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The Implementation of Electronic Intelligent Tag System Based on Wireless Sensor Network

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ABSTRACT

Recently, Wireless Sensor Network (WSN) has been widely applied in many fields. In this paper, we design and implement a WSN-based Electronic Intelligent Tag System (EITS) to provide intelligent management of the modern supermarkets. As a main transceiver, nRF24L01+ wireless module is used in this system, which will make it possible to achieve low-power and low-cost for EITS. This system fully embodies the advantages and characteristics of WSN. This paper will introduce the system architecture, hardware structure and software design in details; and put forward a specific solution. Finally, we achieve the intelligent management of the mall based on wireless sensor network technology.

Keywords: Wireless Sensor Network; Electronic Intelligent Tag System; Architecture

1. Introduction

Electronic Intelligent Tag System (EITS) is a very typical application of the Internet of Things (IOT) [1] in the business world. Electronic Intelligent Tag (EIT) is an electronic display device, which is placed on the shelf and can replace the traditional paper price tag [2]. Simultaneously, it can process Real-time monitoring of environment factors such as temperature, light. The solution of EITS can not only provide enterprises with frequent and effective promotional activities, but also provide more management and optimize the performance of the commodity information, as well as other suppliers.

Wireless Sensor Network (WSN) is listed as the most influential technology in the 21st century and one of ten technologies to change the world [3]. WSN has broad application prospects, such as smart home, industrial automation, medical maintenance, et al, leading the development of emerging short-range wireless communication technology [4].

Currently, EITS is beginning to spring up. Several well-known supermarkets have started to use the system in the United States [5]. The system uses RS485 wired communication, however, which has many defects such as its complex to wire, difficult to move, limited of communication distance et al. This article will take full advantage of the WSN, low-power, low-cost, flexible cloth mesh, to design an Electronic Intelligent Tag System of a large-scale distribution network.

2. System Overall Architecture

WSN is a short-distance wireless communication network with a great advantage of cost and power consumption. Especially, its flexible networking technology is the basis of the communication of EITS [6]. From the introduction of wireless sensor network technology, we know that EITS can monitor the warehouse and undertake wireless transmission of the temperature, humidity and sunshine about the warehouse or shelves. It could ensure that goods are in a suitable environment. Furthermore, the system can achieve real-time, accuracy and secure data transmission. Updating commodity prices in time will improve the efficiency of the shopping centers in various promotional activities.

The architecture of EITS based on WSN is shown in **Figure 1**. The architecture consists of seven parts: Sink, Area Controller, EIT, Handheld Instrument, Server, Data Management Platform and Point of Sale (POS) terminals.

Sink, which is also called gateway, is responsible for receiving and sending commands and tag information. It uplinks with the Server for data exchange, and it

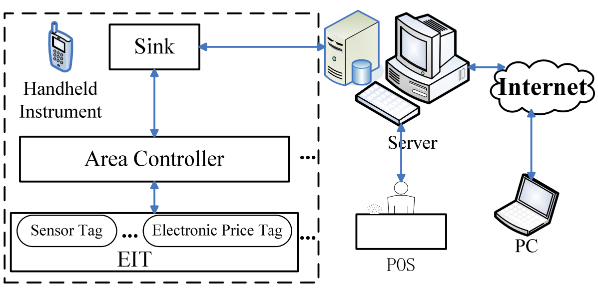

Figure 1. Architecture of Electronic Intelligent Tag System (EITS).

downlinks with Area Controllers for information communication. Area Controllers, located in the middle layer of the Sink and EITs, store and transmit regional data. EIT is a terminal device of environment sensing and information displays. The environment information relates to temperature and humidity, sunshine, Carbon dioxide. Its display contents include product name, price (original price, member price and promotional price), date of manufacture, et al. On the one hand, Handheld Instrument's function is to modify the product information of EITs; on the other hand, it can easily get the sensing information immediately. Server runs a variety of platforms and its main job is to process remote configuration and management of EITS. Finally, Data Management Platform can remotely control and manage the supermarkets.

3. Hardware Architecture

The core hardware architecture of EITS includes EIT, Area Controller, Sink and Handheld Instrument. All of them will be described in the following.

3.1. Electronic Intelligent Tag

Electronic Intelligent Tag (EIT) locates in the bottom layer of EITS. It could sense the environmental information and display commodity-related information. EIT can be divided into Electronic Sensor Tag (EST), Electronic Price Tag (EPT), as well as Electronic Mixed Tag (EMT). The structure of the three tags is basically the same, the main difference of which is that whether it has Sensor Module and LCD Module or not. The structure of EIT is shown in **Figure 2**. The Sensor Module integrating various sensors, such as temperature, humidity, pressure, light, et al, is used to collect local environmental information. The LCD Module mainly displays price-related information of commodities, as well as local sensing information. Wake-Up [7] Module triggers the processor external interrupt to wake up the sleeping EIT. In order to improve the mobility of EIT, the EIT uses the battery power supply.

The Transceiver Module of EIT adopts low-cost and good performance nRF24L01+ [8] chip produced by Nordic company. The nRF24L01+ is a single chip 2.4 GHz transceiver with an embedded baseband protocol engine, suitable for ultra-low power wireless applications.

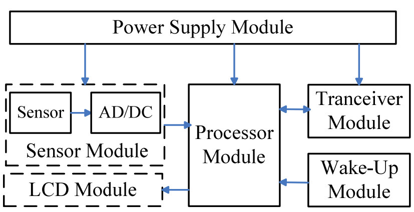

Figure 2. The structure of Electronic Intelligent Tag (EIT).

It has up to 126 RF channels to choose. We can operate and configure the nRF24L01+ through a Serial Peripheral Interface (SPI). The chip also has the feature of automatic acknowledgment and automatic retransmission. As a result, low current consumption is the main feature of the chip, 26μA in Standby-I Module, even 900nA in Power down Module [9].

The EIT will take the 16-bit ultra-low power microcontroller MSP430 as the Processor Module. Further more, we choose MSP430F4132 [10] microcontroller here. Its current consumption has reached μA level. Benefiting from its 16-bit CPU and efficient RSIC instruction system, the processor can achieve 125ns instruction cycle at 8MHz. MSP430F4132 possesses SPI Module, communicating with nRF24L01+, and temperature sensor, directly sensing ambient temperature. The most important characteristic is its LCD driving controller that can directly drive LCD displays by creating the ac segment and common voltage signals automatically.

The EIT should own energy conservation so that battery in tag can work for a desirable time, and the energy conservation algorithm should also be considered [11]. The EIT works on sleeping mode and wake-up mode periodically. It can change the operating mode automatically according to the strength of the received RF signal. Detecting the remaining voltage of battery is another function of the EIT [12]. When their voltage is below a certain threshold, the tags will automatically enter power-down mode, and send feedback information to the managers.

3.2. Area Controller

The structure of Area Controller, shown in **Figure 3**, consists of Processor Module, Wireless Communication Module and Power Supply Module. Processor Module uses 32-bit standard RISC processor based on the ARMv7-M, providing high density performance line and efficient code efficiency [13]. Here, this system will select STM32F103VET6 [14], built-in to up to 512K bytes of Flash memory and 64K of SRAM, operating on 72MHz frequency. The processor has a wealth of peripheral resources. For example, three transceivers could be

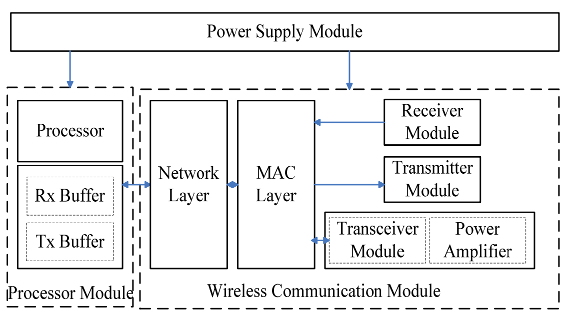

Figure 3. The structure of area controller.

controlled by its three SPI interfaces respectively. Furthermore, the CPU can also be embedded operating system μC/OS-II, to provide efficient management and scheduling. For compatibility with the network communication protocol of EITS, Wireless Communication Module still uses the nRF24L01+ RF chip in receive mode, transmit mode and transceiver mode respectively. While, in order to achieve large-scale distribution networks, the front-end of Transceiver Module adds a power amplifier to improve communications transmission capacity. Area Controller can be powered over Ethernet or AC power.

3.3. Sink

The structure of Sink is shown in **Figure 4**. To reduce the cost of research and development, structure of Sink is similar with Area Controller. In other words, it is a scaled-down version of Area Controller. Processing and memory unit uses STM32F103VET6 based on the Cortex-M3 core. The communication unit uses nRF24L01+ and Power Amplifier as transceiver. Asynchronous communication between Sink and the Server can be implemented through RS232, RS485 or Ethernet.

3.4. Handheld Instrument

Handheld Instrument is a smart hand-held device, which can be used to extract the data of EIT as well as modify the display information of merchandise. The Handheld Instrument can not only wake up the electronic price tag and modify data, but also access the sensor date from sensor tag. With the TFT-LCD display, you can send operating instructions, check the accuracy of product information, and observe the feedback information and data. Power can be supplied by rechargeable lithium battery. **Figure 5** is the structure of Handheld Instrument.

4. Software Design of the EITS

The system software design consists of two parts: embedded software and visualization management software. Embedded software is mainly used for collecting data, sending forwarding data, controlling energy consumption and monitoring the status of devices. Visualization management software is operated by managers. They can control the purchase of goods, adjust commodity prices, monitor changes of the local environment, and check the history data in the supermarkets.

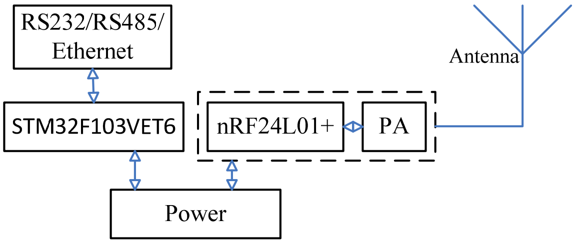

Figure 4. The structure of Sink.

4.1. Communication Architecture

EIT, Area Controllers and Sink communicate with each other in the multi-hop manner, forming the cluster network structure [15]. Server provides the interface for the underlying communication and application software, and converts the sending and receiving packets in a standard format. The system can be divided into five layers, shown in **Figure 6**.

The physical layer provides the signal modulation and wireless transceiver. The data link layer determines the pattern radio channel used and allocates the limited wireless communication resources [16]. The network layer is mainly responsible for routing generation and routing selection. Unlike traditional wireless communication routing protocols, protocols of WSN depends on the specific application. Hence, the system will apply directed diffusion routing protocol. Processing Layer plays a role of processing and controlling information. Moreover, application layer refers to the monitoring and management software, detailed in next section.

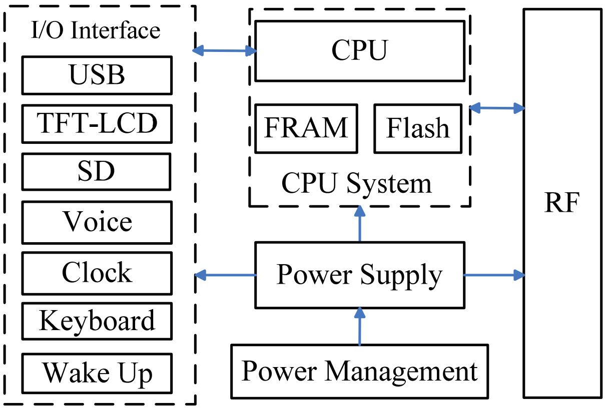

Figure 5. The structure of handheld instrument.

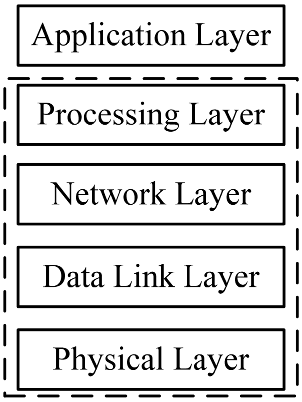

Figure 6. Architecture of software.

In recent years, due to such features as low cost, ease of deployment, increased coverage, and enhanced capacity, there are a growing number of new protocols for WSN. The concept of cross-layer design is based on architecture where different layers can exchange information in order to improve the overall network performance [17]. To maximize the lifetime of a wireless sensor network, mobile Sink [18] is a wise choice. In this way, the sink travels along nodes with few energy or large communication to balance the network for longer life.

4.2. Management Software of EITS

Management software of EITS, that is also called EITSV, is implemented. EITSV is designed to be an interface between users and the server. EITSV provides some tools to simplify deployment and visualization. It also makes it easy to connect to a database, to display products information, and to observe the status of EITs and Area Controllers as well as regional environment information. If an exception occurs, there will be alert notifications. All of display information, status information and control commands will be stored in database.

The structure of EITV, shown in **Figure 7**, consists of four parts: EIT View, AREA View, SINK View and SENSOR View. Merchandise information (name, production place, price, et al) and status information (regional environment, operating voltage, devices status, et al) will show to users through EIT View. EIT, owning the unique ID, can be identified by the system automatically. Whenever it joins into the network or leaves the network will be visualized. AREA View and SINK View are used to monitor operating status and load fluctuation of SINK and Area Controllers for intelligent management. SENSOR View makes the sensing data management and analysis more conveniently, which will ensure that the entire system is in a secure environment.

5. Conclusions

In this article, we take full advantage of wireless sensor network technology to give a whole solution for Electronic Intelligent Tag System, providing intelligent management for supermarkets. The EIT will replace the existing paper tag to improve the efficiency of the malls.

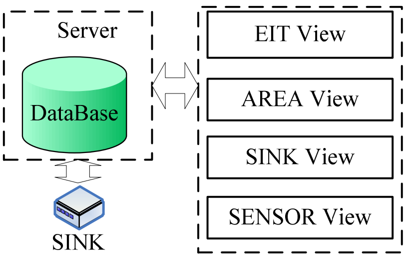

Figure 7. The structure of EITV.

Sensing information of supermarkets will make supermarkets more secure. This system has been applied in practical projects. The results show that the system has high efficiency, low labor costs and good reliability. Therefore, we should further popularize the EITS to benefit our supermarkets.

In the further work, this system will be extended to the whole supply chain, forming a supply chain management system. The commodity, environment, vehicle and related persons could be managed more efficiently. In brief, the successful application of EITS will play an important role in promoting the development of the Internet of Things.

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