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Fault Detection for Large-Scale Railway Maintenance Equipment Base on Wireless Sensor Networks

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Abstract: Focusing on the fault detection application for large-scale railway maintenance equipment with the specialties of low-cost, energy efficiency, collecting data of the function units. This paper proposed energy efficiency, convenient installation fault detection application using Sigsbee wireless sensor networks, which Sigsbee is the most widely used protocol based on IEEE 802.15.4. This paper proposed a systematic application from hardware design using STM32F103 chips as processer, to software system. Fault detection application is the basic part of the fault diagnose system, wireless sensor nodes of the fault detection application with different kinds of sensors for verities function units communication by Sigsbee to collecting and sending basic working status data to the home gateway, then data will be sent to the fault diagnose system. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Large-scale railway maintenance equipment, Energy efficiency, Wireless sensor networks, ZigBee.

1. Introduction

In current state, fault diagnose system of large-scale railway maintenance equipment in field operation is getting to be a key function for manufacturers to pull up their selling number. As the basic part, the fault detection application needs to pursuit the new accurate architecture of sensor units with wireless communication, which the sensor units can be easily installed and replaced as they are not working. Wireless sensor networks with the rapid deployment, self-organization, and fault tolerance characteristics make it a very promising sensing technique for military purpose, health care and some other commercial applications including monitoring production quality [1]. Wireless sensor network equipment can be easily installed on the large-scale railway maintenance equipment function units to gather basic working status data.

Sigsbee protocol based on IEEE 802.15.4 standard is the most widely used in wireless sensor networks field. Sigsbee protocol has advantages on low cost, band free, energy efficiency and fast installation with Bluetooth, Wi-Fi and some other wireless communication technique [1].

The fault detection application released the function of gathering all the basic working status date of the large-scale railway maintenance equipment function units. [2, 9]. After simply processed and packed by the sensor nodes, the data are sent to the home gateway for further process, then the date are sent to the fault diagnose system for analyzing. The fault detection application can do great contribution to solve the breakdown of the working large-scale railway maintenance equipment.

A systematic design and implement of the fault detection application from hardware to software is proposed in this paper. In section 2, the architecture

of the fault detection application is discussed; the hardware components are introduced in section 3; section 4 discusses the software system design; section 5 discusses the battery life and at last section, there is the conclusion of the paper in section 6.

2. Fault Detection Application Architecture

The architecture is shown in Fig. 1, a host computer in control center gathers the data from home gateway then sends the data to the fault diagnose system through Internet. Home gateway based on Sigsbee is the center of the Sigsbee wireless sensor network application, all the data from sensor nodes are further processed. Sensor nodes are deployed on the function units of the large-scale railway maintenance equipment to collect the basic working status information. This fault detection application can monitor all the function units and accurately reflect the breakdown to the fault diagnose system.

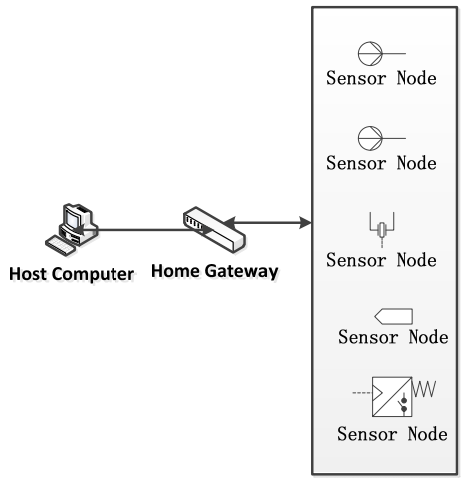

Fig. 1. Fault Detection Application Architecture.

3. Hardware Design

This paper proposed a hardware design by using STM32F103 processer produced by STMicroelectronics and REX3D Sigsbee chips produced by Zhejiang Rexense Technology. STM32F103 processor is based on Cotex-M3 32 bit RISC with three different working modes: Sleep mode, Standby mode, Stop mode. And STM32F103 processor provides three kinds of pinout, LQFP100 pinout, LQFP64 pinout, and LQPF48 pinout. The REX3D chip has the size of 32.20*20.50*10.50 mm, which makes it possible to put the chip in a very small device. The chip also has the communication range of 300 m in version; it works in two working modes: Sleep mode with 0.4 uA power usage, and Normal mode 29 mA with power usage.

3.1. Home Gateway Hardware Design

Home gateway is the supervisor of the Sigsbee wireless sensor network application, it gathers all the information from sensor nodes through Sigsbee wireless communication, and sends the data to the fault diagnose system by Internet. Home gateway has three main parts: processer unit, Sigsbee communication unit, and Internet access unit. The processer unit used STM32F103 processor in 64 pinout, and Sigsbee communication unit used REX3D chips, Internet access unit was based on TCP/IP protocol as 10/10 Mbit/s. The basic design is shown in Fig. 2.

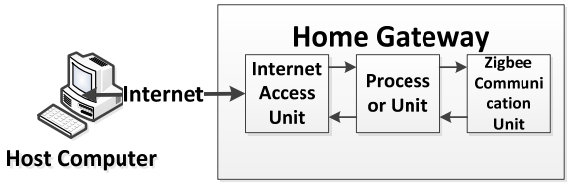

Fig. 2. Basic Design of Home Gateway.

3.2. Sensor Node Hardware Design

B Sensor nodes are deployed on function units of large-scale railway maintenance equipment to collect the basic working status information. Sensor nodes are the basic units of the fault detection application with the functions of collecting information, processing data, sending data. Low-cost, energy efficiency is the basic requirement, to fit this requirement the sensor nodes used STM32F103 processor in 48 pinout as the processor of the processor unit. Sensor nodes had three main parts: processor unit, Sigsbee communication unit, and sensor unit. The basic design is shown in Fig. 3.

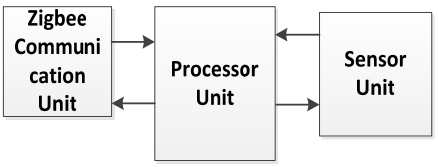

Fig. 3. Basic Design of Sensor Unit.

4. Software System Design

Software system design is divided into two parts: home gateway software system, and Sensor node software. Sensor node software can operate the sensor nodes to collect the basic working status information, do the basic processing and pack the data to send to the home gateway. Home gateway software system is used as to organize the Sigsbee wireless sensor network, further data processing, and to provide information to the host computer through Internet.

4.1. Home Gateway Software System Design

Home gateway software has to meet the requirement, as so the software system has main two processing parts: initialization, data processing unit. Initialization is to initialize the hardware and organize the Sigsbee wireless sensor network, register the sensor nodes. Data processing unit is for further processing the data which gathered from the sensor nodes in the Sigsbee wireless network, checks the CRC code from the data and makes the data is useful. The flowcharts of these three parts are shown in Fig. 4, Fig. 5.

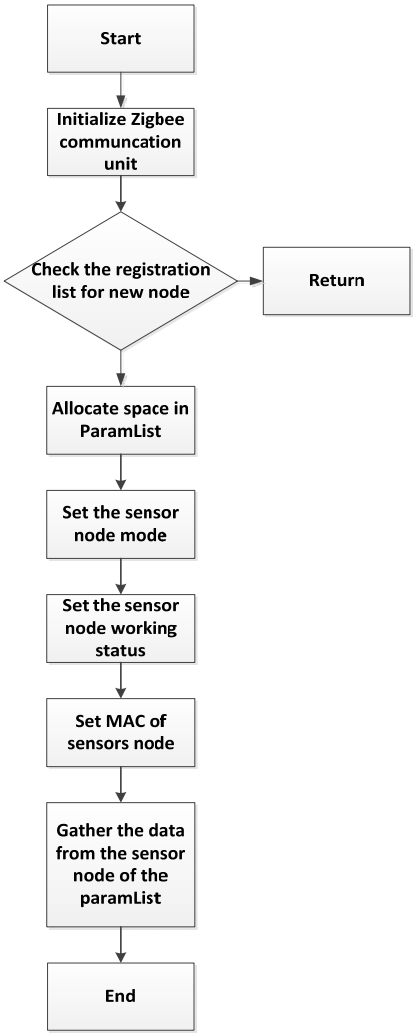

Fig. 4. Home Gateway Initialization.

During the initialization, the home gateway initializes Sigsbee communication unit of the hardware, then organizes the Sigsbee wireless sensor network. Check the sensor node in the registration list, if the sensor node is not in the registration list, which means this sensor node is not a sensor node of the system, the home gateway keep searching the sensor nodes in the registration list; if the node is in the registration list, it will allocate space for this sensor node in the paramList. Home gateway sets the sensor node mode and working status, then sets the sensor node MAC (Media Access Control) in this Sigsbee wireless sensor network as the reason of Sigsbee devices do not have the global identified MAC [10]. At last home gateway sends commands to the sensor nodes in the paramList to gather the information.

The processing unit first checks the data frame which gathered from sensor nodes for a valid head, if the valid head is found seeks the valid tail of the frame. If the valid head is not found or the valid tail is not found, this data frame has to delete. The check the valid data frame CRC bit, if matches this data is useful, the clean the data cache [11].

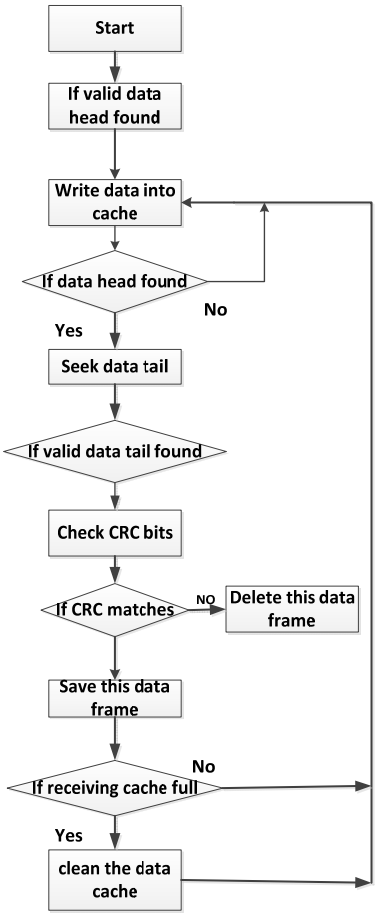

Fig. 5. Home Gateway.

4.2. Sensor Nodes Software Design

Sensor nodes are responsible to collect the basic working status data of the function units, sensor nodes work separately and batteries are their power supply. The sensor nodes software mainly contains two parts: initialization, and RTC timer. The chart flows are shown in Fig. 6, and Fig. 7.

When system starts, the sensor nodes software initializes the STM32F103 processer, the initialization chart flows in Fig. 8. Then sensor nodes

software wakes up the Sigsbee communication unit, which in this procedure Sigsbee communication unit scans the Sigsbee wireless sensor network for home gateway and registers itself. Enable the sensor unit to collect the basic working status data, Sensor nodes software packs the data as Sigsbee protocol, then sends the data to the home gateway through Sigsbee communication unit. At last sensor nodes software puts the sensor nodes into sleep mode to save power supply until there is a RCT timer wake the sensor node up.

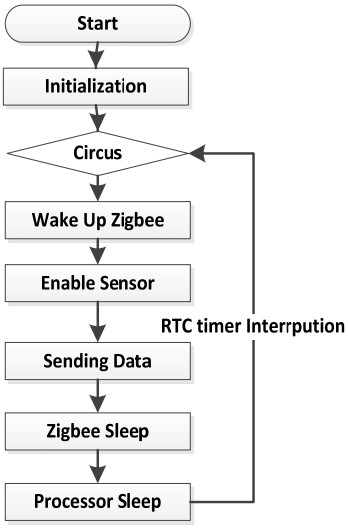

Fig. 6. Sensor Node Initialization Chart Flow.

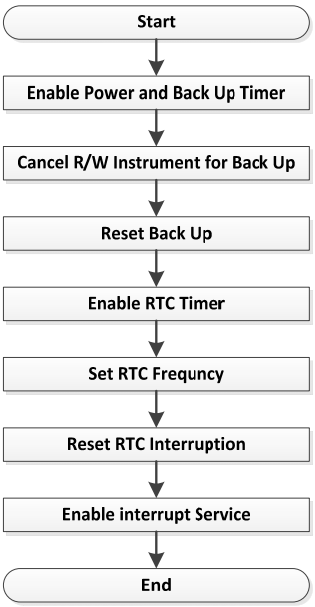

Fig. 7. RTC Timer Chart Flow.

RTC timer meets the energy efficiency requirement [12], Sigsbee communication unit and the sensor unit cost most of the power supply, as mentioned before STM32F103 processer works in Sleep mode with 0.4 uA power usage, and Normal mode 29 mA with power usage. RTC timer wakes up the Sigsbee communication unit and sensor unit to save the power supply.

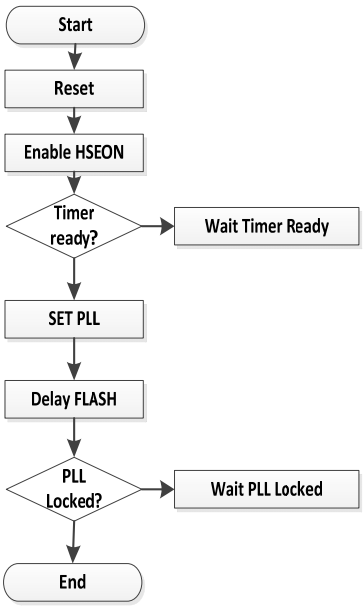

Fig. 8. Initialization of STM32F103 Processer Chart Flow.

To program the RTC timer for realize the functions in chart flow shown in Fig. 7, few registers of RTC timer have to be set as below:

RTC_CTL: this register is responded to set RTC interruption type and R/W (Reading and Writing) instrument.

1) RTC_PRLH: this register is responded to pre-load frequency to RTC timer.

2) RTC_DIV: this register is responded to get more accurate time then second.

3) RTC_CNT: this register is responded to record the seconds of the RTC timer.

4) RTC_ALR: this register is responded to produce a RTC interruption.

Backup Register: this register is responded to back up the user data, 84byte is the limitation. This register is powered by VBAT, not VDD.

5. Evaluation

The battery life of the sensor nodes directly effects the fault detection application, energy efficiency is a basic requirement. As the sensor nodes are powered by battery, the testament of the battery life is necessary. The battery life calculation formula is shown in eqn. (1). Q_a represents the battery capacity, I_w represent the sensor node working mode power usage, t_w represent the sensor node working mode time, Is represent the sensor node sleep mode power usage, and t_s represent the sensor node sleep mode time.

$$T_d = \frac{Q_a \times (t_w + t_s)}{24 \times (I_w \times t_w + I_s \times t_s)} (\text{day}), \quad (1)$$

And the testament set sleep mode for 5 s and 10 s as for comparison, and every 3minites sending data to home gateway. The sensor nodes are powered by 2 batteries. And the test results are shown in Table 1.

Table 1. Battery life testament results.

Sleep mode Time	Beginning Time	Ending Time
5 s	2013-6-3 9:30	2013-7-7 10:16
10 s	2013-7-13 8:40	2013-9-15 15:52
Working Time	**Calculation Time**	
34 D and 0 H 46 Min	38 D and 6 H	
64 D and 7 H 12 Min	69 D and 6 H	

According to the testament results, the sensor nodes battery life meets the requirement of long time working and energy efficiency.

6. Conclusions

Focusing on the specialties of large-scale railway maintenance equipment, this paper proposed a low-cost, energy efficiency, Sigsbee wireless sensor network fault detection application. This fault detection application has fast deployment, self-organization, and extensive characteristics. And the battery lives of the sensor nodes meet the basic requirement. As one of the sensor nodes battery goes down, the machinists only have to change the battery. If one of the sensor nodes breaks down, to solve this problem the machinists only have to replace the sensor node with the spare ones. Thus, this fault detection application is worth for further population in this field.

Acknowledgments

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