Design on the Monitoring System of Physical Characteristics of Dairy Cattle Based on Zigbee Technology

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Abstract

One of the difficult problems in dairy farming is detection of cows' estrus, whose technology has been developed in some countries; however it is still in the developing stage in China. This paper presents a new method which resorts to collecting cattle's body temperature and behavior characteristics for detecting the cow's estrus.

According to the body temperature of dairy cattle rising 1-2 ℃ in ovulation period, and the volume of the movements of dairy cattle increasing significantly, the paper described a monitoring system which is based on Zigbee wireless transmission technology and the system can detect the body temperature and the volume of the movements of dairy cattle at the same time. The system consists of a wireless transceiver and controller module MG2455, a thermopile infrared sensor and a digital acceleration sensor ADXL20.

The system uses a star topology and each signal acquisition node controlled by MG2455 is fixed in the thigh of dairy cattle. The system can determine the identity of dairy cattle for the uniqueness of the transmission address of MG2455. The signal acquisition nodes send the real-time data acquired by the infrared sensor and acceleration sensor and packaged by Zigbee protocol stack to the Full-function device (FFD) within the cluster and then the FFD transfers the real-time data to the client station through the USB (Universal Serial Bus) interface for further professing.

The use of the system not only can make the monitoring of cows' estrus more accurate and reduce the labor burden, but also can help the managers to improve the level of management and can enhance the economic benefits of dairy farming.

Key Words: *Zigbee, cows' estrus, monitoring system, FFD*

1. Introduction

Milk industry, which plays an important role in modern agriculture, is an economic and efficient livestock industry. Today, the most countries focus on the development of milk industry (Jia Xinjian et al, 2004). Since reform and opening-up, milk industry, a sunrise industry, shows strong growth trend as the rapid development of China's national economy and the continuous improvement of people's living standard. With the growing size of dairy farms, the traditional way of rearing has not met the requirements of the development of the modern dairy farming. Intensification and specialization of dairy industry need advanced technology and excellent equipment to help achieving it.

Nowadays, there are several problems in cow's rearing in China. Detection of cow's estrus is one of them in dairy farming. The technology of detection of cow's estrus is quite advanced in some developed countries, while the study is still in the beginning stage in China. The ideal breeding cycle for cow is one year one child. The cow will create milk only after mating, pregnancy and having a child and generally the lactation of a cow is 305 days, so the oestrum diagnosis is a key link for making cow become pregnant and prolonging its lactation.

At present, the traditional observation way to distinguish the oestrum of dairy cattle is still used by most dairymen in China which is inefficient especially at night and the dairymen loss their revenue for missing the oestrum of dairy cattle always. As the initial research work for developing the monitoring system, a new research of detection of cow's estrus which resorts to collecting cattle's body temperature and behavior characteristics is presented in the paper.

2. System design

ZigBee is an emerging wireless standard aim to interconnect and provide interactivity to all those remote controlled devices. It provides the ability to run for years on inexpensive primary batteries for a typical monitoring application and does not need line-of-sight, and single controller can command many devices. The main achievement of the design is identification of dairy cattle, detection and recording their temperature and activity. According to the body temperature of dairy cattle rising 1-2℃ in ovulation period (Wang Xueen et al, 1998) and the volume of the movements of dairy cattle increasing significantly, the paper described a monitoring system which is based on Zigbee wireless transmission technology. In the system, body temperature and physical activities were collected through the infrared sensor and acceleration sensor and the collected data was stored in the database.

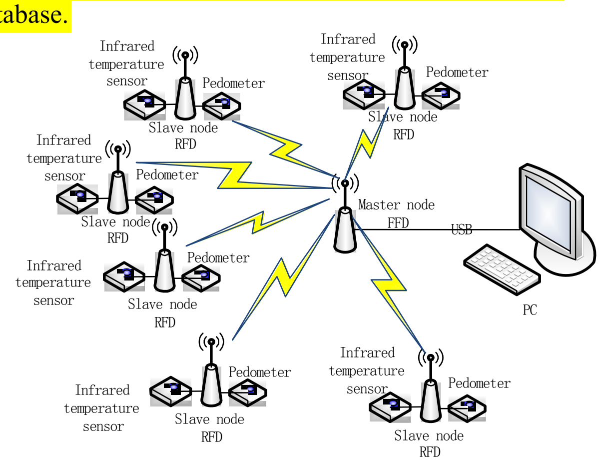

Figure 1. Framework diagram of the monitor system

MG2455 used in the system is a full single-chip solution that is compliant to the specification of IEEE802.15.4 and ZigBee specifications and is a complete wireless solution for ZigBee applications. It consists of RF transceiver with base band modem, a hardwired MAC and an embedded 8051 microcontroller with internal flash memory for application program. It also includes several general-purpose I/O pins and many peripheral devices such as timer and UART (Universal Asynchronous Receiver/Transmitter) (Radio Pulse Inc. 2008). The coordinator (master node) assigns a unique network address to every end device (slave node) joined in the network and the system uses the unique network address to identify dairy cattle. The system uses a star topology and each signal acquisition node controlled by MG2455 is fixed in the thigh of dairy cattle. Framework diagram of the monitor system is shown in figure 1.

2.1 Sensor module design

As the slave node, Zigbee wireless transceiver module MG2455 (RFD, Reduced Function Device), thermopile infrared sensor and digital MEMS accelerometer ADXL202 compose the sensor module in the system as shown in figure 1. Through the ADC converter and general I/O, MG2455 (RFD) gets the real-time data by infrared temperature sensor and acceleration sensor and then the real-time data packaged in accordance with Zigbee protocol is sent to the coordinator (master node) in the cluster.

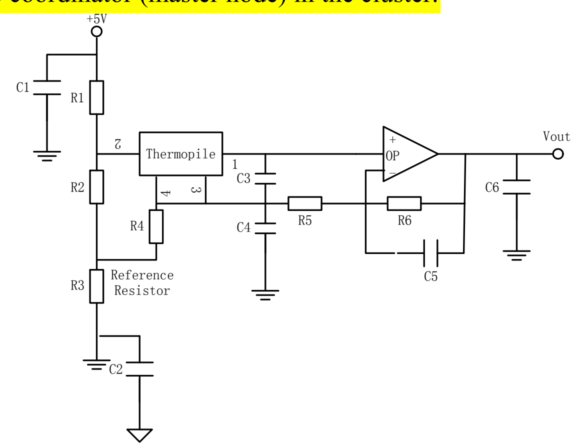

Figure 2. Application circuit of infrared temperature sensor

Pyroelectric effect is a phenomenon which is temperature changes to generate electric charge. Infrared temperature sensor includes pyroelectric infrared temperature sensor and thermopile infrared temperature sensor. The former does not generate signals if the temperature does not change, so it is also known as the differential-type sensor. It can not be applied because the system needs to obtain the real-time temperature. Temperature of light-sensitive parts changes when thermopile infrared temperature sensor receives changing radiation energy of the object and the changes of temperature are detected by spiral structure thermocouple (Matsui Kunihiko. 2005). Above all, thermopile infrared temperature sensor was chosen for the system. Application circuit of infrared temperature sensor is shown in figure2 and thermopile box contains thermopile and thermistor which is used for temperature compensation in the circuit.

The movement of cow gives rise to the corresponding acceleration and the acceleration will quickly reach a peak value. So we can get movement steps by detecting maximum acceleration. We fix the slave node with an acceleration sensor on a medial region of cow's thigh considering for the application of infrared temperature sensor. ADXL202 is a low-power, 2-dimensional acceleration sensor, made in AD company and the digital signal output is proportional with duty-cycle and acceleration. So the digital signal output can be used directly by the counter in single-chip. The acceleration is about ±1g (1g=9.8m/s2) when a cow is walking, so ADXL202 with measurement rang around ±2g (Pang Jing et al, 2004) is chosen in the system.

2.2 MG2455 initialization

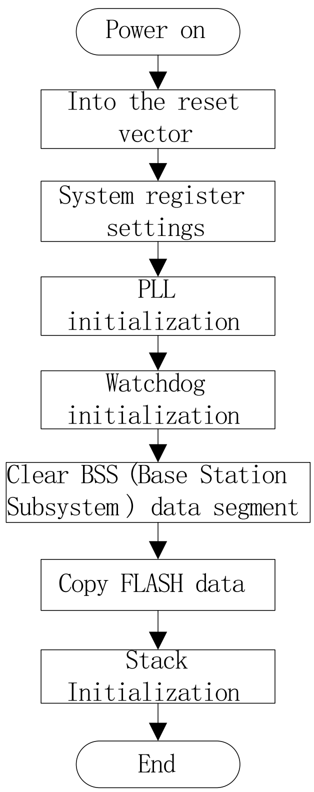

Figure 3. Flow chart of MCU initialization

The initialization of MG2455 is divided into two phases, the first is MCU power-initialization and the second is operating system initialization. PLL (Phase Locked Logic) settings, watchdog setting up, initialization of the stack and establishment of C language environment belong to the one phase. The initialization of hardware resources and the establishment of tasks belong to the second. MCU initialization flow chart is shown as figure 3.

2.3 Design of coordinator

As the master node, it consists of the wireless transceiver modules MG2455. The main task of the node is receiving the data coming from slave nodes in the cluster and transmitting the data to the client station. Coordinator synchronizes the entire network through the broadcast beacon frames and configures the entire network by Start original language when establishing a new network. The work flow chart of Start (Original Language) is shown in figure 4.

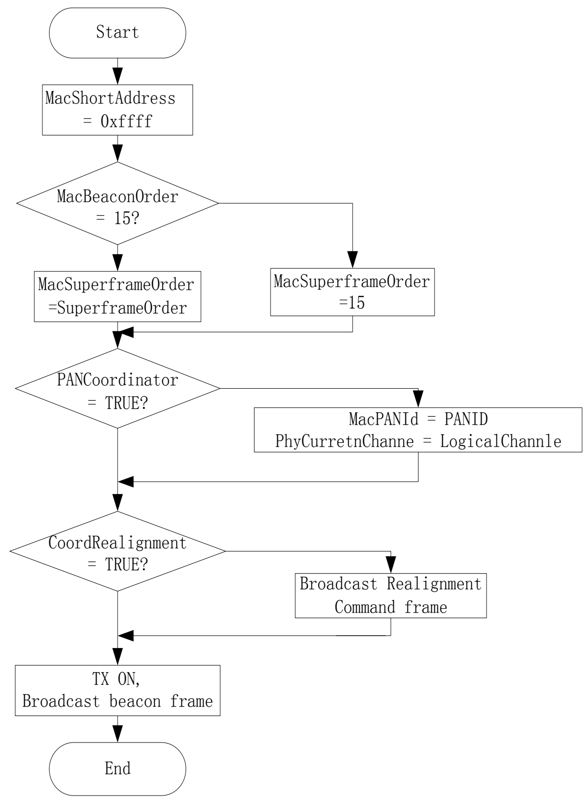

Figure 4. Flow chart of Start

2.4 Design of client station

The client station has an independent database and it can access the real-time data coming from the coordinator. The keeper can query and display the real-time data in use of the client. As the simulation diagram shown in figure 5, when the dairy cattle ID is inputted, the list of the temperature and steps monitored every 60 seconds interval and it is displayed in the window.

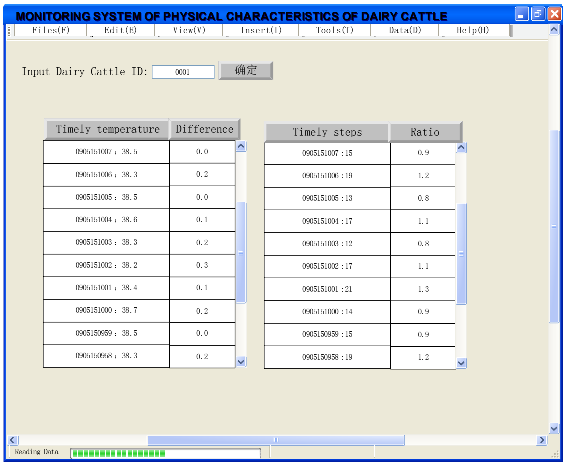

Figure 5. Simulative window of monitoring system

The client will compare the temperature with the average of 60 temperature values before it and give the absolute difference. If the absolute difference is 5 times greater than 0.2, the client will alarm and save the ID number of the dairy cattle. The simulation diagram of temperature alarm is shown as figure 6. The client will compare the steps with the average of 60 step values before it and give the ratio. If the ratio for 5 times greater than 2 or less than 1/2, the client will alarm and save the ID number of the dairy cattle. The simulation diagram of steps alarm is shown as figure7. If the two warnings of the same ID number occur at the same time, the keeper should take care of the dairy cattle corresponding to the ID number.

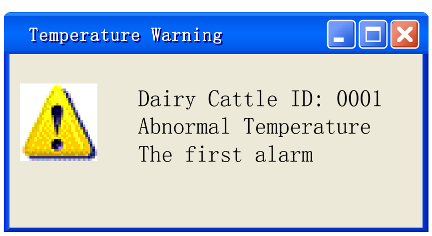

Figure 6. Temperature warning

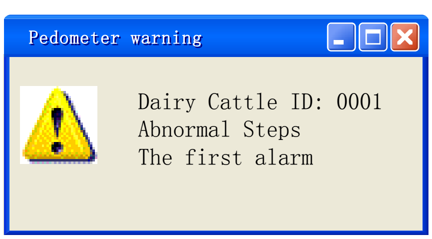

Figure 7. Pedometer warning

3. Conclusion

In this article, we focused on the design of wireless sensor, and discussed the feasibility of the system in China. Simulation results reveal that the system achieves a 250kbps data rate for 70-100m distance wireless communications using realistic specifications. We also conduct an experiment that confirms the feasibility of the system.

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