARM9 used as the system processing unit, Huifu Zhang and Wei Kang (2013); T Vaithianathan et al. (2014) reported 32-bit processor STM32. The concentrator chose 32-bit processor STM32 as the core, receives the data sent from collector by wireless RF module, send data to GPRS module in order to realize remote transmission, The circuit of SIM900A consists of SIM card, antenna, UART, Electro-Static Discharge .etc. VBAT is 4V in this system and SIM900A will automatic startup when power, the wiring diagram is shown in Figure 5.

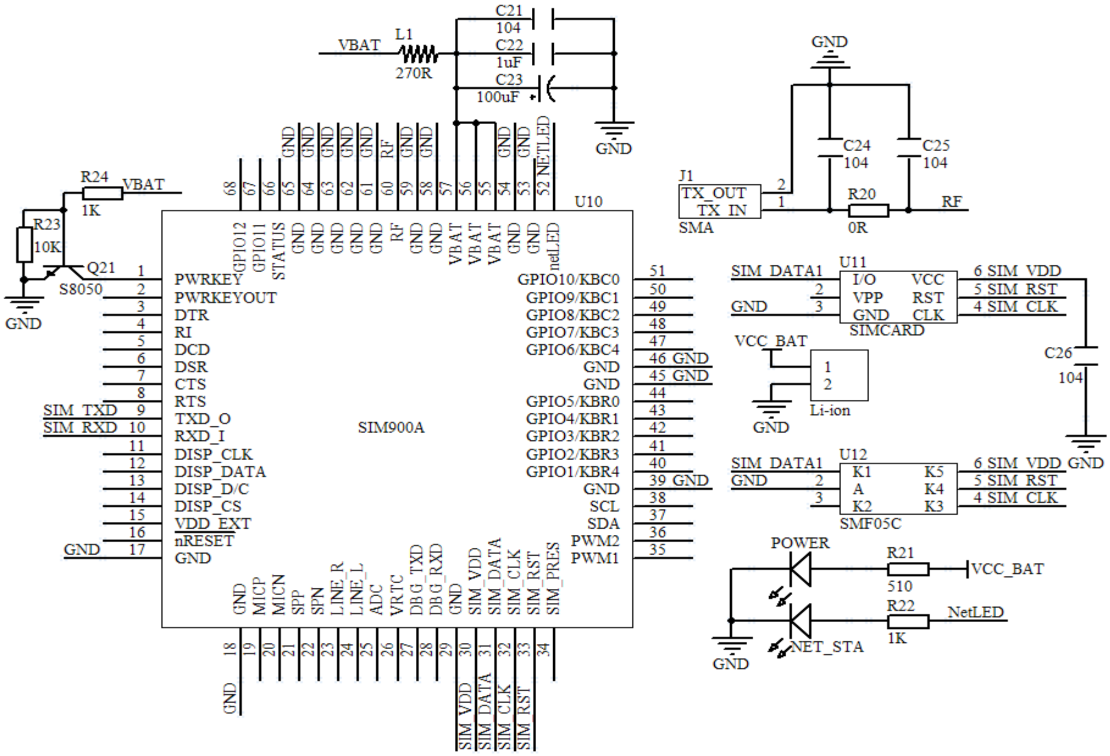

Figure 5: The circuit of SIM900A

The wiring diagram of clock, SD card, reset circuit and wireless radio frequency communication circuit is shown in Figure 6.

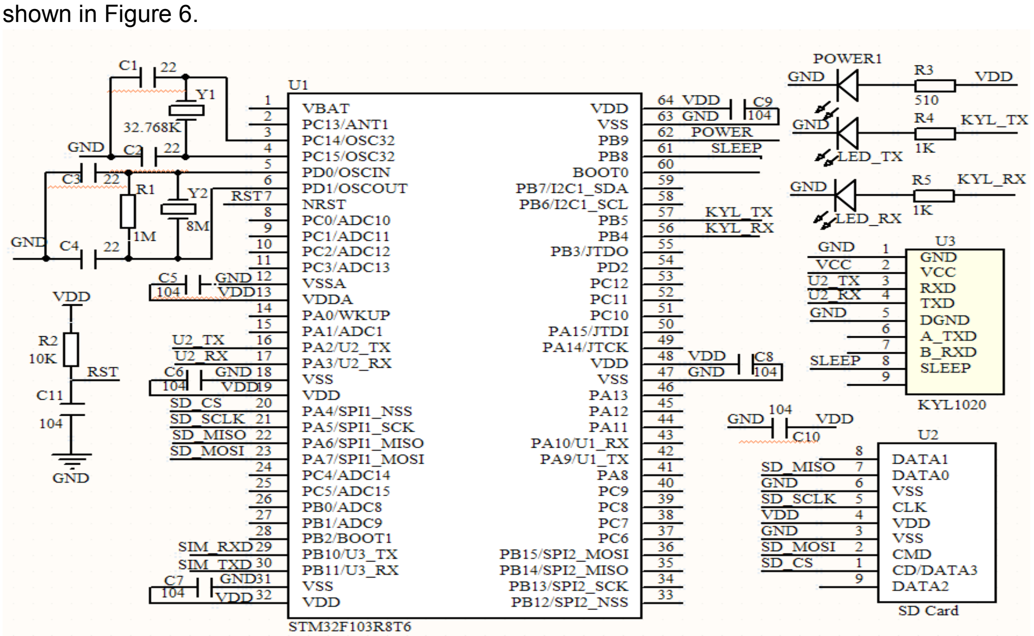

Figure 6: The circuit of STM32

4. Software

The program of STM32F103RC microcontroller is programmed and compiled into HEX file through MDK5 software environment, and then the file is downloaded to microcontroller through the software of FLY MCU.

5. Conclusions

Environmental monitoring system in solar greenhouse has been designed based on 32-bit processor, wireless RF technology and GPRS. STM32 processor with high reliability and low cost increases the processing speed greatly. The carrier frequency of 433 MHz increased the distance of data wireless transmission from 100 meter to 3km. The application of SD card greatly improving the data storage capacity of this system. Preliminary experimentations showed that this system met the application requirements of solar greenhouse monitoring system excellently, and had the advantages of low power consumption, simple structure and strong scalability. However this study will also conduct further research in the following areas: First, measured values are associated with a number of factors, take the carbon dioxide sensor for example, parameters such as temperature, humidity, air pressure will affect the measured values of carbon dioxide concentration, how to correct the sensor so as to improve the measurement precision of the sensor is a problem to be solved urgently, so it is necessary to compensate the measurement result. Second, through a large amount of data got from this system, solar greenhouse crop growth model which describes the relationship between the external variables and the plant environment will be set up the next step.

Acknowledgments

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