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Power Saving Strategy for Sensor Node in Food Tracing and Monitoring System

Shu Liu*, Hong Luo, Yan Sun

Beijing University of Posts and Telecommunications, Xitucheng Road No. 10, HaiDian, Beijing, China
{2012213329, luoh, suny}@bupt.edu.cn

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Abstract. The paper proposes a strategy to reduce the power consumption of sensor nodes in food tracing and monitoring system. So far, we have designed and implemented a mobile sensor node which is used to monitor food's environment and achieve food traceability during transportation. However, in practical use, the power consumption of sensor nodes is great and frequent replacement of its battery will consume a large amount of manpower and resources. Moreover, energy of the sensor node's battery cannot meet the requirement of long-time transportation without charging. We first introduce the architecture of sensor node, and the power saving strategy is carried out in each module of the sensor node. It includes let the control module and A7 module which integrates GPS and GPRS function move to hibernation mode. And then, switch the work pattern of communication and location. Finally, the workflow of the sensor node is adjusted to maximize the power saving method. Experimental results show that the energy cost of the sensor node can be reduced by 70% which reveals the battery saving method can solve the problem.

Keywords: food monitoring and tracing, power consumption, power saving, sensor node,

1 Introduction

With the improvement of China's economic level, the problem of adequate food and clothing for the Chinese people has been basically solved. Therefore, the focus is gradually shifting away from the quantity of food to the quality of food. But in recent years, the domestic food safety problems appear frequently, such as unhealthy cooking oil, Sudan red, melamine, etc. In order to put an end to food safety accidents, the State Council issued a statement in 2013 that Chinese food producers need to offer food monitoring and tracing service [1].

Food tracing and monitoring system refers that food quality, safety and its related logistics information can be tracked consequently (production source to consumer terminal), or reverse backwards (consumer terminal to production source) in all aspects of the period from food production to sales. So that the entire production and business activities of food is always in the scope of effective monitoring [2]. The establishment of food safety and traceability system depends on the Internet of things technology, one of the most important part is the development of various types of hardware equipment specifically for food monitoring and tracing services [3]. They are used to achieve food's environmental data collection, location determination, uploading and recording, we also call this hardware device for the sensor node. They are common in food tracing and monitoring systems now, for instance, U.S. Food and Drug Administration's FDA food-tracking system [4], Japan has the on-line food traceability system SEICA [5]. In China, export food quality safety tracing system run by China Trace also uses sensor nodes [6].

Although the sensor node is a mature technology, in traditional traceability system they are always fixed in large facilities, such as warehouses or factories, which always have stable power supply. Thus the aspect of power saving has been neglected. However, the development of economic globalization and food transportation technology make it possible to trace real-time information on a single piece of food

* Corresponding Author

and most of the time, the transportation is transnational [7]. In these long-distance and long-term food transportation process, many times the environment is closed, mobile sensor nodes in which cannot be charged and replace its battery. Even in some cases, the sensor node can be taken out, however the middle routine may include many third-party logistics companies, which cannot provide appropriate human or technical services. Frequent replacement of the battery and charging will waste a lot of manpower and give rise to high operating cost [8]. So reducing the power consumption of perceived nodes and increasing its battery life become an important issue for these hardware devices in actual use. Previous studies have proposed power-saving strategy for sensor nodes in the aspect of communication [9]. The coding of even-bit marking algorithm (CEBM) is characteristic of its simple coding, low energy consumption for computing and low expenses for hardware. It can be used in the wireless sensor network in the measurement and control system for the condition of stored-grain to compress the data of transmission, lower the energy consumption in communication transmission, and use a small quantity of energy expenses for computing to save a great quantity of energy consumption needed in transmission communication. This settles the problem of energy constraint of the wireless sensor nodes in the measurement and control system. However, this method has limits of the data transmitted to server, and this is only part of the power saving method which has no improvement in the aspect of hardware and program structure.

On this basis, this paper presents a power-saving strategy for sensor nodes used in food monitoring and tracing system. First of all, in the hardware level, the power saving process is performed on the parts of the sensor node, and the working mode is switched on the functional level. Finally, at the software level, the work-flow of sensor node's program is adjusted. According to the influence of the modules in the power saving mode, it is reasonable to design the function module to turn on and switch in order, so that the energy saving effect of the method is maximized.

2 Architecture of Sensor Node

This chapter introduces the sensor nodes from hardware and software respectively. A figure of sensor node is shown in Fig. 1. For ease of use, all of the segments in the sensor node are put in an IP55 box to prevent damage to the sensor nodes during food transportation. The QR code above the box is used to bind the sensor node with the food storage warehouse and the transportation vehicle so that the system can identify the data uploaded by different nodes.

Fig. 1. Sensor node

2.1 Hardware Modules

As shown in Fig. 2, the sensor nodes in food tracing and monitoring system is composed of sensor module, control module, communication module, GPS module and power module. The sensor module is used to collect environmental information of food and GPS module records the routine during its transportation. All of the environmental and GPS data are gathered in control module and transmitted periodically to the server of system by communication module using GPRS and TCP connection. The power module provides the energy needed by sensor nodes.

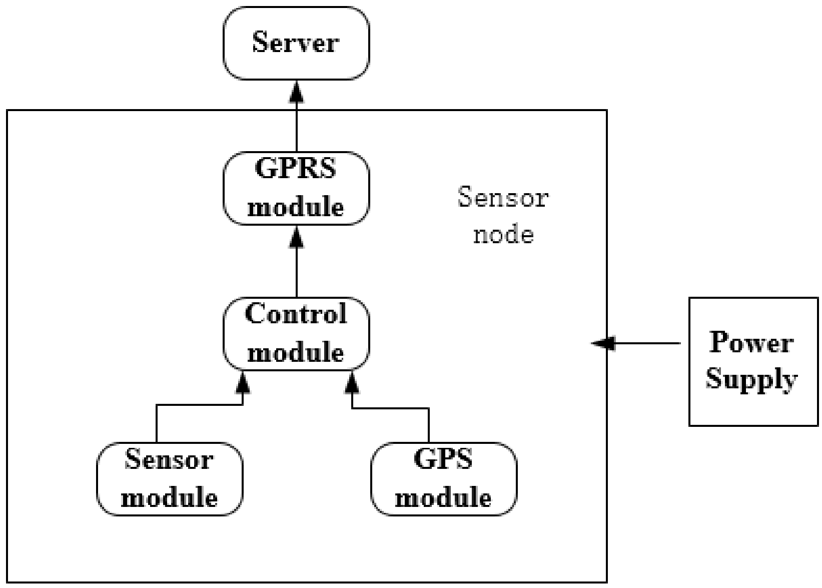

Fig. 2. Structure of sensor node

Sensor module. There are three sensors in the sensor module, DHT11, BMP180 and MPU6050. DHT11 is a calibrated digital signal output temperature and humidity sensor. The BMP180 is the new digital barometric pressure sensor. The ultra-low power consumption down to 3 A makes the BMP180 the leader in power saving for mobile devices. The MPU-6050 devices combine a 3-axis gyroscope and a 3-axis accelerometer. It is designed for the low power, low cost, and high-performance requirements of smart phones, tablets and wearable sensors. Temperature, humidity and pressure are used to ensure that the food is in a normal storage environment and that the acceleration data is used to detect whether the food has been strongly impacted.

Control module. In order to take up less space, Arduino pro mini is used in the sensor node as the control module which is a micro-controller board based on the ATmega328. It is used to manage all the functional modules in the sensor node.

Communication and location module. We use A7 intelligent module to construct communication and location module, which is developed by Ai Thinker Company. It is a complete four frequency GSM/GPRS module supporting GPRS and GPS/AGPS technology and can be widely used in various Internet of things situation.

Power module. The rechargeable lithium battery 18650 is worked as the power supply for the sensor nodes in the food monitoring and tracing system. Its nominal voltage is 3.7V, and the charging cut-off voltage is 4.2V. So there is also a manostat to keep the voltage stable at 3.3V to fit the voltage of Arduino pro mini. The power capacity is 9800mAh for each battery and each sensor node's box can contain 4 batteries.

2.2 Software Modules

The software of sensor nodes are responsible for periodically transmitting environmental information and location information of food in transportation and storage to server. Firstly sensor nodes initialize its sensors and internal clock. Then in each cycle, the sensor nodes operate in a fixed workflow which is shown in Fig. 3. (1) Read location information from GPS module; (2) Read environmental information from sensors; (3) Join the network (4) Create TCP connection and send the data; (5) Close TCP connection and wait for the next transmitting.

The 1, 3, 5 and 6 step always cost a large amount of power and therefore the power-saving method is mainly aimed at these steps.

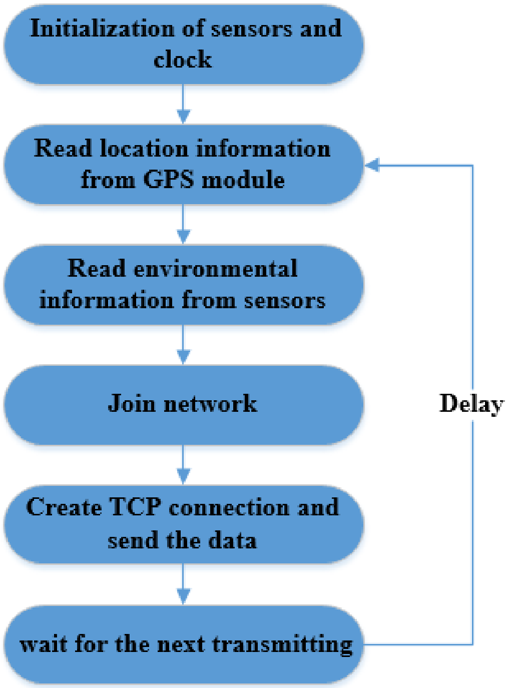

Fig. 3. Basic work-flow of sensor node

3 Power Saving Strategy

This section puts forward the corresponding saving measures for the most energy consumption parts of sensor nodes from the aspects of work mode, hibernation and software structure.

3.1 Switch Work Mode of GPRS Module

The GPRS module has different work modes and we can use the command AT+CFUN=<fun> to switch it. In the interval between running cycle, we set GPRS module go into minimum functionality mode, also known as airplane mode, which works with lower power cost. The GPRS module doesn't automatically send paging signal to base station in this mode and cannot support GSM service or create TCP connection. If the sensor nodes want to send data gathered by sensors or GPS module, we need to adjust the parameter fun and let GPRS module go into full functionality mode.

3.2 Adjustment of GPS Module

AGPS is an additional feature on GPS. Both GPS and AGPS use GPS navigation chips within the device to receive navigational satellite signals, which typically consume a lot of energy during that time. However, due to the small power of the general equipment, it will always take a long time for the GPS module to find the satellite, especially for the first time to start GPS. The AGPS receives the navigation satellite signal, and also obtains the information of the communication base station of the equipment immediately through the network [10]. In other words, through AGPS, the GPS module can directly obtain the location of the satellite from the base station and use these satellites for positioning. This can greatly increase the positioning speed of GPS module and reduce the time of GPS operation to reach the purpose of saving power.

3.3 Hibernation of Control Module

The control module Arduino Pro Mini consists of six sleep modes, and the more power-saving mode is, the less function in Arduino will still be in operation. As shown in Table 1, the theoretical consumption currents are compared against the six sleep modes.

Table 1. Sleep modes of Arduino

Sleep mode	Manage system	Power consumption
Idle	Yes	15mA
ADC Noise Reduction	Yes	6.5mA
Power Save	No	1.62mA
Standby	No	1.62mA
Extended Standby	No	0.85mA
Power-down	No	0.36mA

In order to achieve the utmost power saving purposes, the Arduino Pro Mini could be entered into the "power-down" sleep mode during the time when it doesn't need to collect data and transmit it. However, in the "power-down" mode, only external interrupts and watchdogs are still running on microcontrollers. Considering that sensor nodes cannot rely on external interruption to wake up in transportation, so we use the watchdog timer.

At the end of each running cycle, Arduino firstly set the configuration of WatchDog and sleep mode. Then the sensor node goes into hibernation until WatchDog's timer run out and awaken the control module. At last, we need to disable the sleep and WatchDog function and enable all the power of Arduino to ensure that the control module completely withdraw from hibernation.

3.4 Hibernation of A7 Module

In addition to the power saving method of GPRS and GPS components, A7 smart module also has a low-power mode to reduce power consumption. GPIO1 of A7 is used to control whether the module enters the low power mode, the high level exits and the low level enters. According to user's development manual, in this mode, the standby current is less than 1mA. Note that the serial port cannot be used in this mode which can be waked by phone, text message, GPRS data, etc.

3.5 Adjustment of Work-flow

The low-power strategy reduces the power consumption of the sensor nodes, but in general, these power-saving modes are premised on the inability to use certain functions. Therefore, in the design process, the interaction between the power saving modes should be considered carefully. For example, the GPRS module needs to be set to full function mode before the data is ready to be sent. And after completing all functional steps, first make the A7 module into sleep, and then make Arduino into low power mode. Because in this mode GPIO and serial port are not available so that Arduino cannot control the A7 module.

Not only to join the low power mode can make sensor node's power consumption reduce, a good program structure is also useful. When reading GPS information, we add timer Settings instead of reading fixed time. The program tries to get information inside the timer, and if it gets it, immediately jump out of the timer and proceed to the next step. This reduces the time it takes to run the program. The last is to add some judgments and restart mechanism to prevent power consumption caused by the program stuck. For instance, at the end of hibernation of the sensor node, we can firstly check whether it can join the network or not. If it cannot access, set the flag variable flag = 1 and this will be considered to be caused by program stuck. To restart the network again, if still failed, then the reason may be no signal and other factors. At this time the sensor node cannot send the information to the server so the process of collecting data becomes a waste of energy, we can directly let the sensor node into sleep phase and wait for the next opportunity to upload. Improved work-flow is presented in Fig. 4.

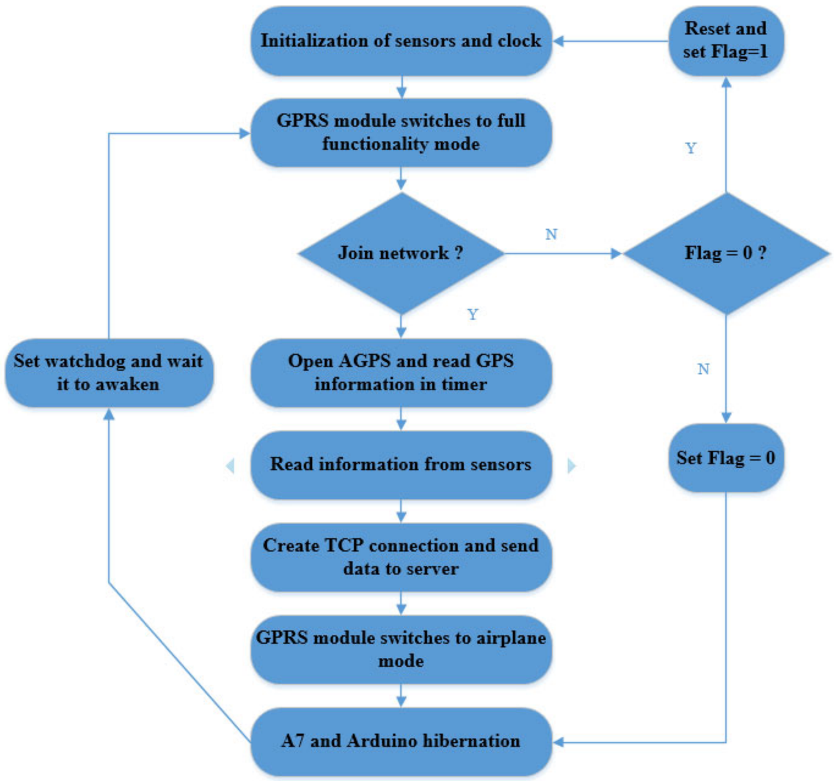

Fig. 4. Work-flow with power saving strategy

4 Performance Evaluation

This section presents the basic performance evaluation of the proposed method which is used to reduce the power consumption of sensor nodes. Section A compares difference of electric current in normal mode and power-saving mode. Section B shows the current change in a running cycle.

4.1 Difference of Current with Normal and Power Saving Mode

The GPRS communication module uses the antenna to transmit signals when communicating with the base station so that the current changes frequently during operation. By testing current with a multimeter, Table 2 shows the power consumption of the GPRS communication module in full function mode and the flight mode.

Table 2. Current of communication module

GPRS functional mode	Join network	Power consumption
Full functionality	Yes	From 0.01A to 0.06A
Minimum functionality	No	0.01A

The control module, Arduino Pro Mini, does not need to monitor the sensor's data in real time after the data is uploaded, so the power-down mode is used to reduce power cost. The power consumption of the control module Arduino Pro Mini is shown in Table 3.

Table 3. Current of control module

Arduino functional mode	Manage system	Power consumption
Full functionality	Yes	0.02A
Power-down mode	No	Approximately 0.00A

The A7 smart module integrates GPRS function and GPS function so it can also go into hibernation after communication and location. The power consumption of the A7 module is shown in Table 4.

Table 4. Current of A7 module

A7 functional mode	GPRS or GPS	Power consumption
Full functionality	Yes	0.02A
Sleep mode	No	Approximately 0.00A

4.2 Variation of Current in a Running Cycle

Table 5 and Table 6 show the time and energy cost for each operation of the sensor nodes that have not joined the power saving methods and the sensor nodes with the power saving method. The time and cost in some steps are always same however the time used to get GPS information changes every time. We set 65s for the GPS module to locate since it needs 50s to 60s in measurement to get GPS information. With the improvement in GPS module, the time is not fixed. After multiple measurements, we take an average time of 47 seconds (including opening AGPS) for the required time.

Table 5. Time and cost of basic work-flow

Operation Time	Time	Power consumption
Initialization	2s	0.04A
Join network	9s	0.07A
Get GPS	65s	0.12A
Read sensors	2s	0.04A
Send data	5s	0.09A
Delay	According to period	0..04A

Table 6. Time and cost of advanced work-flow

Operation Time	Time	Power consumption
Initialization	2s	0.04A
Join network	9s	0.07A
Get GPS	47s	0.12A
Read sensors	2s	0.04A
Send data	5s	0.09A
A7 hibernation	2s	0..04A
Arduino hibernation	2s	0.01A
Delay	According to period	Approximately 0.00A

Fig. 5 shows the result of sensor node's current consumption in a working period. For the convenience of analysis, in the experiment, if there are current fluctuations, we take an approximation. According to the chart, we can see that not only the sensor node's power consumption has declined, but also the time spent for a working cycle from 83s down to 67s, so the method is effective.

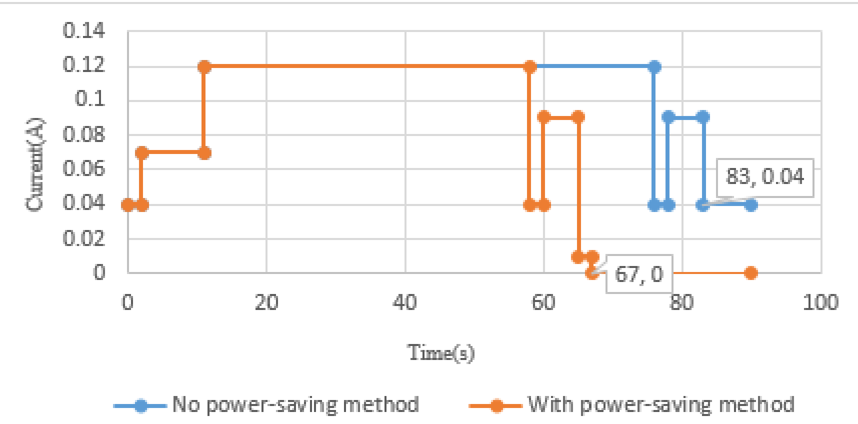

Fig. 5. Current in a running cycle

4.3 Battery Life of Sensor Node without Charging

In order to facilitate our analysis of the experimental results, we use one battery in the experiment for power supply, and in practical applications, the sensor nodes have four batteries. So the use of time can be nearly four times the experimental data. In the experiment, we set the sensor node to work every ten minutes and the battery voltage is collected by Arduino.

As shown in the Fig. 6, the sensor node which doesn't use power saving method can run 40 hours while that the advanced ones can run 93 hours. It improved 125% battery life for the system without charging.

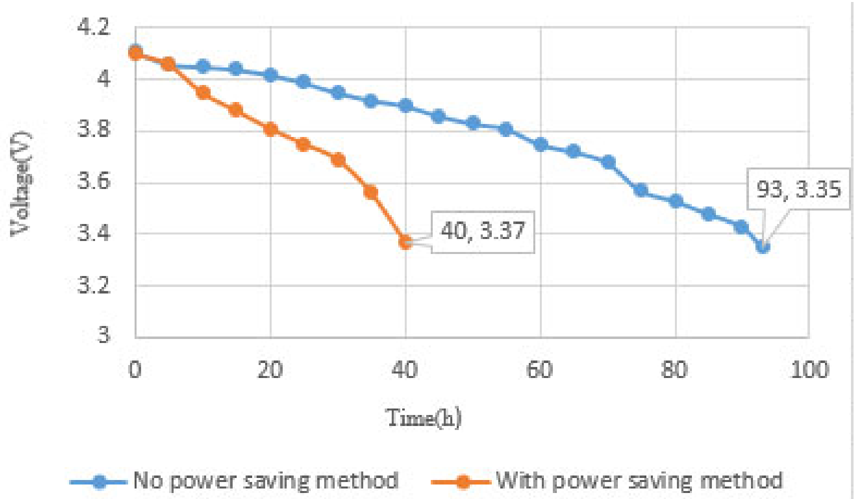

Fig. 6. Lifetime of sensor node's Battery

5 Conclusion

In order to solve the problem of high cost of operation and meet the requirements of tracing single piece of food's information in real time in the new food monitoring and tracing system, we design a power saving strategy for its mobile sensor node. It includes hibernation of hardware module, switching of work mode and adjustment of work-flow. After testing, in the case of data reported once every ten minutes, the sensor node can be used for 15 days without charging. The strategy increases 125% of its use of time so that basically meet the long-distance transportation and saving human resource's need.

In the future work, Owing to different food maybe need different uploading frequency, we can analyze working cycle of the sensor nodes, and its influence with the power saving method. Based on these we can design the best energy saving method for sensor nodes which monitor and track different food.

Acknowledgements

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