Design of Electronic Shelf Tag System Based on Simpliciti

Ma Yin-ping, Ma Wen-rui

***Abstract*— in view of the great updating and maintaining work and high real-time requirements for the price tagging system in supermarkets, a kind of SimpliciTI-based e-shelf tagging system design plan is proposed. The design adopts microprocessor MSP430FR2433 and CC1100 integrated with radio-frequency transceiver as main control chip, electronic paper as display, and low-power-consuming software and hardware to realize such functions as real-time data receiving and sending and electronic display. The system test proves that the electronic shelf tagging system has such features as reliable wireless transmission, high real-time performance, low cost, and less power consumption.**

***Index Terms*— Electronic shelf tag system, SimpliciTI, Wireless transmission, real-time**

I. INTRODUCTION

Commodity price tag made of paper is widely used in the commodity sales, and the updating of information on such paper tags in supermarkets usually depends on manual operation[1]. With expansion of supermarket scale and commodities species, the price tag should be frequently changed or altered. Due to a sea of products, the tag replacement demands a good deal of labor force, efforts, and paper. Moreover, some mistakes are inevitable so that the customer satisfaction is greatly affected. Against such background, the e-shelf tag comes into being.

The so-called e-shelf tag is a kind of electronic display device that is fixed on the shelf to replace the traditional paper tag. Each e-shelf tag is connected with the shopping mall's backstage management center through wireless or wired network to display the latest commodity information through the electronic display on the tag[2][3]. At present, domestic e-shelf tagging system mainly adopts such communication techniques as low-power consuming Bluetooth and ZigBee wireless communication. The former is troubled with slow speed while the latter has several defects, including high cost and complicated networking agreement. SimpliciTI can exactly remedy the shortcomings of existing wireless standards, for it occupies less resources in the hardware, fewer nodes in the network, and smaller and simplified network. The paper adopts SimpliciTI as the basis for designing a kind of e-shelf tag that is characterized by low cost and power consumption and can meet with the control requirements.

Ma Yin-ping, College of Electrical Engineering and Automation, Jiangsu Maritime Institute, Nanjing, China, +86 18260097229
Ma Wen-rui, Electron Information Engineering College, XiDian University , Xi'An, china , +86 18710335161

II. GENERAL SYSTEM DESIGN

SimpliciTI can form star or point-to-point network, and makes use of the Range Extender to extend the network topology. The devices provided by SimpliciTI network can be divided into three kinds: namely AP (Access Points), ED (End Devices), and RE (Range Extenders). Among them, AP is used to form network and process the data sent from all the subsets or routes. ED receives the data packages from AP node, picks up useful commodity information from the packages and stores it into the FRAM (ferroelectric random-access memory) of SCM (single chip microprocessor) so that the data can be shown on the electronic display through the data transmission and processing capacities of SCM. The tagging system employs the structure of star topology network which has a relatively stable networking and exercises communication only between all the scattered electronic tags and AP module instead among all the tags. In such circumstance, the whole networking can maintain very low power consumption when assuring the communication quality.The network structure of the e-shelf tagging system is illustrated in Fig. 1.

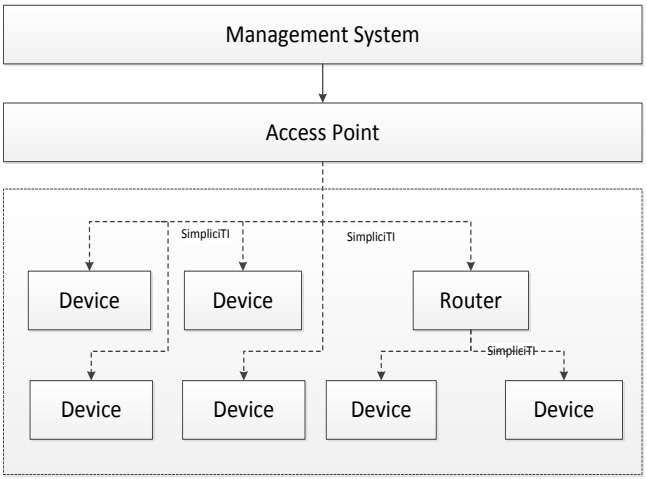

Fig.1 The network structure of the e-shelf tagging system

III. HARDWARE CIRCUIT E-SHELF TAG

The paper designs an e-shelf tagging system specially for the hypermarkets. The system can achieve wireless communication between all the e-tags and intermediate transmission nodes as well as the data transmission among all independent modules and terminal data display in order to guarantee the completeness of the communication data. One e-tag is provided for every commodity in the system, which reveals all the information about the commodity in real-time way, such as its name, price and bar code. A complete e-shelf tagging system is composed of following parts: AP, ED and e-tag.

A. *End Devices Design*

The overall hardware structure of the ED is as shown in Fig. 2, mainly made up of MCU (Micro Controller Unit), wireless transceiver module, display module, and power module[4][5]. With built-in FRAM within MCU, it is thus unnecessary to expand the Flash memory area. The power supply is the battery of proper capacity and volume.

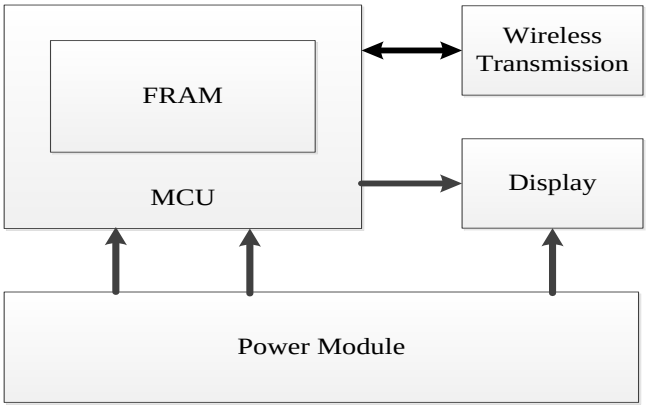

Fig. 2 The overall hardware structure of the ED

(1) MCU module

MCU module adopts MSP430FR2433 as the master controller. When compared with traditional MCU, this module blends the unique embedded FRAM and ultra-low-power-consuming system structure so as to achieve quick storing velocity and strong anti-disturbance capacity. As the system is updating the information, current consumption is only several microamp. In addition, when the system is in sleep state, its power consumption is extremely low. It is, thus, very proper to be used in the development and design of e-tag system.

(2)Wireless transmission module

CC1100 radio-frequency chip is a kind of UHF transceiver of low power consumption and cost but real SCM, especially designed for the low-power wireless application[6]. Master controllers, namely CC1100 and MSP430FR2433 are configured through the 4-wire SPI compatible interface (SI, SO, SCLK, and CSn) which can also write and read the cache data. SPI is a kind of synchronous serial communication interface; CSn is chip select pin; when CSn is in low level, SPI can carry out communication; otherwise it can't; SI is used for data input while SO for data output; SCLK means the synchronous clock in rising or falling edge of clock. In the e-shelf system, CC1100 works at the frequency of 433MHz which has relatively rich bandwidth, fewer interference signals, and is proper for the complicated environment among different communication nodes in hypermarkets.

(3)Display module

Electronic paper is used as the display device of system. It is of WF0213-01 model procured from Wuxi Vision Peak Technology Co., Ltd. Such kind of display is a TFT electrophoretic matrix composed of related interfaces and control logic and a reference system design. The display screen has a resolution of 212x104 and sufficient gray scale display function. It integrates the hardware drive circuit of electronic paper, being convenient for the product development. Moreover, the electronic display can keep the contents even after being disconnected from the power supply. Its static power consumption is very low, costing some power only in picture shift.

B. *AP Center Hardware*

E-shelf tagging system is usually used in hypermarkets in which there are a variety of commodities and thousands of price tags. In such circumstance, it is nothing easy to exert an efficient management. As the core of system, the data center should be equipped with very high processing capacity. The processor used in the ED is MSP430FR2433 which works at a frequency as high as 16MHz and owns 64K FRAM. But when used as a processing zone for coordinator or router to manage several or even thousands of ED, it seems to be far from being competent. Such problems as message routing failure, network congestion, accidental off-network of nodes, and network collapse may arise so as to affect the network communication efficiency and quality. TM4C129XNCZAD with strong select function is selected as a the master processor of the AP. Since it is SimpliciTI protocol stack that is operated within both TM4C129XNCZAD and MSP430FR2433, they have no problem concerning compatibility. The AP center hardware is as shown in Fig. 3.

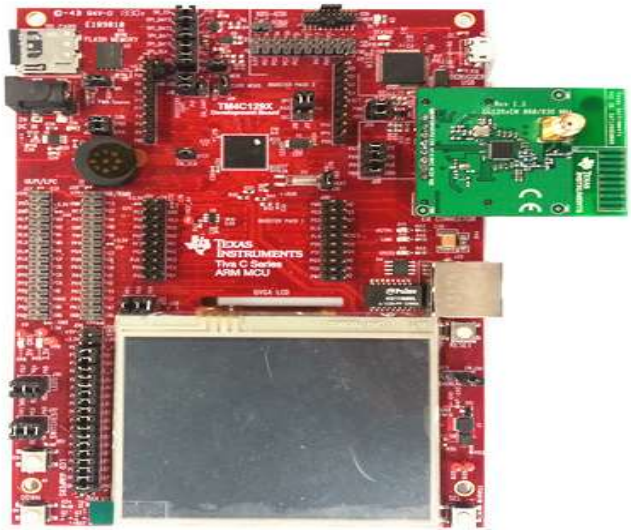

Fig. 3 AP center hardware

IV. SOFTWARE IMPLEMENTATION

A. *SimpliciTI protocol*

The SimpliciTI network protocol is an exclusive LP network protocol advocated by American TI (Texas Instrument) for the communication frequency band below 1GHz[7]. Such protocol does not demand much resource in hardware, and it is easy for development with low cost and power consumption. It is made up of three parts, including Network Layer, Application Layer, and Lite Hardware Abstraction Layer[8][9]. Among them, the application layer is actually divided into two sections: network application layer and user program application layer. The lite hardware abstraction layer is composed of Radio layer and BSP (Board Support Package) layer[10]. The radio layer is responsible for receiving data while BSP providing SPI for the communication between radio layer and network layer[11][12]. The structure of network protocol is depicted in the figure 4.

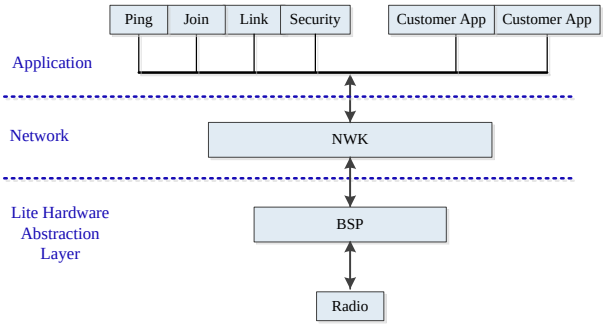

Fig. 4 The structure of network protocol

B. *System Software Implementation*

The general framework of the system is as shown in Fig. 5. The software mainly includes the AP program design and ED program design. The software of AP covers network management, file system, and radio transmission, whereas ED program is about the radio receiving, data display and low-power processing.

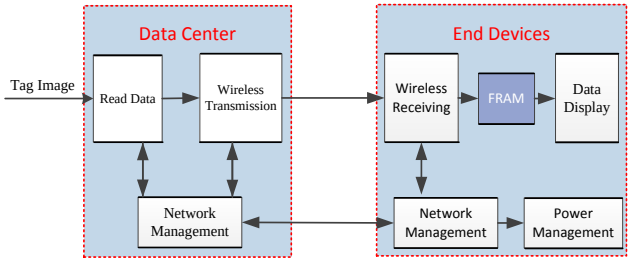

Fig. 5 The general framework of the system

(1) AP program design

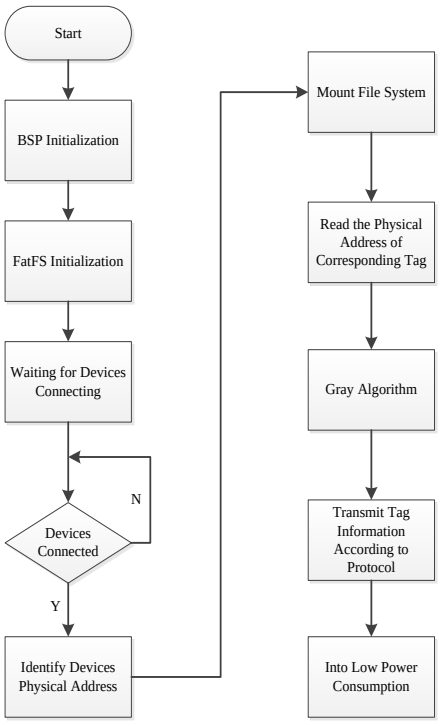

Fig. 6 The major program operation

The major program operation is displayed in Fig. 6. The AP design is completed in IAR Embedded Workbench. After being initialized by the BSP and FatFS, AP waits for the entrance of ED; when star network is successful erected, AP will identify the physical address of ED in the network, find out corresponding tag image as per the address, exert gray scale processing of the image since the final display device supports only the images of 4 gray scales, convert it to be array of 5,512 bytes, and sub-pack and distribute it according to SimpliciTI.

(2) ED program design

After ED is powered on, it is initialized by BSP first, then wait for joining the AP and data transmission, next transmits the received tag message to FRAM for storage. Later MCU sends the data in FRAM to electronic paper display device through SPI, and electronic paper refreshes the latest goods information on the screen as per the received data. It can be inferred that the most important program in the ED design is the data receiving by radio module and display by the electronic paper.

1)Radio receiving program

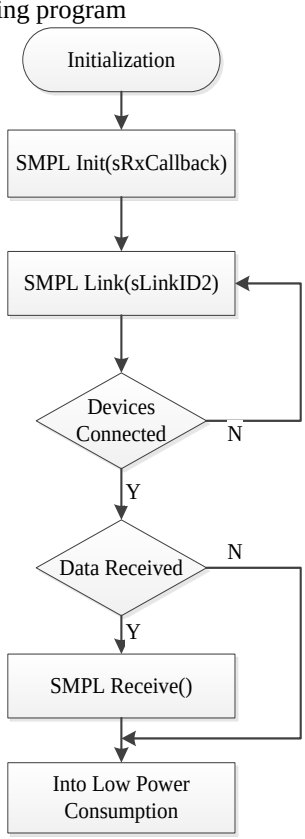

Fig. 7 The radio receiving process

Fig. 7 displays the radio receiving process: the system initializes the radio layer and SimpliciTI network protocol stack through SMPL_Init () function, and then begins waiting for network connection. Upon detection of built network, it starts receiving data information. After the data receiving is done, the whole system is in the low-power consuming mode.

2)Display program

The electronic paper adopts electrophoretic display (EPD) technology. The function of the electronic paper drive program is to convert the image pixel data received from MCU to the level signal of electronic paper driver through hierarchic control in the program so as to realize the screen display function of the electronic paper. The process for the electronic paper display to present one image is as follows:

① Initialize the hardware circuit drive of WF0213-01 and invoke and realize the EPD_W21_Init () function;

②Fill in the register of electronic paper, configure the gray scale and display mode in the display area, and wipe the buffer data sent to the display area;

③Start up the refresh display mode of electronic paper and wait for data from FRAM;

④Process the received effective data, such as the pixels and pixel arrangement order in each area; or the electronic paper will display messy code or wrong information;

⑤ After displaying the received data, re-configure WF0213-01 electronic paper register so that the whole electronic paper is in the power failure mode.

V. Wireless Communication Performance Test

The communication distance among nodes and corresponding package loss probability are two important factors for measuring the performance of node device. The so-called package loss probability means the rate of lost data package in all the received data packages due to environmental disturbance and noise. In order to study the performance of wireless communication system, communication performance test was carried out between a certain AP and ED with or without obstacles between them[13][14]. The linear test distance was 10m, 50m, 200m, 400m and 500m, respectively. The obstacle-free test was conducted in open field while the obstacle test in a supermarket to better simulate the application circumstance. The test results are provided in Table 1:

Table 1: The result of wireless communication test

Communi-cation distance	Package loss probability (without obstacles)	Package loss probability (without obstacles)
10m	0%	0%
50m	0%	0%
200m	0%	0%
400m	0%	0%
500m	0%	1/424=0.2%

In light of the table, we can find that the communication package loss probability is 0% in obstacle-free circumstance and only one package is lost at 500m communication distance in the obstacle circumstance. Therefore, the whole system can completely meet the requirements of supermarkets. Should the supermarkets pose higher requirements about the communication distance, we can raise the transmitting power to 16dBm and even optimize the retransmission mechanism algorithm of the protocol stack.

VI. Conclusion

In the paper, by designing the software and hardware modules in e-shelf tagging system on the basis of SimpliciTI protocol, the system can successfully send the tag images processed by AP node to each corresponding ED and display them normally on the ED electronic paper when completing the data processing, sending and receiving functions. Test was also conducted to verify the wireless communication performance of the system. It is proven through the test that the system features high stability, low power consumption and cost and has encouraging development prospect.

References

[1]Breggin L K, Myers B, Wilensky M. It's Time to Put a Price Tag on the Environmental Impacts of Commodity Crop Agriculture[J]. Environmental Law Reporter News & Analysis, 2013.

[2]Choi B H. Electronic shelf label tag, electronic shelf label system and operating method thereof[J]. 2016.

[3]Choi G Y. Rfid electronic shelf apparatus and method of detecting poisitons of tags using the same[J]. 2012.

[4]Raleigh G C, Cioffi J M. Spatio-temporal coding for wireless communication[J]. Communications IEEE Transactions on, 1996, 46(3):357-366.

[5]Tarokh V, Seshadri N, Calderbank A R. Space-time codes for high data rate wireless communication: performance criterion and code construction[J]. IEEE Transactions on Information Theory, 1998, 44(2):744-765.

[6]Larsson E G, Stoica P. Space-Time Block Coding for Wireless Communication[J]. 2003.

[7]Tang Z, Shuai W, Luojun. Wireless Home Alarm System Based on CC1110 and SimplicTi[J]. Procedia Engineering, 2011, 15:105-109.

[8]Singh V P, Chandrachoodan N, Prabhakar A. A Time Synchronized Wireless Sensor Tree Network using SimpliciTI[J]. International Journal of Computer & Communication Engineering, 2013, 2(5):571-575.

[9]Skrzypczak L, Grimaldi D, Rak R. Basic Characteristics of ZigBee and Simpliciti Modules to use in Measurement Systems[J]. Proceedings of Imeko World Congress, 2009:6--11.

[10] Mikhaylov K, Plevritakis N, Tervonen J. Performance Analysis and Comparison of Bluetooth Low Energy with IEEE 802.15.4 and SimpliciTI[J]. Journal of Sensor & Actuator Networks, 2013, 2(3):589-613.

[11] Ribeiro B, Espirito-Santo A, Calixto W, et al. Development of a low power wireless network to support elderly people based on eZ430-Chronos and SimpliciTI[C]// Education and Research Conference. IEEE, 2014:11-15.

[12] Tornier recently announced they have received FDA clearance to market the Simpliciti Shoulder System.Indicated for use in total shoulder arthroplasty, the Simpliciti Shoulder System was designed in conjunction with shoulder surgeons to treat patients exhib[J]. Orthopedics.

[13] Veillette B R, Roberts G W. A built-in self-test strategy for wireless communication systems[C]// Test Conference, 1995. Proceedings. International. IEEE, 1995:930-939.

[14] Heutmaker M S, Le D K. An architecture for self-test of a wireless communication system using sampled IQ modulation and boundary scan[J]. IEEE Communications Magazine, 1999, 37(6):98-102.

Ma Yin-ping

Publications :
1) Design of Cascade Control System Based On CS4000 Experimental Device
2) Design of Smart Socket Based On MSP430