Research on Water Meter Reading System Based on LoRa Communication

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***Abstract*—IoT water meter and remote meter reading technology has become an important part of energy measurement. In order to realize low power consumption and remote reading of water meters, this paper proposes a wireless meter reading system by using both the multilevel relay and the concentrator based on LoRa communication. In order to meet the meter's ultra-low power need, the ST's low power consumption microcontroller (STM8l151G) has been selected for controlling SX1278 and flow measurement. The water meter works in an average current of 50 μA. And the relay uses MSP430F169 ultra-low power microprocessor and SX1278. On the basis of "'CJ / T 188-2004' user data transmission using measurement instruments and technical conditions industry-standard protocol and" Q/GDW 1376.1-2013 'power users information collection system communication protocol'" industry standard protocols, this paper modifies both of them to fit for the water meter reading industry and increase the address defined for multi-level relay, the concentrator and master station address, and then develops a multi-level wireless repeaters and concentrators Reading downlink protocol and a uplink protocol between the concentrator and the data center. The system has completed the design of hardware and software, and achieved the accurate measurement of the water meter data, and transmit the data to the concentrator through the multi-level relay by LoRa. Finally, the remote data transmission is carried out by the concentrator through GPRS channel. By testing, the system's meter reading distance, the quantity of the meter accessed and the reliability of data communication can meet the application requirements.**

Keywords- water meter reading; LoRa; multi-level relay; concentrator; GPRS

I. INTRODUCTION

With the emergence of smart cities, smart communities and smart homes, the wireless meter reading technology has been greatly developed and applied. Nowadays, the wireless meter reading methods are commonly used, such as GSM, GPRS, WIFI, ZigBee, etc.. LoRa is a kind of technology which is specially used for radio modulation and demodulation by Semech company[1]. It integrates digital spread spectrum, digital signal processing and coding technology of forward error correction. LoRa technology, through the use of high spread factor, can transmit a small capacity data through a wide range of radio spectrum. It is possible to obtain a wider transmission range and distance with low transmit power by using LoRa technology[2]. In the smart city (street, parking and traffic sensor), energy metering (electricity / water / gas intelligent instrument), and industrial / commercial / home automation (HVAC control, intelligent home appliances, security systems and lighting), SX1278 wireless transceiver module developed by the Semech company, has gradually formed a new system of the internet of things with the features of ultra low power and long distance[3-6]. So the water meter with the internet of things and remote meter reading technology has become an important content of energy measurement[7,8]. In order to realize the low power consumption and remote meter reading function of water meter, this paper has developed a remote meter reading system with multi-relay and concentrator structure based on LoRa and GPRS.

II. THE STRUCTURE AND COMPOSITION OF THE SYSTEM

The system is composed of a wireless intelligent water meter, a multistage repeater, a data acquisition concentrator, a workstation and a data center, as shown in Figure 1. Intelligent water meter with LoRa wireless communication function is installed in high-rise residential buildings, which is used for water meter monitoring and measuring equipment status, by using LoRa to realize the meter reading instruction and the meter reading data. Each building or each unit needs to install a data acquisition concentrator, which communicates wirelessly through LoRa. The concentrator mainly complete the downlink meter reading of the users' water meters in the building or unit by LoRa wireless communication, and through the GPRS it also transmits the meter data to the remote water flow monitoring platform of the workstation or data center, so as to complete the function of users' water pricing and condition monitoring. It can

penetrate 7 floors to complete the wireless meter reading in the unit of high-rise residential building by using the water meter and the concentrator based on SX1278 wireless transceiver module. Therefore, the structure of multilevel remote meter reading system is formed by using multi stage repeater and data acquisition concentrator in high-rise buildings or units. The relay can achieve the wireless communication function of downlink instructions and uplink real-time transmission of the meter data. Each repeater can access 100 meters, and the routing and data transmission can be completed according to the address information in the downlink instruction and the relay is also linked by LoRa, but and the number of the relay is not more than 6. The concentrator manages the downlink repeater and the meter through the key and the LCD, and it can connect 20 relays and 1000 meters.

Figure 1. System composition block diagram

III. THE HARDWARE DESIGN OF SYSTEM

A. *The Hardware Design of the Meter*

The water meter can include the functions, such as flow measurement, valve control and data remote. The water meter hardware structure is shown in Fig.2, which is divided into meter function module and communication module. The meter function module contains Reed switch (for flow measurement) and Valve controller. The communication module is composed of a SX1278 wireless transceiver, a receiving transmitting circuit and an analog switch for antenna control. The microprocessor STM8L151G and each functional module interface can realize the function of flow measurement, valve control and data transfering .The power supply of the meter is supported by 3.6V lithium battery.

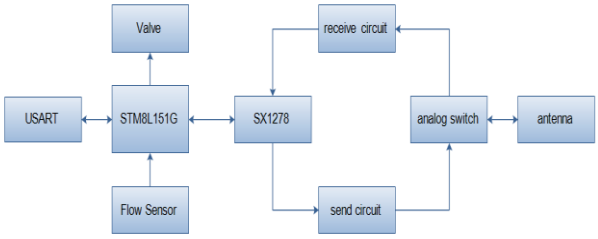

Figure 2. Meter hardware structure diagram

B. *The Hardware Design of the Relay*

The relay is used to link Relay and meter, relay and relay to mainly achieve the communication and data caching. Its hardware structure is shown in Fig 3. And the relay is mainly composed of MSP430F169 and SX1278.

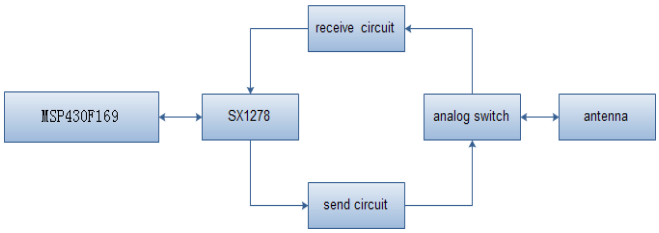

Figure 3. Relay hardware structure

C. *The Hardware Design of the Concentrators*

As is illustrated in Fig 4, the data collector uses the STM32F103ZET6 hybrid microprocessor and the SX1278 wireless transceiver, the M6310 GPRS module interface to realize the data transmission between concentrator and meter, concentrator and data center. A Large Capacity SD card is used to achieve the data storage of the flow of data, table records and the like. The design of TFT LCD and keyboard provides a convenient man-machine interface for the on-the spot management. To meet the demand of the power supply system, the system designs 5 V and 3.3 V power supply output.

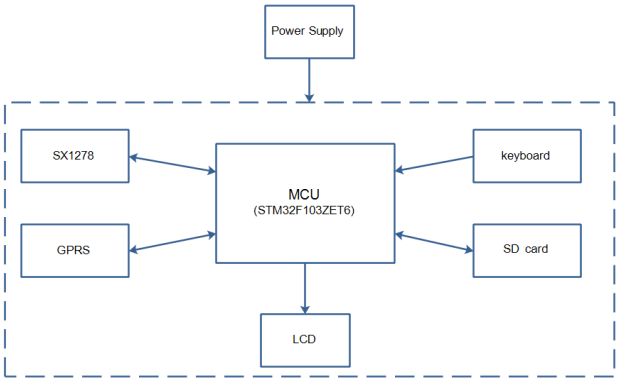

Figure 4. Concentrator hardware structure

IV. THE COMMUNICATION PROTOCOL DESIGN AND SOFTWARE IMPLEMENTATION OF THE SYSTEM

The structure of the whole meter reading network is composed of three main nodes: meter, repeater and concentrator, which can achieve data acquisition, transmission and management. The network system uses a mode of a hierarchical management, and the concentrator, being a key component, stores all the information of the meter and the relay. The meter reading instruction of the concentrator contains the path information (the relay series and the address of each relay, the meter address). The relay contains the address information of 100 water meters registered in this relay and the address information of the relay before and after. When it receives its own data frame,

the relay analyzes it to determine the sending direction of the data frame(as Figure 5 in more detail). Each node in this whole system has a clear and unique address number which is the key factor to ensure data communication, and the correct flow of all data is through the data frame address information to select the flow through the node. According to the location of the node, the corresponding meter and the relay number is set to determine the transmission path of the meter data. In addition, the system has developed a set of uplink and downlink protocols to ensure the fast and reliable data transmission.

A. The Design of Downlink Communication Protocol

The downlink communication between the meter, relay and concentrator is based on Lora wireless as a hardware interface. In the design of communication protocol, on the basis of the"CJ/T 188-2004" technical standard for the data transmission of household metering instruments " industry standard agreement, the address definition for the multi-level relay and the concentrator is increased, and the wireless downlink protocol is developed through the multi-level relay and the concentrator .

The data frame is composed of 10 parts: start character, meter type, water meter address filed, control character 1, control character 2, data length, data filed, relay address, sum and check code and end character. The start character, data length, sum and check code and end character are used for checking error code that appears in the transmission process. The terminal communicates accurately with every water meter according to meter address filed, realy address and control character 1. The control character 1 contains transmission direction, transmission status, function code and other information. There are N byte in data filed which determine the contents of the data to be written or read. By changing data representation, we can obtain different data, such as water meter's real-time data，historical data , daily data and so on。

In addition to the design of the reliability of the data transmission through the communication protocol, the system has been designed on the real-time reading and re-read meter mechanism. From the test, we found that the time of the data transmission between the two points by Lora is about 4S (communication rate can be accelerated, but taking into account the response speed and power consumption, this rate is selected). Different meter reading time is set for different network nodes. So when the concentrators send meter reading instruction, the timer begins to time at the same time. If the concentrators do not receive the answer back after timeout, the meter address would be recorded as " meter reading failure " , and the concentrators stop reading this meter to the others. After completing reading all the meters in file, the concentrators will reread the meters with failure in the record. In this way, the system could ensure real time and not miss any meter.

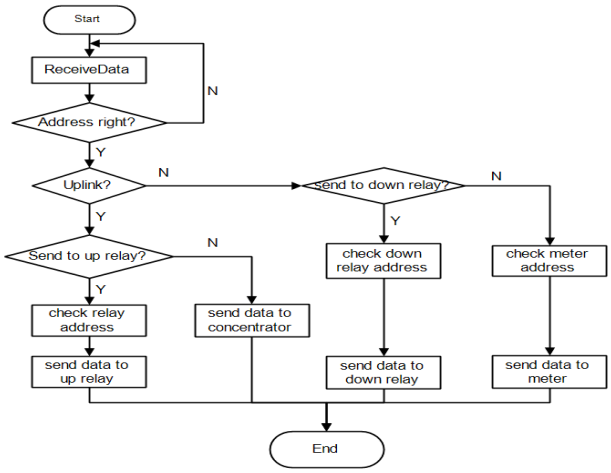

Figure 5. Relay Path choice

B. The Design of Uplink Communication Protocol

The Uplink communication between concentrator and data center use GRPS channel for remote data exchange. In the design of communication protocol, on the basis of the "Q/GDW" 1376.1-2013 "power user information collection system communication protocol" industry standard agreement, the modification of water flow data acquisition system is carried out, as a result, the communication protocol of data acquisition concentrator, server and data center is developed. The general format of the data is shown in Figure 6.

68H	RTUA4	RTUA3	RTUA1	RTUA2	MAS1	MAS0	68H	CMD	LEN_0	LEN_1	DIO	DI1	DATA	PW2	PW1	PW0	CS	16H
StartCode	GatewayAddress				Master Station Address	CSN	StartCharacte	ControlFiled	DataLength		DataidentIfication		DataFiled	PassWord			CS	EndCode

Figure 6. The general format of data frames for uplink communication protocol

As is illustrated in Fig 6, similarly, the data frame is composed of 11 parts: start character, Gateway address filed, master station address, CSN, control filed, data identification, data length, data filed, sum and check code, password and end character. The start character, data length, sum and check code and end character are used for checking error code that appears in the transmission process. The master station accurately combines with every data acquisition terminal according to the Gatewayaddress. The control character contains transmission direction, exception flag and function code. The data identification and data filed contains data information in transmission.

A problem should be solved when using GPRS: by using GPRS channel, if the master and the terminal disconnect the link, the terminal needs to send a login request, and only in this way can the link reconnect. So a reasonable reconnection mechanism is necessary for on-line data acquisition and monitoring system. In our system, we design this method: After the system powered up, the terminal connects to the master station and sends login frame, and then the terminal

waits for confirm frame, if receiving confirm frame, the terminal begins to send heartbeat (The transmission frequency is adjustable), else the terminal connect to the master station and send login frame again, after sending heartbeat, the same as before, the terminal waiting for confirm frame, if receive it, the terminal send heartbeat in a common transmission frequency cyclically, otherwise, send three times consecutive heartbeats with an interval of 10 seconds, if one of this three heartbeats has been answered, the terminal sends heart beat in a common transmission frequency cyclically, if not, the terminal connects to the master station, as is shown in Fig7.

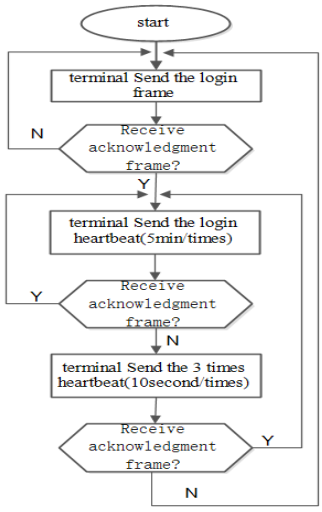

Figure 7. The terminal connected to the master station

V. CONCLUSION

The wireless meter reading system, composed of intelligent water meter and multi-level relay and concentrator, realizes the data management and transmission through LoRa wireless communication classification, and wireless meter reading distance of each level can penetrate the 7 floors, so it can solve the defects of the other RF wireless meter reading mode, as the transmission distance is short and the ability to passing through the wall is weak. Because the use of LoRa wireless communication needs the selection between the meter reading efficiency and the power consumption, the requirement for the power consumption of battery power supply system is strict and demanding, and the frequent meter reading will bring greater power consumption, so in the design of the system, we will set the successful communication time as 4s in LoRa wireless meter reading system. If the concentrator contains a large number of meters and some meters may pass through multiple relays, the meter reading efficiency will be low. But considering the actual movements in meter reading is unfrequent, read all meters within one day can basically meet the demand, and in the practical application, each relay levels generally reaching level 3 can meet the design requirements. Concentrator in the maximum load of 1000 meters for a full table operation time costs 12000 seconds or so on the theory of maximum time, a total of about 3.4 hours,which can meet the demand. And this design can ensure that the average working current of the meter is about 50μA, which can meet the needs of power consumption design and complete the task of reading meter. So the whole system has strong practicability and low cost, and it has a strong application prospect.

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