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Design on wireless SO_2 sensor node based on CC2530 for monitoring table grape logistics

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Abstract

Grape preservative always is adopted in the grape logistic to ensure that the grape fruits are fresh and appealing via release sulfur dioxide (SO_2) slowly to prevent mold and decaying of table grapes. This paper designed and developed a wireless SO_2 sensor node based on CC2530 to monitor the sulfur dioxide concentration and provide rapid and accurate transmission of ambient parameter during the logistics. The results show that sensor node has a good communication and monitoring performance and can improve the transparency and traceability of table grape logistics.

Key words: Grape logistics, SO_2 concentration, wireless sensor network, CC2530, sensor nodes, ZigBee.

Introduction

Table grape shelf life is often shortened because it is subject to serious water loss, stem browning and decay during long transportation and storage from farm to tables. As one of most easy to use, safe non-toxic methods, grape preservative always is packed with the grapes to ensure that it is fresh and appealing after arrived to consumers [1, 2].

Because of its effectiveness in delaying stem browning and decay, sulfur dioxide gas (SO_2) is currently broadly adopted as the treatment of choice in many countries for prolonging shelf life of grapes. Usually, via adsorbing sulfur dioxide with surfactant in porous matter, mixing with solid acid matter and stabilizer, pelletizing or tabletting and packed with paper or plastic film, the sulfur dioxide-releasing pads can release sulfur dioxide (SO_2) slowly to prevent mold and decaying of table grapes [2, 3]. Some experiments show that cased by Kyoho grapes stored at 0°C, the grape shelf life can prolong until 5-7 months with good fruit rate of more than 95% and stems fresh as ever.

However, there are also disadvantages to sulfur dioxide use. If the SO_2 concentration is lower than the standard necessary level, it fails or is insufficient to prevent mold and decaying of grape. On the other hand, higher SO_2 concentration may induce injuries in grape fruits and stems, and sulfite residues pose a health risk for some individuals [3, 4].

Wireless Sensor Network (WSN) has been rapidly developed in recent years. Atmosphere monitoring system based on WSN is a typical application. This paper aims to design and develop a wireless SO_2 sensor node to monitor the table grape logistic and make sulfur dioxide essential to identify safe and improve the chain transparency and traceability.

Hardware Design of the Wireless SO_2 Node

The wireless SO_2 sensor node is responsible for collecting ambient information and transferring the data the routing nodes via the adjacent nodes. It consists of a sensor module, a processor module, wireless communication module and power supply module. This research adopted CC2530 chip as the MCU and the electrochemical SO_2 sensor MF-20 (with its peripheral circuit) as the sensor module. The diagram of node hardware principle is shown in Fig. 1.

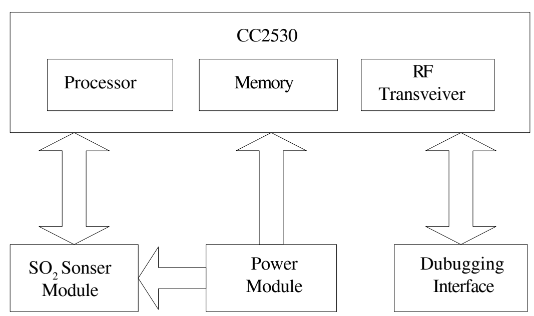

Figure 1. Hardware block diagram of the wireless SO_2 sensor node.

CC2530 microprocessor: CC2530 is a product of the Texas Instrument Company (TI) in the United States. As the second generation system on chip and compared with previous products, CC2530 has excellent performance of RF, with a programmable 256 KB flash, smaller package size and IR generating circuit. It supports for ZigBee PRO, ZigBee RF4CE and other agreements [5-7]. CC2530's preposition frequency range is 2394 MHz ~ 2507 MHz, with the resolution of 1 MHZ. The transmission rate of data can achieve 250 kbps. Under ideal conditions, the sensor node designed is available to transmission distance of 400 m.

SO_2 gas sensor: The SO_2 concentration in the grape storage and transportation environment usually should be controlled within 20 ppm. This research adopted the MF-20 SO_2 sensor produced by Membrapor Company in Swiss as the SO_2 sensor. MF-20 sensor is based on the three electrode electrochemical system, the basic electrical properties are shown in Table 1.

Table 1. Electrical characteristics of the MF-20 sensor.

Nominal Range	0~20 ppm
Maximum Overload	100 ppm
Output Signal	500 ± 150 nA/ppm
Temperature Range	-20°C - 50°C
Relative Humidity Range	15% - 90%
Recommended Load Resistor	10Ω
Output Linearity	Linear

Fig. 2 shows the communication of the sensor module and CC2530 module. VCC is for external 5 V power supply. The SIGN end of the sensor module is the voltage signal output end, connected to the P0.0 of CC2530.

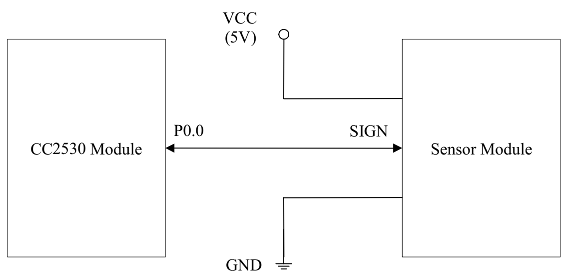

Figure 2. Connection diagram of the sensor module and CC2530.

Software Design of the Wireless SO_2 Node

ZigBee protocol: ZigBee is a standard that defines a set of communication protocols for low-data-rate short-range wireless networking. ZigBee-based wireless devices operate in 2.4 GHz frequency bands. The maximum data rate is 250 K bits per second [8-10].

The ZigBee standard has adopted IEEE 802.15.4 as its Physical Layer (PHY) and Medium Access Control (MAC) protocols. ZigBee wireless networking protocol layers are shown in Fig. 3.

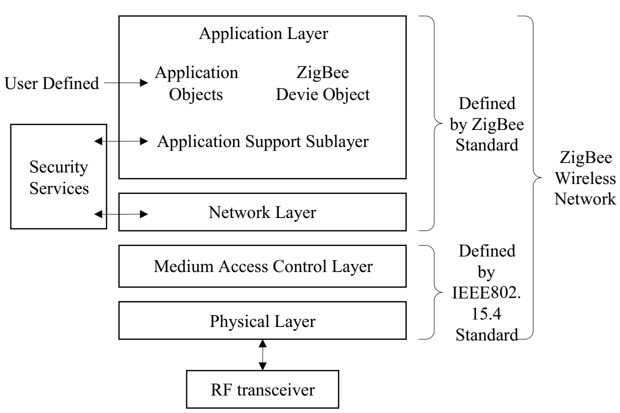

Figure 3. Relation of the ZigBee Protocol and IEEE 802.15.4.

Data acquisition module: Through the regulating of the external circuit, the output signal of the SO_2 sensor is set to 0.4 ~ 2V voltage value, linear corresponding to 0 ~ 20 ppm gas concentration. Analog data is changed to digital variable through the transformation of the CC2530 ADC. SO_2 data acquisition module program flow is shown in Fig. 4.

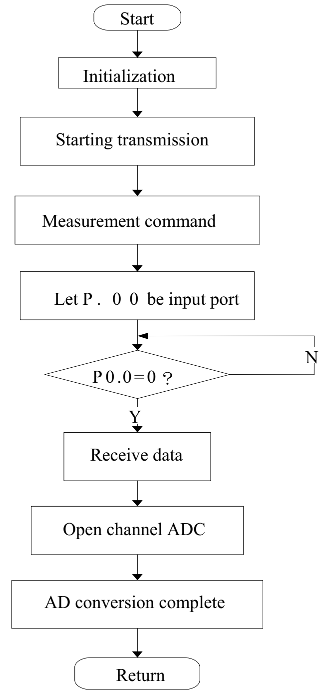

Figure 4. Program flow chart of data acquisition module.

Wireless communication module: Taking the communication between two nodes as an example, this section introduces the point to point communication software design process. The completion of a data transmission procedure is shown in Fig. 5.

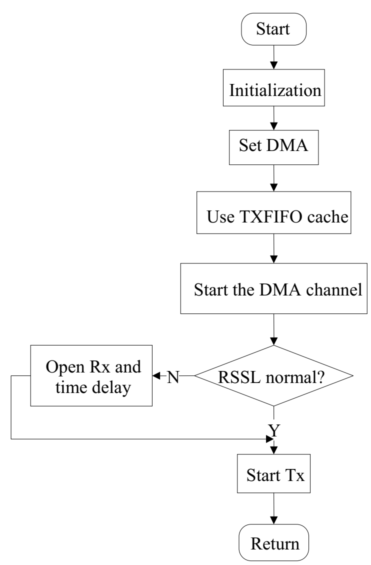

Figure 5. Flow chart of data sending program.

In the process of data receiving, the node working frequency must be set as 32 MHz to ensure that the Rx and Tx work in the same channel. As the set of DMA, where DMA data source to register RFD, DMA trigger signal is set to Radio. Data receiving program flow is shown in Fig. 6.

Performance Test on Wireless SO_2 Node

Node communication performance testing: Node communication performance testing is mainly targeted at the “packet error rate”

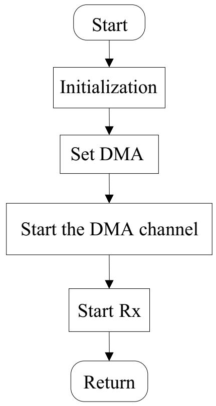

Figure 6. Flow chart of data reception program.

(Packet Error Rate) test between two nodes, which will be a node set to a transmitter, the other receiver set for realizing one-way RF connection. A LCD screen was added to display the results, including packet error rate and Received Signal Strength Indication (RSSI). 0 dBm is used in the test as transmission power, transmission of packet number is 1000, and the rate is 50 data packets per second. A joystick was designed to help transmitter control data transmission.

The experiment was designed three different scenarios: existing concrete wall (about 40 cm thick), exiting partition wall and barrier free.

The results are shown in Fig. 7. The horizontal axis represents the distance and the vertical axis represents the PER. From the figure, we can see that the communication is good and the effective transmission distance (PER<10%) can reach 55 m in the barrier free environment. As the wall exists, the PER greatly increases, however, the design still accords with the requirement.

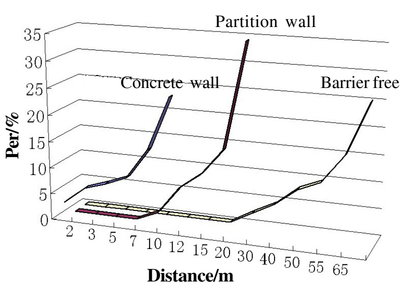

Figure 7. Testing results of PER.

Comparative experiments of monitoring: The experiment was done in the laboratory of College of Food Science & Nutritional Engineering at China Agricultural University. The wireless SO_2 node designed and conventional method were used to monitor the SO_2 concentration in confined space, respectively. The result is shown in Fig. 8. The horizontal axis represents the test sequence number. The vertical axis represents the SO_2 concentration (ppm).

The results show that the sensor node can monitor SO_2 concentration in 0~20 ppm range. And the measured value is very close to the true value. In more than 20 ppm (when the output signal is no longer a linear correlation), the sensor measurement accuracy decreased.

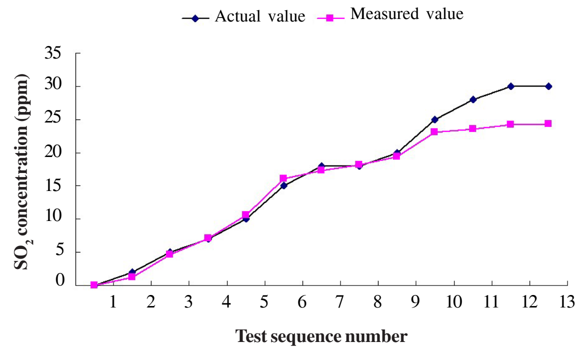

Figure 8. Results of the comparative experiments.

Conclusions

This research designed and developed a wireless SO_2 sensor node based on ZigBee protocol to meet the requirements of the table grape logistics system monitoring. The experiments of the communication between two nodes show that the developed wireless SO_2 sensor node can monitor accurately the ambient SO_2 concentration and achieve stable data communication, furthermore improve the transparency and traceability of table grape logistics. Further research should integrate the developed wireless SO_2 sensor node with other sensor nodes to develop the monitoring system for table grape logistic and achieve the chain traceability.

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