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Environmental Monitoring Wireless Sensor Network Node Energy Technology Analysis

Xiaoli Cai*, Shahreen Kassim and Van Huong Dong*****
*Chongqing Chemical Industry Vocational College, Chongqing 400020, China
**University Tun Hussin Onn, Malaysia
***Ho Chi Minh City, University of Transport, Vietnam

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ABSTRACT

At present, the energy problem has become one of the hotspots in the research of wireless sensor networks. In this paper, the design scheme of low-power technology is adopted by using real-time clock to control the on-off power supply, so that the dormancy power consumption of sensor nodes can be reduced to uA level, and the energy consumption of sensor nodes can be solved to the maximum extent. At the same time, the sensor interface of the sensor node designed in this paper has universality and is very suitable for environmental monitoring applications. After systematic test, it can be proved that the maximum working current of sensor nodes can reach 34.75mA and 0.0008mA in the system sleep state. If the acquisition is carried out every half hour, each time only needs 150s, and the power consumed by the sensor node every half hour is 1.4454mAh. The capacity of lithium battery is calculated according to the nominal value of 3800mAh. Without considering the self-discharge of the battery, the sensor node can work for 55 days without energy supplement. It is further verified that the wireless sensor network nodes can meet the requirements of long-term environmental data acquisition tasks in the field.

INTRODUCTION

Because wireless network sensor technology has been widely used in industry, commerce, medicine, consumption, military and other fields (Li et al. 2019), the energy problem has been the key to extend the service life of wireless network sensor and reduce the cost. It is very difficult or even impossible to change the battery when the environment is harsh or when the network nodes are moving or changing, so it is a wise choice to effectively reduce the power consumption of wireless sensor networks, especially the power consumption of wireless sensor networks that are dormant most of the time (Mukherjee et al. 2019). Although there are many node scheduling algorithms, these nodes fail to consider the energy consumption of a single node, which leads to excessive energy consumption of the node and seriously affects the network coverage effect and the life cycle of the whole network (Zhang & Chen 2019, Abella et al. 2019, Sheikhi et al. 2019). In this paper, the design scheme of low-power technology is adopted by using real-time clock to control the on-off power supply, so that the dormancy power consumption of sensor nodes can be reduced to uA level and the energy consumption of sensor nodes can be solved to the maximum extent. At the same time, the sensor interface of the sensor node designed in this paper has universality and is very suitable for environmental monitoring applications.

PAST RESEARCH

The research of sensor network started in the late 1990s. At the very beginning, wireless sensor networks have obtained abundant research results in the university of California, Berkeley, University of California, Los Angeles and Cornell University (Wang et al. 2019, Amini et al. 2019, Abella et al. 2019). Many famous companies have researched and developed sensor networks from different levels and perspectives. The United States has proposed the "national intelligent transportation system project plan", and the United States Intel Corporation has released the "new computing development plan based on the micro-sensor network". The natural science foundation of the United States of America has developed a research program for wireless sensor networks to support basic research. Intel Corp. demonstrated a wireless sensor network system for home care. By embedding semiconductor sensors in props and equipment such as shoes, furniture and household appliances, the system helps elderly people, Alzheimer's patients and disabled people in their family life, and uses wireless communication to connect the sensors to efficiently transmit necessary information so as to facilitate nursing (Roch et al. 2019, Li et al. 2019).

Table 1: Running status of wireless network sensor nodes.

Running state	Processor	Memory	Data conversion	Wireless communication	Data acquisition	Real time clock
S_0	Active	Active	Active	Accept, Send	Active	Active
S_1	Active	Active	Active	Accept	Active	Active
S_2	Free	Dormancy	Active	Accept	Closed	Active
S_3	Insomnia	Dormancy	Dormancy	Accept	Closed	Active
S_4	Closed	Closed	Closed	Accept	Closed	Active
S_5	Closed	Closed	Closed	Closed	Closed	Active

MATERIALS AND METHODS

Wireless network sensor nodes are mainly composed of processor, wireless communication, memory, data conversion, energy supply, real-time clock and data sampling modules. Each module has different working states and each state has different power consumption. The effective dormancy states of sensor nodes are shown in Table 1. From the point of view of energy cost, the energy cost of sensor nodes in wireless network is obviously different with the different running states. As can be seen from Table 1, S0 has the largest power consumption, followed by S1, followed by S2, S3, S4 and S5.

So is the fully functional normal operation mode, S1 can complete the collection, conversion and storage of sensor data, S2 can complete the conversion task, S3 is the general idle mode, and S5 is the idle mode with the lowest power consumption. In S4, only the receiving part of the wireless communication module and the real-time clock module work, and the rest are in the closed state with low power consumption. In S5, only the real-time clock module works, and the rest is closed with the lowest power consumption. With the S5, you can only wake up the system with a real-time clock.

In the system, the low-power real-time clock chip PCF8563 and the electronic switch ADG821 are used to manage the energy of each module. The schematic diagram of its overall scheme is shown in Fig. 1. The energy supply module directly supplies power to ADG821 and PCF8563, and the rest of the modules are supplied by ADG821.

Temperature Sensor Test and Research

PTWD-3a is a commonly used platinum resistance temperature sensor, which is widely used in environmental temperature measurement. The sensor performance is stable, the range of 40 ~ + 150°C, the measuring accuracy of plus or minus 0.2°C. According to the operating instructions of the temperature sensor, its output is a resistance signal, and the calculation formula of output and temperature is shown in equation 1.

$$R_t = R_0\left(1+0.0039083t-0.0000005775t^2\right) \quad \ldots(1)$$

Where, the Rt for the current temperature sensor output resistance, R0 sensor output value to 0°C, taking 99.99 Ω here, t is the current temperature value.

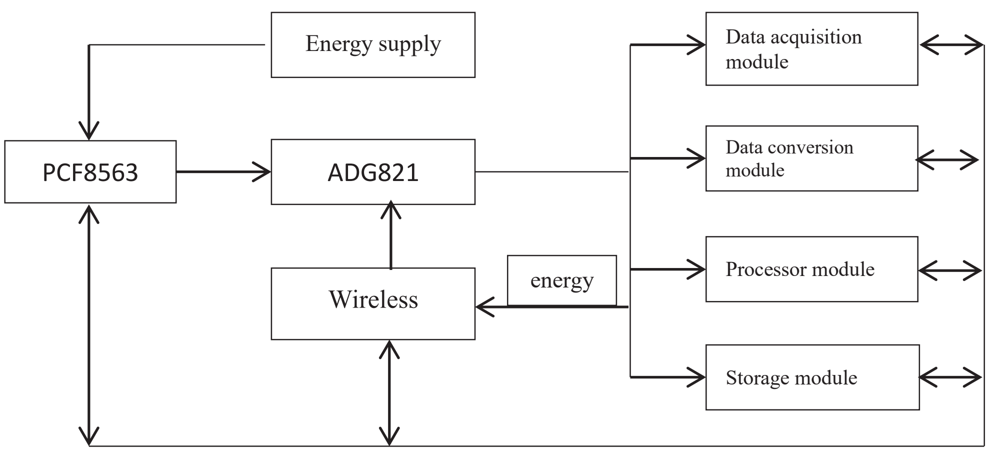

Fig. 1: Overall energy scheme design of nodes.

Table 2: Test results of temperature sensor.

Test content	Reference temperature	Collect temperature
The calibration	16.9°C	16.9°C
Test 1	3.8°C	4.0°C
Test 2	7.8°C	8.0°C
Test 3	38.8°C	38.9°C

Table 3: Test data of air humidity sensor.

Test content	Reference temperature	Collect temperature
The calibration	57.50%	57.60%
Test 1	62.4%	61.60
Test 2	67.80%	68.90
Test 3	75.2%	75.60%

The test method of the temperature sensor is as follows: First, calibrate the amplification factor of the temperature sensor, perform linear fitting, that is, randomly measure a standard temperature and modify the amplification factor of ADC. Then, three random temperature points were selected for measurement, and the difference between the collected temperature value of the sensor and the actual temperature value was observed to obtain the collection accuracy of the sensor node. In actual measurement, electrothermic constant temperature water bath pan and precision temperature and humidity meter are selected. Considering the large temperature fluctuation range of electrothermic constant temperature water bath pan, mercury thermometer reading is used alone. The test result of temperature sensor is shown in Table 2.

According to the actual measurement result, when the temperature is 16.9°C (room temperature), the calibration of sensor node voltage magnification, and to measure the temperature of the other 3 points. Measurement results and the reference temperature, the smallest gap is 0.1°C, the biggest gap is 0.2°C, meet the design requirements.

Soil Moisture Sensor Test

The soil moisture sensor TDR-3 selected by the system is widely used in soil moisture monitoring, and it can detect the soil moisture content in the region within the cylinder with a diameter of 3cm and a length of 6cm around the central probe. The range is 0-100% and the accuracy is 2% in the range of 0-50%. According to the operation manual of soil moisture sensor, its output is 0-2.5V dc voltage signal, and the calculation formula of output and humidity is shown in equation 2. Where V_{OUT} is the output voltage value, the soil moisture content in the monitoring area can be calculated reversely according to the formula q_v % (m^3/m^3). According to the experimental results, the moisture content of the dry soil was 0.6%.

$$\theta_V = 0.0337 \ V_{OUT}^3 - 0.0426 \ V_{OUT}^2 + 0.2008 \ V_{OUT} - 0.0041 \quad \ldots(2)$$

Air Humidity Sensor Test

The environmental humidity sensor PTS-3 is used to measure the air humidity. The humidity sensor adopts the high polymer film moisture sensitive capacitor, and its dielectric constant changes with the change of relative humidity. The measuring range of the sensor is 0~100% RH, the measuring accuracy is 2% RH, and the supply voltage is 0~24V dc. According to the operating instructions of the environmental humidity sensor, its output is 4-20ma dc current signal, and the calculation formula of output and humidity is shown in equation 3. T_{OUT} (unit: mA) is the signal output of the humidity sensor. As a result of the system ADC reference voltage of 2.5 V, so choose 120 Ω sampling resistor, the output current signal is converted into a voltage signal.

$$\text{Humidity (\%RH)} = 6.25 \bullet I_{OUT} - 25 \quad \ldots(3)$$

The measurement method of air humidity sensor is similar to that of temperature sensor. The current amplification was first calibrated using testosterone 625 as the standard value. Then spray water into the air and measure it three times. Observe the difference between the humidity value collected by the sensor and the actual humidity value. The acquisition accuracy of sensor nodes is obtained. The actual measurement results are shown in Table 3. According to the actual measurement results, when the humidity is, the current amplification factor of the sensor node is calibrated, and then the humidity of the other three points is measured. The minimum difference between the measurement result and the reference humidity value is 0.4%, and the maximum difference is 1.1%, which meets the design requirements.

Table 4: Discharge test data of lithium battery.

Time	Voltage (V) \Current (A)
13:20	411V\0.78A
14:20	3.86V\0.74A
15:20	3.69V\0.71A
16:20	3.61V\0.67A
17:20	3.55V\0.68A
18:20	3.99V\0.66A
19:20	Stop discharge

Table 5: Sensor node current test data.

Serial number	Test content	Current (mA)
1	System status (RX)	34.75
2	System status (TX)	25.62
3	System idle state	7.75
4	System sleep state	0.0008
5	Temperature sensor	11.67
6	Soil moisture sensor	81.29
7	Ambient humidity sensor	60.36

RESULTS AND DISCUSSION

Power Analysis of Wireless Sensor Network Nodes

The power consumption of the wireless sensor network node test is divided into two parts, the first part is to measure the node under all kinds of working state of current, by current and node of working time, the life of the compute nodes. The second part is to measure the voltage of the node battery regularly through the actual network work of the node, estimate the power consumption of the node through the battery voltage drop, and calculate the life of the node. When calculating the life of a node, you must know the actual capacity of the battery. The selected lithium battery has a nominal capacity of 3800 mAh. A simple discharge circuit was used to measure the lithium battery. The measurement results are shown in Table 4. The test shows that the total discharge time of the sensor node battery is more than 5 hours, and the average discharge current of the battery is about 0.7A. The calculated battery capacity of the sensor node is greater than 3500 mAh, which basically meets the nominal value of the battery.

Wireless Sensor Network Node Current Test

There are three types of sensors used in this paper, including temperature sensor PTWD-3a, soil moisture sensor TDR-3 and environmental humidity sensor PTS-3. When measuring the working current of each working state of the sensor, it is necessary to measure the working current of the above sensors. However, because the acquisition time of sensor nodes is very short and the working time of each sensor is very short, it basically has no influence on the calculation results. The measuring instruments are carried out through five semi-table multi-metres ESCORT3146A. The current test results of sensor nodes are shown in Table 5. According to the measurement results, the maximum working current of the sensor node in the system operation state is 34.75 mA, and the current in the system sleep state is 0.0008 mA. The sensor node works at the frequency of acquisition every half an hour, 150s each time, so the power consumption of the sensor node is 2.8907mAh per hour. The capacity of lithium battery is calculated according to the nominal value of 3800mAh. Without considering the self-discharge of the battery, the sensor node can work for 55 days without energy supplement.

Node Voltage test of Wireless Sensor Network

Under the normal networking condition, the sensor node receives the command issued by the node manager, collects data and uploads it, and then goes to sleep normally according to the sleep instruction. The lithium battery voltage of the sensor node was measured regularly and the number of times the sensor uploaded data was calculated. The life of the sensor node was calculated through the voltage drop of the lithium battery. According to the measurement results, the initial voltage of the battery of sensor node 1 is 4.1934 V, and the initial voltage of the battery of sensor node 2 is 4.1580 V. The sensor node works at the frequency of acquisition every half an hour, 150s each time, and the sensor works 145 times in the actual test process. The voltage of node 1 lithium battery drops by 0.061 V, and the average voltage drops by 0.0004 V each time. The voltage of node 2 lithium battery drops by 0.060 V, and the average voltage drops by 0.0004 V each time. According to the discharge, from the perspective of network functions, sensor nodes have dual functions. Firstly, as terminal devices, sensor nodes are responsible for sensing information and pre-processing. Secondly, as a routing device, the sensor node is responsible for transmitting data of other nodes or commands issued by the node manager to assist other nodes to complete monitoring tasks. Compared with node managers, sensor nodes are limited by hardware resources and limited in computing and storage capacity, and can only perform simple computing functions. Node manager can complete data fusion and more complex computing functions, and has a strong storage capacity. The node manager receives commands from the processing centre, broadcasts to the sensor nodes, coordinates each node to complete monitoring tasks, collects monitoring data and uploads it. The node manager realizes the communication protocol conversion between the external network and the wireless communication network, and the node flow is shown in Fig. 2. Characteristics of lithium battery, sensor nodes can work for about 48 days without energy supplement.

For a wireless sensor network, the lifetime of the sensor node is the lifetime of the entire network. Nodes are limited by their own size and carry limited battery energy. Meanwhile, nodes are usually used to perform unattended tasks, so it is extremely inconvenient to replace batteries manually. Once the energy of the node is exhausted and cannot be replenishment in time, the node will stop performing monitoring tasks and routing functions, and the robustness of the entire network will be directly affected, and the survival time of the network will be shortened directly. Compared with sensor nodes, there are only a limited number of node managers in each network, so the manual maintenance cost is low and the difficulty is small. Therefore, sensor nodes are the research focus of wireless sensor networks. Sensor nodes have application relevance, different requirements, different designs, it is impossible to meet all the application requirements in the same network. However, the basic structure of sensor nodes is the same, including processing unit, sensing unit, energy unit and communication unit, as shown in Fig. 3.

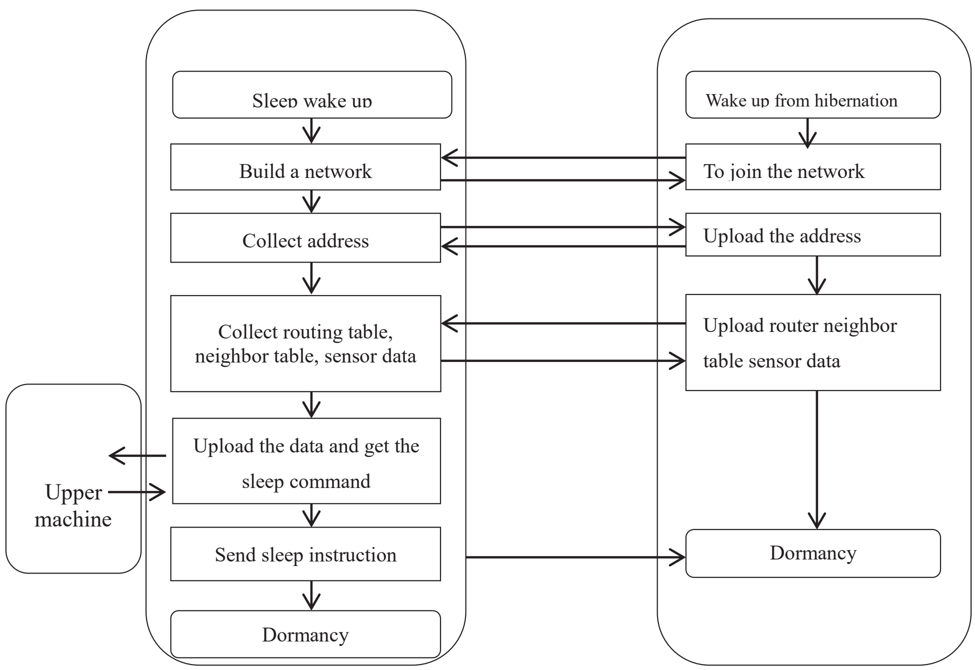

Fig. 2: Wireless sensor network communication flow chart.

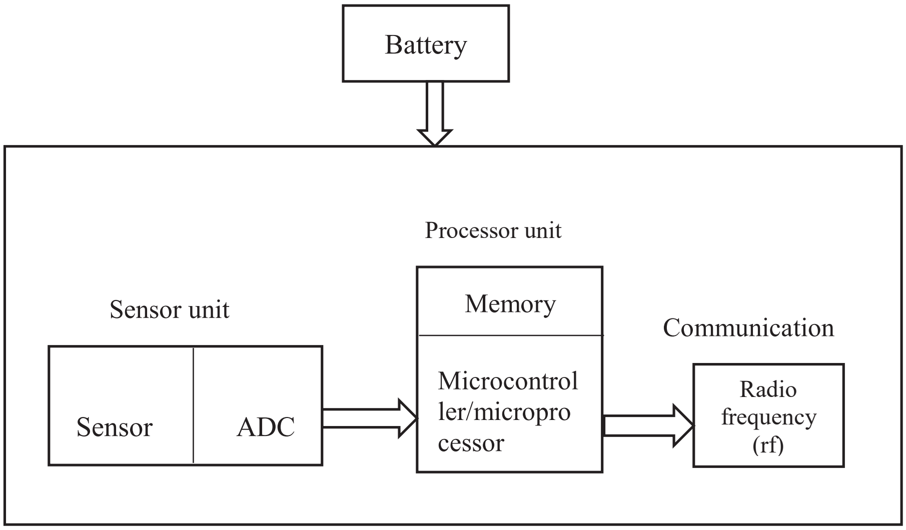

Fig. 3: Sensor node structure.

Wireless sensor network nodes are tiny and carry very limited lithium-ion batteries. There are four states of sending, receiving, idle and dormant in a wireless sensor network node. The energy consumption of the network node is the largest in the sending state, the capacity consumption in the receiving state and idle state is the same, slightly less than that in the sending state, and the energy consumption in the sleeping state is the smallest.

Because the microprocessor chip CC2530 used in this system only has a 24-bit internal sleep timer for setting the system to enter and exit low-power sleep mode. This is a 24-bit positive counter running at 32.768khz constant frequency, and the maximum count time is only 512 seconds. When the counter overflows, the microprocessor needs to wake up to clear the terminal flag. In this way, the microprocessor frequently switches between idle and dormant state, resulting in a large amount of energy consumption. At the same time, wireless sensor network node is to collect environmental information, not only to record environmental information but also to record the sampling time. Moreover, because the environmental information of a place is guaranteed within a period of time, intensive collection is meaningless, and sensor nodes only need to sample at intervals, so the system design must meet the requirements of absolute time, and the external RTC clock chip must be considered.

Through I2C bus serial transmission of all addresses and data, can achieve the automatic operation of the clock and absolute timing. Support alarm function and timer interrupt output as well as a variety of complex timing services, especially suitable for long sleep/wake system. At the same time, the local time of all sensor nodes can be guaranteed to be consistent in a certain period of time without considering the inherent clock differences, so as to facilitate the cooperative work among nodes.

CONCLUSION

Wireless sensor network (WSN) is applied to the environmental monitoring is a new way of environment information acquisition. Through this paper, the wireless sensor network node energy technology in-depth exploration and research is done, to be able to clear that wireless sensor with small volume, strong environmental adaptation, the characteristics of the discharge characteristics of stable and low cost, no pollution, and therefore is very suitable for application in the field of environmental monitoring; in addition, it should be noted that, although the current wireless sensor has been able to work in the field for a long time, but in order to effectively extend the life of sensor network environment monitoring, can make the wireless sensor in the environmental monitoring work longer, However, it is undeniable that the application of node energy technology in wireless sensor network provides a better research direction for environmental monitoring.

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