Greenhouse Environment Monitoring System using Near Field Communication

(NFC) Technology

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Abstract — The best growth environment of greenhouse crops needs to obtain the information such as temperature, humidity and carbon dioxide concentration. In Near Field Communication, NFC, technology, the Arduino control module and the sensor are combined to develop a set of greenhouse environment monitoring system. The greenhouse environment monitoring system adopts modular solution. It includes Arduino control module, NFC R/W module, NFC tag, sensor, DS1302 clock module, SIM900A GSM module, etc. The sensor collects greenhouse environment data, and the data is converted to digital form. NFC R/W module writes the binary format of the data in NFC tags word for word, and through the verification of data, ensures the validity of the data transmission. Software section divides the NFC tags into sectors and blocks through the Arduino language programming, and writes the corresponding data in the hour sector, minute sector, temperature sector, humidity sector and carbon dioxide concentration sector. Through the program, the interval time and total time of writing data are set respectively. When reach the total time, the system sends text messages to remind users to read the data, and imports the data into the computer database for further analysis. The data of NFC tags is finally reset. The experiment shows that the monitoring system can meet the needs of greenhouse environment control with the characteristics of stability and authenticity.

Key word - Greenhouse; Environment monitoring system; Sensor; NFC; Android

I. INTRODUCTION

With the rapid development of agricultural engineering technology, the existing plant management system has been unable to satisfy the needs of agricultural development[1]. The improvement and update of traditional agricultural technology must be carried out. To improving the level of agricultural modernization and intelligence, many countries in the world have taken measures to increase investment intensity [2]. China is a traditional agricultural country. Enhancing the level of agricultural plant technology is the key to realize the integrated development of the country-side. Greenhouse agriculture is an important part of modern agriculture. It is a necessary supplement to natural cultivation. Plant factory constructs a factory production environment by using new type facilities and advanced engineering techniques, which is completely different from traditional agriculture. Plant factory represents a new direction of agricultural development, but it is still in the experimental stage.

Plant factory is in urgent need of environmental information monitor, information transmission, data processing, automatic control and many other key technologies. The environment monitor is the link between the greenhouse environment control and information processing, and the important premise of plant factory. At present, the greenhouse environment monitoring system is generally based on infrared, Bluetooth, wireless sensor network technology. Although these monitoring system can gather the environment information, but there are many
shortcomings, such as numerous nodes, complex structure, high power consumption, high cost, sensitive to environment.

NFC (Near Field Communication) is a kind of short distance high frequency wireless communication technology[3]. The working frequency is 13.56 MHz, which allows contactless data transmission between electronic devices. NFC is developed on the basis of RFID (Radio frequency identification) technology[4]. The technical details of the NFC are defined in ISO/IEC 18092. NFC technology is different from RFID because it is capable of bidirectional connection and recognition communication. It can quickly establish P2P (point-to-point) wireless communication without fixed subordinate relationship. Communication can be initiated by any NFC device, while NFC can work in a variety of operating modes[5]. The active device generally has a power supply unit, such as a card reader and a mobile phone with NFC module. The passive device is no power supply module, such as contactless smart card and identification. Otherwise, the NFC tag is capable of storing large data, and can record the multi-group data. Currently, NFC technology has been widely used in access control, bus, mobile payment and other fields. The application of NFC technology in the greenhouse environment monitor has broad prospects.

Aiming at the problems of greenhouse environment control, this paper puts forward NFC-based greenhouse environment monitoring system. When the system works, it first sets up interval time and total time of writing data according to the users’ actual needs, then writes acquisition temperature, humidity and carbon dioxide concentration data into NFC tag along with the corresponding sampling time. When it comes to the set time, the system will send text messages to remind the user to read data. Finally, the user reads data to do analysis processing, and take the corresponding environment control measures depending on the growing of crops. It will be applied to greenhouse environment monitoring places that requires convenient installation, reliable data transmission, low equipment cost and small energy consumption.

II. ARCHITECTURE AND IMPLEMENTATION OF ANDROID NFC

NFC uses the basic structure models of Service and Manager in Android architecture through communicating with Binder and Service, as shown in Figure 1. Android uses the kernel module Binder to transfer the session data between each process[6]. It is a character device driver, which exchanges data with the process of user space via IOCTL[7]. A session is executed between a proxy object of Binder and a service object of Binder in different processes or in the same process. Session is a synchronous operation. Via the proxy object, Binder sending requests, it can be completed until the service object of Binder replies to the proxy object of Binder. In order to support the NFC, Android allows the applications to read data from the tag and interact in the message format of NDEF(NFC Data Exchange Format). In the software architecture of NFC Android, the following data structures are defined:

- **NFC Manager**: It is the programming interface provided to the applications and the entrance of the Android application accessing the NFC. It mainly obtains a instance of NFC Adapter.
- **NFC Adapter**: A NFC Adapter is on behalf of a NFC device and provides all NFC operation including NFC device switch, tag access, NDEF data alternation, NFC security access, point to point communication, etc..
- **NDEF Message**: It is the standard package format of the data that is passed between the

![Figure 1. Android architecture of NFC](image-url)
device and the tag, which is composed of one or more NDEF data records and reads NDEF messages by receiving ACTION_TAG_DISCOVERED Intent in the applications.

- NDEF Record: It is the fundamental unit of a NDEF data packet. A NDEF data packet can have one or more NDEF records.

### III. SYSTEM DESIGN

The system adopts modular design scheme, which mainly consists of Arduino control module, NFC reading and writing module, NFC tag, sensor, DS1302 clock module and SIM900A message sending module. With mutual cooperation between each module, it achieves real-time monitor and records the greenhouse environment data and information, and sends text messages to remind the user to read. The topology structure of system is shown in Figure 2.

Using Arduino module as the control core system, the microprocessor is ATmega328 with 16 MHz clock frequency, 5V operating voltage, and 7-12V input voltage range; It is equipped with 14 digital bidirectional I/O, six of which provide PWM output, and another six analog input pin, and the maximum output current of each I/O pin is 40 mA; It has 32 K bytes Flash Memory, 2 K bytes SRAM and 1 K byte EEPROM. The control structure is shown in Figure 3.

Temperature and humidity sensor adopts relative temperature and humidity sensor SHT11 that is total calibration digitized single chip with I2C bus interface produced by Swiss Sensirion Company. The sensor uses unique CMOSensTM technology to have the ability to integrate temperature and humidity sensor, signal amplifier, A/D conversion and total lines interface. The humidity value output resolution is 14 bit and temperature output resolution is 12 bit. As to carbon dioxide content monitoring, it chooses solid state electrochemical sensor TGS4160 produced by FIGARO company. Its working voltage is 4.5-7.0 V, the average working current is 30 mA, measurement range is 0-5000 ppm. The connection mode of sensors is shown in Figure 4.

Clock module uses a trickling water fine current charging capacity and low-power real-time clock chip DS1302 launched by American DALLAS company, which adopts 32.768 KHz crystal vibration, 5 V working voltage with reverse diode protection, power lost time clock. It also has memory cell that can accurate correct time information, and record the corresponding time of sensor collecting data into NFC tag. Message sending module uses SIM900A development board from SIMCOM company, which has the
feature of text messages sending and receiving, voice communication, GPRS network data transceiver and other functions. It achieves corresponding operation function by the AT command. The working voltage is 5V, data transfer rate is up to 150 Kbps. Through TXD, RXD and GND three wire serial interfaces’ simple connection, it can achieve SMS messages. NFC reading and writing device is ST95HF from STMicroelectronics NV. Its working voltage is 5V and working frequency is 13.56 MHz. It has SPI, I2C and UART communication interfaces that support ISO 14443A/B, ISO 15693, Felica and NFC protocol with transmission speed up to 26 Mb/s. It includes three patterns, that is card reader, card and point to point, which can write data in NFC tag accurately.

IV. SYSTEM OPERATING MODE

A. NFC tag division

NFC is a new technology that evolves RFID and Internet-based technology, which is also a kind of short-range wireless communication technology standard. It can be integrated contactless card reader, contactless smart card and point-to-point communication functions on a single chip. As to close range transmission technology, Philips MIFARE technology and Sony FeliCa technology is compatible with NFC standards, which are widely used. The system chooses NFC tag that based on Sony FeliCa system. The label has 2 K bytes of memory capacity, data communication rate is 212 Kbit/s, which is suitable for a large amount of data transmission quickly. Tag is divided into 32 sectors (ID: 0-31), and each sector is divided into 8 (ID: 0 to 7) blocks, each of which can store 16 bytes data. Different sectors can be used as time, temperature and humidity, carbon dioxide concentration data storage address. Data stored information in each sector is as follows:

- Manufacturer using area. 0 in sector 0 is special for holding the manufacturer’s code. The size is 16 bytes, being cured, cannot be changed but can only be read. It adopts manufacturer’s unique encryption to be called “sector 0”.
- Password storage area. Each sector 7 (that is 8th sector) contains the code of the sector A (6 bytes), access control (4 bytes) and password B (6 bytes), which is considered as a special password storage block, the remaining 7 block is general data block.
- Tag setting area. Sector 0 block 1 is used to hold reset instructions which accounts for 16 bytes. When stored data is full, it will perform the function of automatic reset. Sector 0 block 2 is used to write continuous data and write data that can be erased. It selects through the instruction and takes up 16 bytes; Sector 0 block 3 deposits NFC tag reading and writing agreement, different read and write software and NFC tag reading and writing agreement matchent can successfully read data information.
- Data storage area. Sector 1-4 block 1-7 are used to store hour data, so it is defined as hour sector, and takes up 448 bytes; Sector 5-8 block 1-7 are used to store minute data, and is defined as minute sector taking up 448 bytes; Sector 9-13 block 1-7 are used to store temperature data, and is defined as the temperature sector (448 bytes); Sector 14-17 block 1-7 are used to store relative humidity data, which is defined as the humidity sector (448 bytes); Sector 18-23 block 17 is defined as the carbon dioxide concentration sector as it is used to store carbon dioxide concentrations (672 bytes).
- Reserve zone. The rest of the sector is used to store expansion area that can be used to extend more data to store and upgrade and preservation of the encryption algorithm.

B. NFC data read and write implementation
Information written string in NFC tag includes hour, minute, temperature, humidity and carbon dioxide concentration. Program sets the sampling interval, ATmega328 gives corresponding data collection instructions to each sensor by connecting pin. Sensor information is written in NFC tag in a certain way. If reaching the set data storage volume, it starts the message sending module to remind users data collection is completed and ready for them to read data. Control core ATmega328 built-in crystal frequency is 16 MHz, clock cycle is 62.5 ns and each instruction execution time is two machine cycles, namely 125 ns on average. Written address is distributed within the corresponding sector block and it uses reading the bytes word by word. According to the corresponding frame format, it applies odd-parity check to ensure the accuracy of data transferring instructions. Taking writing temperature data 23.8 °C as an example: writing tens, ones and decimal place of the temperature in turn, its frame format is 0000 0010, 0000 0011, 0000 1100 respectively.

The corresponding frame format is shown in Figure 6. Then it will adopt the same frame format to write humidity and carbon dioxide concentration data in NFC tag. Data writing address is in the corresponding hour sector, minute sector, temperature sector, humidity sector and carbon dioxide concentration sector. When it comes to the interval of writing data, the second set of data should be written in the corresponding sector until it reaches the set written data total time \( T \). Finally, ATmega328 starts SIM900A SMS module to send reminder text messages to the user. The Arduino control center is closed at this time, which is no longer used to read new data. Users’ reading data is composed of multiple character strings, and each string includes hour, minute, temperature, humidity and carbon dioxide concentration values. There is a total of 12 bytes with the first 2 bytes representing hour; third and fourth bytes mean minute; 5th, 6th and 7th bytes show the current temperature; 8th and 9th bytes describes greenhouse relative humidity; the last three bytes (10th, 11th, 12th) is carbon dioxide concentration. At the end of the data reading, Arduino invokes the NFC sector reset instructions to clear the data and start to record next set of data. The work flow is shown in Figure 7.

![Figure 6. Corresponding frame format of temperature](image)

**C. Work flow**

First, it sets writing data time interval \( t \) and writing data total time \( T \) by the Arduino language program. Then it opens the equipment power supply, ATmega328 will give data collection instructions to sensors to read the current moment of temperature, humidity and carbon dioxide concentration from high to low, word by word to write in NFC tag when it comes the writing time interval. Different data and different time are written into tag corresponding sector within the block. After the first set of data is written in the tag through ATmega328, ATmega328 will provide another set of data read and write instructions after \( t \) moment. This circulates until it reaches the set written data total time \( T \). Finally, ATmega328 starts SIM900A SMS module to send reminder text messages to the user. The Arduino control center is closed at this time, which is no longer used to read new data. Users’ reading data is composed of multiple character strings, and each string includes hour, minute, temperature, humidity and carbon dioxide concentration values. There is a total of 12 bytes with the first 2 bytes representing hour; third and fourth bytes mean minute; 5th, 6th and 7th bytes show the current temperature; 8th and 9th bytes describes greenhouse relative humidity; the last three bytes (10th, 11th, 12th) is carbon dioxide concentration. At the end of the data reading, Arduino invokes the NFC sector reset instructions to clear the data and start to record next set of data. The work flow is shown in Figure 7.
V. RESULT ANALYSIS

There is a test used for validating the rationality and practicability of the developed NFC technology-based greenhouse environment monitoring system. It sets writing data time interval \( t \) is 10 min and writing data total time \( T \) is 5h. After getting the total time, it reads tag data using NFC card reading built-in mobile phone. Data acquisition starts from 11 am to 3 pm, and it collects data every 10 minutes. Some data is selected to plot the change of temperature and humidity, carbon dioxide concentration over time. Arduino control module writes collected hour, minute, temperature, humidity, carbon dioxide concentration value in NFC tag through the binary frame format. As shown in Figure 8, the first group of data represents 11:00, temperature 23.8 degrees, humidity 86% and carbon dioxide concentration 526 ppm. When using NFC mobile phones to read data, it presents in the form of decimal numbers. It uses mobile phones to read required data information, and inputs data into PC database so that a large number of data can be analyzed. It is convenient for users to quickly understand and record data. Through the analysis of the greenhouse environmental data changes over time, it is found that different plants should take corresponding heating, cooling, humidifying and carbon dioxide concentration increase and other measures in different time periods to maintain the growth of greenhouse crops.

VI. CONCLUSIONS

In this paper, a system based on NFC technology is presented, which has the capability of environment monitoring and data acquisition. Experiments are then demonstrated, which show the system’s well performance and convenience to obtain data. The system has made several achievements in: (1) the system is a practical environment monitoring application that sensors periodically sense their ambience and the data can be eventually uploaded to PC database. (2) The system adopts modular design scheme, which makes it less aware of environment disturbances.

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