Design of wireless monitoring system for greenhouse based on LoRa

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Abstract. With the wide application of Internet of Things technology, information collection systems based on Internet of Things technology have been gradually applied to the construction of smart agriculture, and the remote monitoring system of greenhouse environment is an example. Some technologies, such as Zigbee and Bluetooth, are widely used, with short communication distances, complex networking, low network reliability, and no coverage of large area applications. In this paper, an information acquisition system based on LoRa technology is designed and implemented in the light of the application needs of greenhouse sheds and the advantages of long distance and low power consumption of LoRa technology.

1. Introduction  
In modern agricultural cultivation, greenhouse cultivation is one of the most popular planting methods [1]. Greenhouse planting improves quality and yield by controlling factors affecting crop production [2]. Temperature, humidity and light intensity in greenhouses are important factors affecting crops. Monitoring and regulating these parameters is conducive to improving the quality and yield of crops. Traditional greenhouse wired monitoring system has wiring problems, and wireless greenhouse monitoring system based on WiFi, Breezing, etc. has the problem such as short communication distance [3].  
Low Power Wide Area Network (LPWAN) technology is a revolutionary New Internet of Things wireless access technology, compared with Wi-Fi, Bluetooth, ZigBee and other existing mature commercial wireless technology, with long-range, low-power, low-cost, large coverage capacity and other advantages [4], suitable for long-distance transmission of small data and battery-powered IoT terminal devices. As an LPWAN wireless technology of unauthorized spectrum, LoRa has a more mature and commercial application than other wireless technologies such as Sigfox, NWave, etc. Therefore, a wireless monitoring system based on LoRa is proposed, which consists of a LoRa-based greenhouse wireless monitoring device and a remote control monitoring platform to realize the multi-parameter remote wireless monitoring of greenhouse environment.

2. System Architecture  
The system architecture of LoRa-based greenhouse wireless monitoring system is shown in Figure 1, the system is mainly composed of sensor nodes, gateways and LoRa server Internet of Things cloud
platform, using a star topology network, the application of LoRa technology is the characteristic of the system design [5]. Gateways can communicate with the remote LoRa Server cloud platform based on existing host networks through wifi, wired transmission, 4G and other technologies, allowing users to access data stored on the cloud platform and control the entire system through web or mobile clients. In the system implemented in this paper, the gateway communicates with the Lora Server cloud platform via WiFi.

![System architecture](image.png)

**Figure 1.** System architecture

3. **System Total Design**

3.1. **System Operation Process Design**

Lora WAN-based low-power long-distance Internet of Things system, when the sensor on the node detects data, it passes through the gateway and server for data transmission. The LoRa node consists of the MCU (STM32) and SX1262 modules, the LoRa Gateway consists of the Raspberry Pi and the module SX1301, and the LoRa server consists of LoRa-Gateway-Bridge, Lora Server, LoRa-App-Server [6].

The MCU (STM32) control SX1262 modulation demodulation module of the LoRa node, which can only be received or sent on one channel and is in half-duplex mode [7]. LoRa-Gateway-Bridge on the LoRa server is responsible for converting the UDP packet of the LoRa gateway to MQTT packets to send to LoRa-App-Server, or to convert the MQTT packets of LoRa-App-Server to the UDP packet to the gateway. Lora Server handles LoRa network data. LoRa-App-Server handles LoRa's application data. The Raspberry Pi (MCU) of the LoRa Gateway controls the SX1301 modulation demodulation module, which can only be received or sent on one channel and is also in half-duplex mode. In the system from The MQTT broker, the packets processed by LoRa-App-Server are monitored and forwarded to the application layer through program calls. The system operation flowchart is shown in Figure 2.
3.2. **Illumination Acquisition Design**

The illumination sensor BH1750 uses the standard I²C bus transmission mode, built-in 16-bit AD converter, can directly carry out digital output, eliminating complex calculations and calibration. The BH1750 reads data by sending a starting signal, device address and read signal to the sensor via the I²C bus, waiting for the sensor to answer, reading data after an answer, and sending a stop signal to the sensor. The block diagram of the BH1750 is shown in Figure 3.

![Illumination sensor block](image)

**Figure 3.** Illumination sensor block

3.3. **Temperature and Humidity Acquisition Design**

The HDC1080 is a digital humidity sensor with low-cost and low-power integrated temperature sensors that deliver superior measurement accuracy at ultra-low power consumption. The HDC1080 reads data in the same way as the illumination sensor above. The block diagram of hdc1080 used in this system is shown in Figure 4.
3.4. CO2 Concentration Acquisition Design

The CCS811B air quality sensor is used to detect the value of carbon dioxide in the air. The CCS811 supports a variety of low-power optimized measurement modes, with power consumption of less than 1.2mW per minute for active sensor measurements and less than 6 μW in idle mode, and optimized low-power mode for extended battery life in portable applications. Compared to conventional metal oxide gas sensors, the CCS811 offers a highly reliable gas sensor solution and a fast test cycle, significantly reducing average power consumption. In line with the low power consumption requirements of this system, so adopted. The system uses the CCS811B block diagram as shown in Figure 5.

3.5. Node Hardware Design

The LoRa node uses the ASR6501 chip, which integrates the ARM Cortex-M0-Plus core and the SX1262 LoRa chip on the ASR6501 chip. The chip has the characteristics of low power consumption, the reception mode power consumption is less than 10mA, 17dBm emission mode power consumption is less than 52mA, and Active power consumption is reduced by more than 40%. Deep Sleep consumes 2μA in internal low-power RC mode and 3μA in external low-power XO mode. Reliable data transfer with the LoRa gateway over a long period of time. The ASR6501 block diagram used in this system is shown in Figure 6.
3.6. Gateway Hardware Design

The system is used in Chengdu HELTEC Automation Technology Co., Ltd. HT-M01 gateway. The core chip of The LoRa Gateway is the SX1301 baseband chip produced by Semtech, an industrial-grade standard, and a LoRa gateway module with high performance and small size. There are different LoRa communication bands in different regions of the world, and the 470MHz band is used in this system. In this system, the LoRa gateway communicates with the MCU controller through the SPI interface, and the MCU controls the LoRa gateway configuration and data transmission and receives the relevant wireless communication functions.

3.7. LoRa Communication Security Design

In order to ensure the security of LoRa network transmission, the terminal node and server message must be encrypted before interacting. The LoRa network message security encryption process is shown in Figure 7. Step 1: Use the NwkSKey or AppSKey key to encrypt the MAC Load Frame (FRMPayload), where the encryption scheme uses AES encryption based on IEEE 802.15.4/2006B Annex (IEEE802154) with a key length of 128 bits. Step 2: Sampling is based on the [RFC4493]: The AES-CMAC Algorithm, June2006's AES signature algorithm CMAC generates a message consistency code (MIC), which uses only the key NwkSKey. Wherein, the frame load contains only the MAC command when FPort is 0, and the frame load only contains the transfer data when FPort is 0, where the FPort value represents the size of the frame load data.
3.8. Cloud Server Design

The system uses an open source LoRa Server server and deploys it on the Tencent cloud, as shown in Figure 7. The server has the characteristics of stable, intuitive interface, convenient for users to manage gateways and nodes. In this system, it is necessary to configure the node gateway and other parameters, build a base64-based codec to decrypt the packets coming from the gateway, and configure the MQTT communication interface.

![Figure 7. Message security encrypted flowchart](image)

![Figure 8. Lora server](image)
3.9. **Data Monitoring Software Design**
To make it easier to view the data, a web project is deployed on the server to forward the data to other applications by accessing Lora Server’s MQTT broker.

4. **System Test**
A physical map of the LoRa-based greenhouse wireless monitoring device is shown in Figure 9.

![LoRa-based greenhouse wireless monitoring device](image)

**Figure 9.** LoRa-based greenhouse wireless monitoring device

4.1. **Data Acquisition Test**
The node is located in the indoor greenhouse, the gateway is deployed in a location with wireless wifi, and the two are about 500 meters apart, for data collection. The data collected by different sensors on the server side is shown in Figure 10, Figure 11, and Figure 12.

![Temperature and humidity data acquisition](image)

**Figure 10.** Temperature and humidity data acquisition

![Illumination data acquisition](image)

**Figure 11.** Illumination data acquisition

![CO2 concentration data acquisition](image)

**Figure 12.** CO2 concentration data acquisition

Application-side data is shown in Figure 13, and the application can correctly receive and display data from the server side. The whole system can realize the remote wireless monitoring of the greenhouse environment.
5. Conclusion
In this paper, a greenhouse wireless monitoring system based on LoRa is proposed, the main features of which are: (1) the introduction of wireless communication technology LoRa in greenhouse environmental monitoring, and increasing the communication distance between nodes and gateways. (2) A LoRa-based greenhouse wireless monitoring device is designed, which has the functions of temperature and humidity acquisition, lighting acquisition, air quality acquisition and LoRa communication. (3) The use of cloud servers, to solve geographical restrictions, cloud storage data, management equipment. And design forwarding program, according to the need to the sensor data in real time forwarded to the user's application. The next step will be to study the long distance and low power consumption of the system and optimize the application design.

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