The Application of Wireless Sensor Network In the Irrigation Area Automatic System

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Abstract—In the irrigation area automatic system, high-performance embedded micro-controller and low-power technology is used to design the water wireless sensor network. The sensor node gathers the hydrographic information such as water-level, gate position and rainfall. The sink node receives the real-time data; the information center stores and processes those data which are transmitted from the sink node through the GPRS network. The system replaces the wired transmission with the wireless transmission, which reduces the costs in installment and maintenance, and improves the system's reliability and extension. It has better application prospect.

Keywords—Wireless sensor network; Irrigation area; GPRS; Sensor node; Sink node

I. INTRODUCTION

Wireless sensor network is an intelligent private network made by a large number of sensor nodes which have specific function[1]. They transmit the information mutually, and collaboratively complete the specific function through self-organization's wireless communication. It synthesizes the sensor technology, the embedded technology, the modern network and wireless communication technology, the distributional information processing technology and so on. It may real-time monitor, sense, gather and process the information of environment. Then it is transmitted to the terminal user.

The traditional irrigation area automatic system mostly uses the wire to connect the water-level, rainfall and gate position sensors and the data acquisition to transmit the hydrographic information. It brings the complex wiring, and the line is easily damaged, and the cost in installment and maintenance is high. At the same time, when the survey parameter is needed to be increased, the hardware and software of the data acquisition are often needed to be revised. The system's extension is not good, so it is not convenient. The wireless sensor network is applied in the irrigation area automatic system, and the wired transmission is replaced by the wireless transmission. It can reduce the cost in installment and maintenance and enhance the system's reliability and extension. The sensor node gathers the hydrographic information, and transmits it to the sink node by the wireless way. The sink node will transmit the survey information to the information center through the GPRS network[4]. It will provide the reliable hydrology data to the management department, to better serve for the water resources management and agricultural production.

II. THE SYSTEM STRUCTURE AND FUNCTION

The irrigation area automatic system is a wireless sensor network application system. It is made of the sensor node, the sink node and the information center. The structure of the
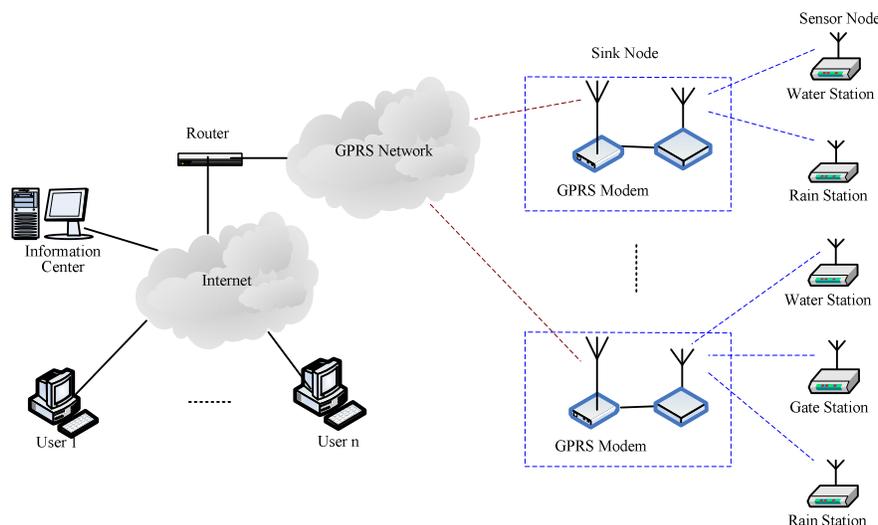

Fig.1 The structure of the system

System is shown in Figure 1:

The sensor node is responsible for gathering the water-level, the gate position and the rainfall information. The sink node is responsible for receiving the data transmitted from each sensor node, and real-time uploading to the information center through GPRS network. The information center is responsible for receiving the data, and providing to the terminal user to visit.

III. NODE DESIGN

The irrigation area automatic system uses the wireless sensor network, and it contains the water-level node, the gate position node, the rainfall node and the sink node. It selects the wireless multi-channel UHF transceiver CC1020[5] which is low-power consumption and low-voltage to carry on the wireless data communication, and the high- performance and low power consumption MCU C8051F310 to gather and process the sensor data. The low-power consumption software and hardware design method is used to design the water-level or gate position node and the rainfall node, which enables the sensor node to work for long time in the battery power supply situation. This satisfies the design request.

A. Water-level or gate position Node

The output data form the water-level sensor and the gate position sensor is similar. They use the same hardware interface connecting with the C8051F310[6]. The water-level sensor is a photo-electricity encoder. The mechanical movement of the float and the hammer drives the coding dish, and then the gray code is outputted. The gate position sensor generally uses the absolute encoder to produce the switching output data and the output gray code or other code. The MCU C8051F310 reads the sensor data through the I/O port[2], and then transmits to the sink node through radio frequency module CC1020 after transforming to the binary data. The schematic diagram of the node hardware is shown in Figure 2:
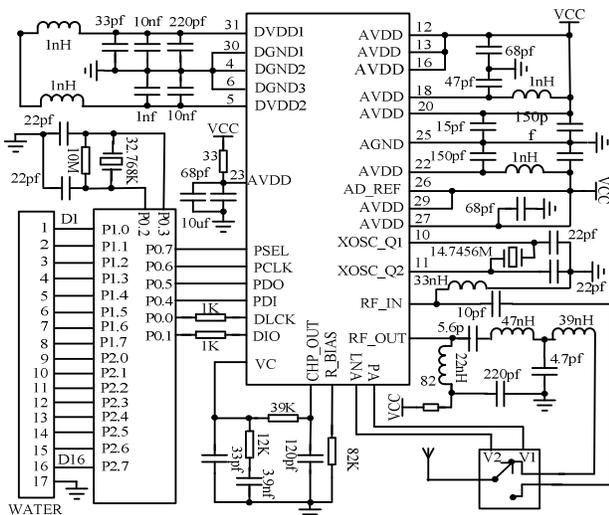

Fig.2 Schematic of the water-level or gate node hardware

C8051F310 enquire the sensor data periodically. If the sensor data changes, MCU runs in the internal 24.5M clock, and awakens the CC1020 to transmit the changed sensor data.

Otherwise, the MCU runs in the exterior 32.768 KHz clock, waiting for the next cycle period. The entire node's static power consumption is very low (only 18uA). It can work for a long time with the ordinary battery power supply, and satisfies the design request of the water-level wireless sensor node.

Moreover, in the rivers and reservoir, there may have wave in the water surface as the result of ship and so on, which may cause the water-level gathering to have an inaccurate data. Therefore, the Water Node must be able to avoid the wave. When sampling the water-level, CPU compares the sampling value with the historical data. If the water-level has changed, CPU samples again after 5 minutes, if the change is still maintained, it means the water-level has had truly changed. The data is sent out promptly after converted and processed. Otherwise, it means that the water-level change 5 minutes ago is caused by the wave, and CPU doesn't process.

B. Rainfall Node

The rainfall sensor is a photo-electric pulse output. It collects the raindrop through 2 dump vessel in turns. The vessel will automatically overturn empty after collecting full raindrop. Simultaneously it produces a pulse which represents a unit of rainfall. After detecting the rainfall pulse, C8051F310 transmits the data to the RF transceiver CC1020. Then CC1020 transmits the data to the sink node. The schematic diagram of the rain node hardware is shown in Figure 3:
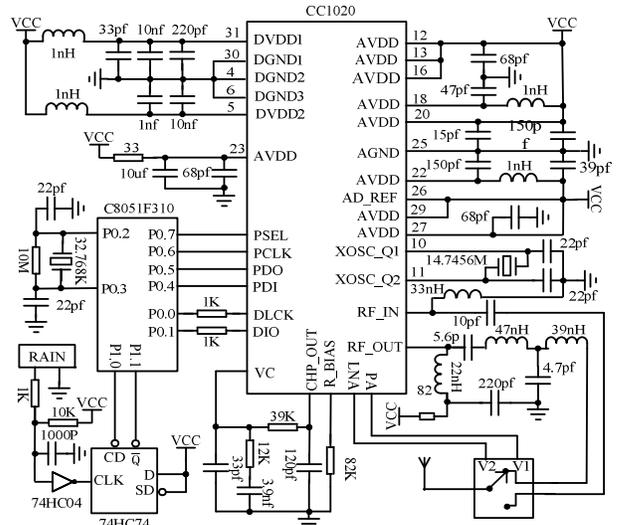

Fig.3 Schematic of the rain node hardware

Usually C8051F310 runs in external 32.768KHz clock when no task. The rainfall pulse signal is transmitted to an interrupt input pin of C8051F310 after locked by 74HC74, and it awakens CPU to process the rainfall by a low level. As the node runs in power-down method[9], the static power consumption is very low (only 18uA). It can work for a long time with the ordinary battery power supply, and satisfies the design request of the Rain Node.

In the rainfall sampling circuit, there may exist interference. Therefore the trigger is used to solve the problem. According to the local maximum rainfall and the measuring range of the rain gauge, we calculate the time T_0 that the rain gauge needs to collect a unit of rainfall. Once CPU detects a rainfall pulse,

it will process promptly and send it out. Simultaneously it starts to time. If there has another rainfall pulse in T_0, it means that it is interference. CPU only needs to eliminate the trigger output and continue to the normal work again after T_0.

C. Sink Node

The Sink Node connects the sensor network with external network, and its processing ability, storage capacity and communication capability are quite strong. In the irrigation area automatic system, the Sink Node and the sensor nodes compose the wireless sensor network through the RF transceiver CC1020, and it connects to Internet through the GPRS module, and exchanges the data with the information center. The schematic diagram of the sink node hardware is shown in Figure 4:
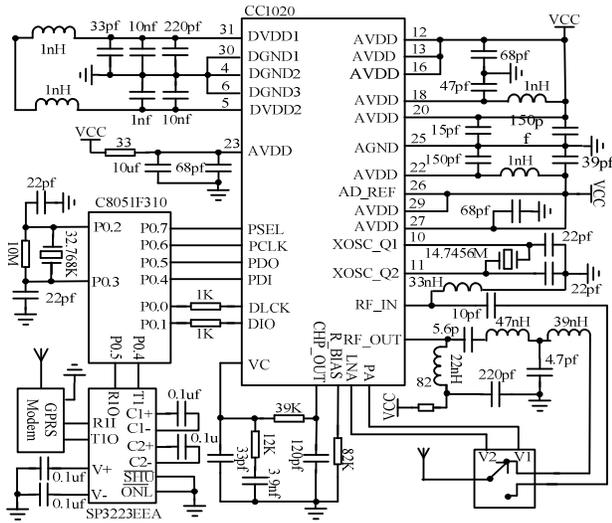

Fig.4 Schematic of the sink node hardware

After receiving one frame from CC1020[10], 8051F310 transmits the data to the GPRS module through RS232[8]. The data is transmitted to the information center through the GPRS network; displayed, stored and inquired in the information center, and the information can be issued through the Internet.

IV. COMMUNICATION PROTOCOL

A. Protocol design

The system is the multiple to single wireless sensor network, and the position of the sensor node and sink node is relatively fixed in this wireless network system. The system uses the broadcast communication protocol which is based on the transmission beacon frame to satisfy the low power consumption and redundant reliable request[3]. The protocol has defined two kinds of frame forms: beacon frame and data frame.
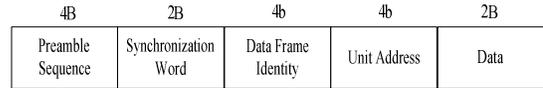
1）Beacon frame

The beacon frame is broadcasted to the sensor node by the sink node. It includes preamble sequence, synchronization word, beacon frame identify and beacon frame sequence. When a sensor node has new data to transmit,it make CC1020 enter RX state[10] to receive the beacon frame. The beacon frame is defined as follows:

4B	2B	4b	4b
Preamble Sequence	Synchronization Word	Beacon Frame Identity	Beacon Frame Sequence
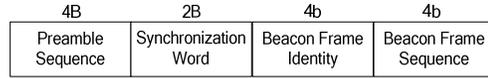
Each beacon frame has 7 bytes. The preamble sequence synchronizes the transmitter and receiver; the synchronization word marks a data frame; the beacon frame identify differentiates between the data frame. The system uses 0110 as the sign of beacon frame. The beacon frame sequence marks the different beacon frame, and its valid range is 0~15.

2）Data frame

The data frame is the data message transmitted to the sink node by the sensor node. It includes preamble sequence, synchronization word, data frame identify, unit address and data. It is defined as follows:

4B	2B	4b	4b	2B
Preamble Sequence	Synchronization Word	Data Frame Identity	Unit Address	Data

Because the value of the water-level or gate position sensor and the rainfall sensor needs only two bytes to express, therefore the data frame contains 9 bytes. The data frame differentiates between the beacon frame. The system uses 1001 as the sign of data frame. The unit address marks the different node's terminal, and it contains four bits, and can be expanded if needed. The Data contains 2 bytes, expressing the sensor data.

The sink node enters the TX state, and transmits 16 beacon frames. Then it enters the RX state to receive the data frame. The time in the TX state and RX state is equal[10]. If the sensor node needs to transmit data, it waits to receive the beacon frame from the sink node, and has a fixed time's delay. The delay time of different sensor node is dissimilar. This can well avoid the data collision. The sensor node is in the pattern of low-power consumption in other times. The schematic diagram of the protocol structure is shown in Figure 5:
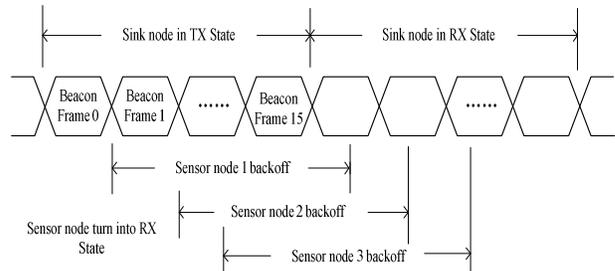

Fig.5 Schematic view of protocol structure

B. Test

In the wireless communication, the reliability of the data transmission is important[7], and it decides the system's performance. The sink node periodically transmits the beacon frame unceasingly. Once received the beacon frame, the sensor node transmits a certain number of data frame in the corresponding slot. The sink node receives the data transmitted from various sensor nodes, and the received data is checked and counted. In the laboratory, the single-single test and the multiple-single test are carried on separately.

1）Single-single

The experiment is carried on with a gate position sensor node and the sink node. The node begins to transmit the data packet after received the beacon frame. It transmits altogether 3000 data packets, and then obtains the empirical result. The result is shown in Table 1:

TABLE I.   SINGLE-SINGLE

NO	Packes ransfered	Packet eceived	Packet Error Rate(‰)
1	3000	2991	3.0
2	3000	2987	4.3
3	3000	2994	2.0
4	3000	2991	3.0
5	3000	2990	3.3

2）Multiple-single

The experiment is carried on with four sensor nodes and the sink node. Each sensor node begins to transmit the data packet after received the beacon frame. Each sensor node transmits altogether 3000 data packets, and then obtains the empirical result. The result is shown in Table 2:

TABLE II.   MULTIPLE-SINGLE

NO	Packet received				Packet Error Rate (‰)			
	Gate1	Gate2	Rain	Water	Gate1	Gate2	Rain	Water
1	2992	2984	2979	2979	2.7	5.3	7.0	7.0
2	2991	2991	2976	2979	3.0	3.0	8.0	7.0
3	2991	2983	2979	2972	3.0	5.7	7.0	9.3
4	2990	2988	2983	2973	3.3	4.0	5.7	9.0
5	2990	2985	2980	2976	3.3	5.0	6.7	8.0

3）The experiment analysis

From the experimental result, it can be seen that the PER is less than 1% because no disturbance from other nodes. The PER is low enough to satisfy the system's application request. The rainfall node can store the data; the output of the water-level and gate sensor can be maintained. If there is a data loss in the communication, it has little impact on system performance.

In the view of hardware point, there mainly have two aspects which cause the data loss。 The time for CC1020 to change state is uncertain. CC1020 runs to the RX state from the idle state, and runs to the TX state from RX state. After changed the state, the stable time is random, and it makes C8051F310 can't accurate time and causes the data packet loss. On the other hand, the periphery components around CC1020

have quite influence on the stability. From the experiment, it can be found that the PER[7] of the water node is 0.7%~1% which is bigger than the others. It is not related to the transmission order but related to the precisions of the periphery capacity, inductance and resistance of CC1020 and welding quality.

V.   CONCLUTION

Wireless sensor network is obtaining the more and more widespread application by its outstanding merit, and its research for application also becomes popular. Applies the wireless sensor network in the irrigation area automatic system, can reduce the system's cost, enhance the system's extension and improve the system's performance. The system has high stability   indicated by the experiment, and so it can be used in water resources dispatch, flood prevention direction and so on.

The system will be further improved in its future research in these two aspects:

1) Reduce the power consumption by choosing lower-power RF chip and MCU which has a variety of work modes to extend the life of the battery.

2) Optimize software and hardware design to reduce the PER. If considered fully about the time for changing states in the software, choosing the periphery components and enhancing the welding quality, the PER can be reduced and the system's performance can be enhanced.

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