

## The Study of System of Tracking and Positioning Library Books Based on RFID and ZigBee Technique\*

Tie-jun Chen

College of Electrical Engineering  
Zhengzhou University  
Zhengzhou, China  
e-mail :tchen@zzu.edu.cn

Xue-xia Li

College of Electrical Engineering  
Zhengzhou University  
Zhengzhou, China  
e-mail :alsian@126.com

**Abstract** - A wireless sensor network monitor system is designed based on CC2520 to solve the problem of confusion existing in management of library books. This method innovatively combines RFID radio frequency technology with ZigBee technology with the goal of tracking and positioning the books wirelessly. The designing principle and hardware structure of the system are introduced in detail in this paper. In order to track the exact position of a certain book the method, i.e. virtual routing tracking algorithms based on RFID network is applied. In addition communication frequency choice, network topological structure and the software design of the system are briefly introduced. This system can expand easily and is open to other areas, which also realized the short distance communication of wirelessness, low power consumption and low cost. At last, the feasibility and stability of the system is verified through experiments.

**Keywords**- Radio frequency identification; CC2520; ZigBee network; Virtual route tracking; MSP430.

### I. INTRODUCTION

With the development of information era, the number of books in library is increasing rapidly. As a result, the traditional managements and service methods dealing with the library can not meet needs of readers for much more literature information. As the increasing of the amount of collections in library it becomes more difficulty to gather and search books, which would cause a series of problems, such as, putting books on the wrong or disordered frame, readers keeping books of their own privately, and difficult to count and classify etc. Bar coding technique can not meet the requirements any more. It is a new challenge to improve the level of book management and service by applying the advanced information technology.

As for solving the problems in the library management mentioned above, a system is established by using RFID wireless radio frequency technique and ZigBee technique [1] to compose reader network [2] to ensure the typing and position tracking of the books and papers. This system makes the readers seek what they want easily, and decreases the possibility of putting the books at the wrong place or bringing them out of library. Combining RFID Reader and ZigBee short-range wireless communication technology,

both of which compose the Ad\_hoc network of RFID reader, and applying a network tracking algorithm [2] based on RFID the system can track and position all of the bibliographies that labeled RFID tag. Finally, it was proved feasible and actually useful according simulating experiments. Compared with the traditional bar coding technology, the system of lower cost and consuming less is also more expandable and open and worthy of further studying.

### II. RFID AND ZIGBEE TECHNOLOGY INTRODUCTION

#### A. RFID Technology[3]

RFID (Radio Frequency Identification) is an automatic identification technology without contact to realize the automatic identification of objects using RF signal and spacial coupling (inductor or electromagnetic coupling) or the transmission properties of radar reflection. In the practical application of RFID technology, an electronic label is attached to the object to be identified. When the object with electronic label is going through the readable area of reader, a wireless communication link will be established between the label and reader with the label sending their information to the reader and the reader receiving and decoding it. After that these information is transmitted to the computer running back to complete the whole information process. The advantages of which are as follows: quick scanning (RFID reader device can identify multiple RFID labels simultaneously); volume being miniaturable and, shape of diversification; not easy to be polluted; being of strong durability and reusable; reading without barriers, being of large data memory; the safety property being strong.

RFID is mainly consist of labels, reader, antenna and a set of system transmitting and processing data. The working principle and structure is shown in Fig.1:

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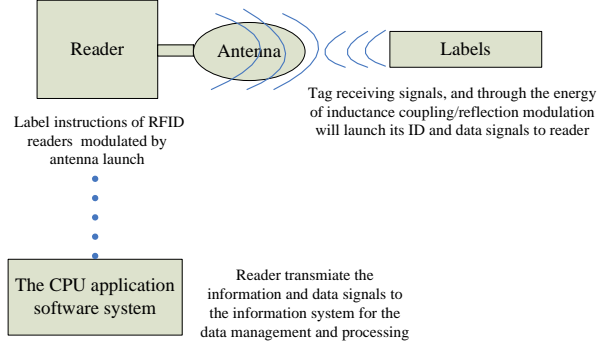


Fig.1. Working principle and structure of RFID

### B. ZigBee Technology

ZigBee which adopts IEEE802.15.4 communication standard can work on 2.4 GHz frequency and the other two frequencies universal all over the world. It is a communication technique that is related to network, security and the applied software. The transmission distance ranges from 75m to hundreds of meters. It is also a newly wireless network technique with short distance, low power consumption, low cost, good reliability, and strong flexibility. Because of those advantages such as huge network capacity, short delay, high data security, it has been widely applied to various fields and achieved high economic and social benefits.

ZigBee wireless sensor network is composed of many sensor nodes which are in charge of data acquisition, transceiving and forwarding in the network. The nodes can be classified into three classes including the main nodes, routing nodes [6] and terminal nodes in ZigBee network which supports two types of physical devices defined by IEEE802.15.4: the full functional equipment (FFD) and the simplification of functional equipment (RFD). FFD and RFD are distinguished by the function of node. FFD can be used as a tuner, router which can be worked as main node in network. Thus, at least one FFD should be contained in a network. RFD being easily realized can just communicate with the main equipment and, be used as the terminal equipment node. Routing node being the wireless transceiver in network must be FFD too. Two kinds of physical devices are defined as three types of logical devices in ZigBee network: tuner, router, terminal equipment. A ZigBee network includes a tuner node and several router nodes and terminal equipment nodes.

The topological structure of ZigBee network includes the following three types: star, cluster tree and mesh network. The mesh network is chosen in this paper in order to efficiently reduce time delay of transmission and improve the information communication reliability so as to position timely. Mesh network is an Ad Hoc network of high reliability. Direct communication can be carried out between the FFD nodes with routing function, which can provide more communication paths for the whole network. Its topology structure is shown in Fig.2:

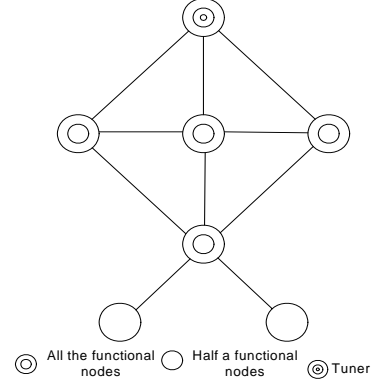


Fig.2. Mesh network topology structure of ZigBee

## III. THE ESTABLISHMENT OF TRACKING SYSTEM MODEL

### A. Tracking System Structure

The system of library books tracking and positioning is a wireless Ad\_hoc network composed of RFID readers which are distributed according to matrix arrangement on the bookshelf. ZigBee which is a kind of short-range wireless communication module is embedded in these readers. Label information collected by RFID readers can be transmitted to background processing system through ZigBee wireless network. Only one computer is needed in the entire network as the control terminal, which greatly reduces the complexity and cost of the system. This new network structure is given a new name of RFID readers' network in this paper. Meanwhile, a tracking algorithm of the RFID reader named network-virtual routing tracking algorithm is applied, which can realize the tracking and positioning of labeled bibliographies in the RFID readers' network.

### B. Virtual Routing Tracking Algorithm

Virtual routing tracking algorithm tracks a mobile bibliography which is labeled by a RFID tag using RFID readers of fixed and known position. In the algorithm, three parameter sets are defined as tracking vector including: the identity number (ID) of the tracked RFID tag, the time of reader perceiving the label and the identity number of the label read by the RFID reader, which are

noted as follows:  $\langle T_i, t_j, R_k \rangle = \langle \text{Transponder } i, \text{timestamp } j, \text{Reader } k \rangle$ . When a tag is being read, a

tracking vector would be produced in the network and be sent to the controlling terminals for calculating the tracking path. The perception distance of the RFID system is shorter than that the distance between nodes of RFID readers' network [7], so the position of RFID reader that detects the tag can be used to mark the label's position, which can realize exactly locating and tracking of books.

The complex part of RFID readers network of this books tracking system is shown in Fig.3, which includes five nodes. Each node's perception range is different and the

distribution is irregular either and with overlapped situation. There are two tags which get into the network almost at the same time along path a and b respectively and two tags trigger RFID reader constantly. Applied system collects 10 tracking vectors which are processed according to the virtual routing algorithms to produce two paths. The calculating process is as follows:

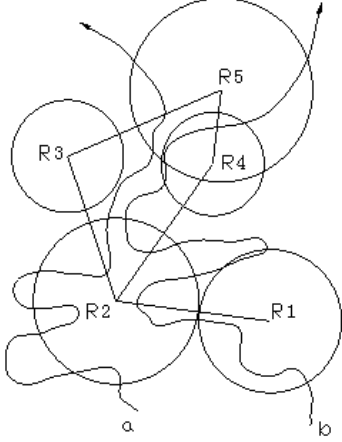


Fig.3. Tag path chart

Step 1: Grouping the tracking vectors

$$\left\{ \begin{array}{l} \langle T_b, t_1, R_1 \rangle \quad \langle T_a, t_2, R_2 \rangle \quad \langle T_b, t_3, R_2 \rangle \quad \langle T_a, t_4, R_2 \rangle \\ \langle T_a, t_5, R_2 \rangle \quad \langle T_b, t_6, R_1 \rangle \quad \langle T_a, t_7, R_5 \rangle \quad \langle T_b, t_8, R_2 \rangle \\ \langle T_b, t_9, R_4 \rangle \quad \langle T_b, t_9, R_5 \rangle \end{array} \right\}$$

$$\text{Step1} \left\{ \begin{array}{l} \langle T_b, t_1, R_1 \rangle \quad \langle T_b, t_3, R_2 \rangle \\ \langle T_b, t_6, R_1 \rangle \quad \langle T_b, t_8, R_2 \rangle \\ \langle T_b, t_9, R_4 \rangle \quad \langle T_b, t_9, R_5 \rangle \end{array} \right\} + \left\{ \begin{array}{l} \langle T_a, t_2, R_2 \rangle \quad \langle T_a, t_4, R_2 \rangle \\ \langle T_a, t_5, R_2 \rangle \quad \langle T_a, t_7, R_5 \rangle \end{array} \right\}$$

Those belonging to the same RFID tags are gathered as one group.

Step 2: Deleting tracking vector with time redundancy

$$\text{Step2} \left\{ \begin{array}{l} \langle T_b, t_1, R_1 \rangle \quad \langle T_b, t_3, R_2 \rangle \\ \langle T_b, t_6, R_1 \rangle \quad \langle T_b, t_8, R_2 \rangle \\ \langle T_b, t_9, R_4 \rangle \end{array} \right\} + \left\{ \begin{array}{l} \langle T_a, t_2, R_2 \rangle \quad \langle T_a, t_4, R_2 \rangle \\ \langle T_a, t_5, R_2 \rangle \quad \langle T_a, t_7, R_5 \rangle \end{array} \right\}$$

Only one of tag vectors that are perceived at the same time is kept according to the distance from the reader's position.

Step 3: Dealing with the effect of PingPong

$$\text{Step3} \left\{ \begin{array}{l} \langle T_b, t_1, R_1 \rangle \\ \langle T_b, t_3, R_2 \rangle \\ \langle T_b, t_9, R_4 \rangle \end{array} \right\} + \left\{ \begin{array}{l} \langle T_a, t_2, R_2 \rangle \\ \langle T_a, t_7, R_5 \rangle \end{array} \right\}$$

According to table tennis effect, only one of vectors that belong to the same reader is kept.

Fourth step: Searching virtual routine

$$\text{Step4} \left\{ \begin{array}{l} \langle T_b, t_1, R_1 \rangle \\ \langle T_b, t_3, R_2 \rangle \\ \langle T_b, t_9, R_4 \rangle \end{array} \right\} + \left\{ \begin{array}{l} \langle T_a, t_2, R_2 \rangle \\ \langle T_a, t_x, N \rangle \\ \langle T_a, t_7, R_5 \rangle \end{array} \right\}$$

$$\left( t_2 < t_x < t_7, N = \frac{R_3 + R_4}{2} \right)$$

Finally two paths are acquired:

$$\begin{cases} a = \text{VirtualRoute} = R_2 \rightarrow N \rightarrow R_5 \\ b = \text{VirtualRoute} = R_1 \rightarrow R_2 \rightarrow R_4 \end{cases}$$

routing algorithm is applied by the whole library network to realize books locating and tracking.

#### IV. HARDWARE DESIGNING

In order to get accurate location data, ZigBee short-range wireless communication module is embedded in the RFID readers, making its nodes form mesh structure, which is beneficial to transmit data. Additionally, this books positioning system is divided into two phrases including process monitoring and library field device, their topological structure is depicted as Fig.4:

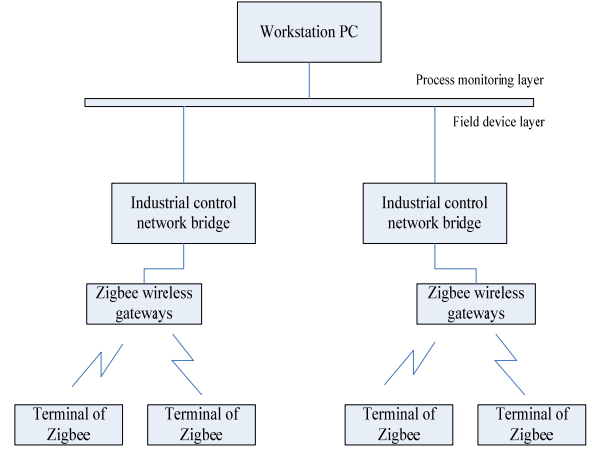


Fig.4. Topological structure of the system

##### A. Hardware Design of ZigBee Wireless Terminals Node

In book positioning system, the terminal node RFD [8] is mainly consist of processor module, sensor module, wireless communication module and power supply module. The single-chip processor MSP430F2618 with ultra-low power is applied in this system and CC2520 is adopted in the wireless communication modules[9] for exchanging information, sending and receiving data with other nodes. Its hardware structure diagram is shown in Fig.5:

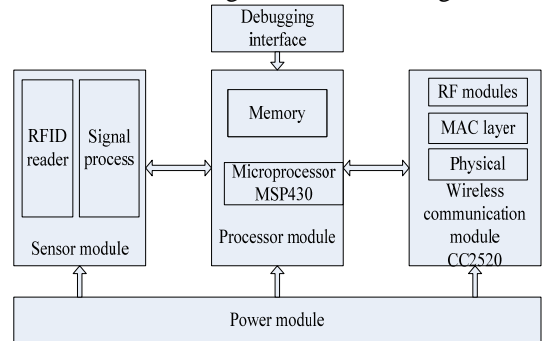


Fig.5. Hardware structure of wireless sensor network terminal node

The communication frequency of CC2520 is ISM frequency band of 2.4 GHz [10], which has a wide working temperature range, high sensitivity, good coexist performance and supports frame processing, data buffering, unexpected transmission, data signing power, the empty channel monitoring connection quality instruction and frame timing information and reducing the loading quantity of the main controller. There are two clock inputs in

MSP430F2618: 32.768 MHZ crystal provided system clock and 6MHZ crystal provided system the other working clock. The high frequency clock is chosen when gathering or processing signal in order to get a high processing speed while the low frequency clock is used when the system is on dormant to reduce system power consumption, which can realize real-time books tracking . The principle terminal node circuit is shown in Fig.6:

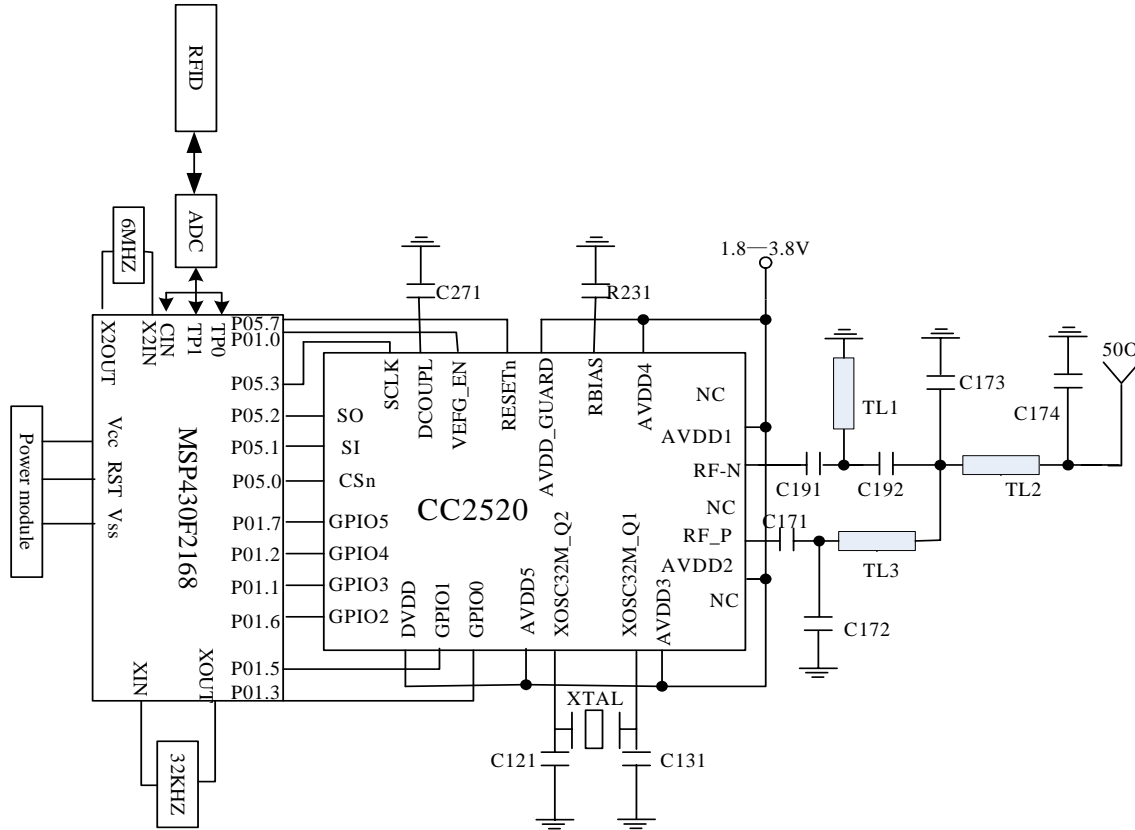


Fig.6. Terminal node circuit principle diagram

### B. ZigBee Wireless Gateway Designing

The wireless gateway hardware platform of books tracking system is composed of ZigBee wireless communication module which is based on CC2520 in the S3C2410A peripheral configuration, 10M Ethernet, flash restorage, debugging ports of JTAG(Joint Test Action Group). The gateway node is of strong data processing ability and high running speed, which is especially suitable locating and tracking system of low power consumption and requiring response timely. Its hardware structure diagram is shown in Fig.7:

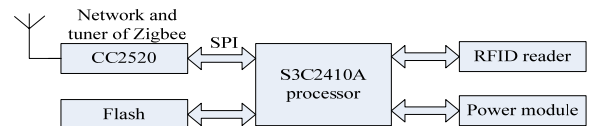


Fig.7. Hardware structure of wireless gateway

### V. SOFTWARE REALIZATION OF THE SYSTEM

This software part of the system mainly includes the realizations of wireless ZigBee terminal nodes and wireless gateway [4]. Terminal node software is mainly responsible for collecting data from RFID readers, processing and sending it while gateway is used to receive, analyze and encapsulate data,, and then convert them into the formation

which can be sent to the monitoring center, at last transmit data to workstation PC.

#### A. Software Design of ZigBee Wireless Terminal Node

First, CC2520 and LCD are initialized and then the protocol stack is initialized and interruption is open, the network began to be established and the network ID is displayed. When some new nodes apply to join in, a network ID would be given to this node. When new data is received, interruption is started and A/D conversion is executed, To encapsulate data and send it after conversion, then into suspended animation waiting be awoken. The flowchart is as shown in Fig.8:

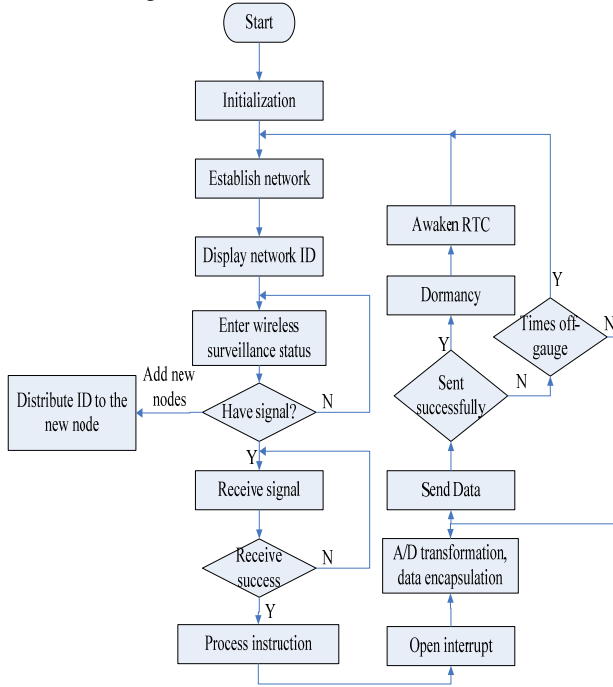


Fig.8.Wireless terminal node flow chart

#### B. Software Design of ZigBee Wireless Gateway

This part of design includes initialization, ZigBee wireless terminal management database and other modules [5]. Through the microprocessor programming, control communications between the ethernet and wires. The specific flow chart is shown in Fig.9:

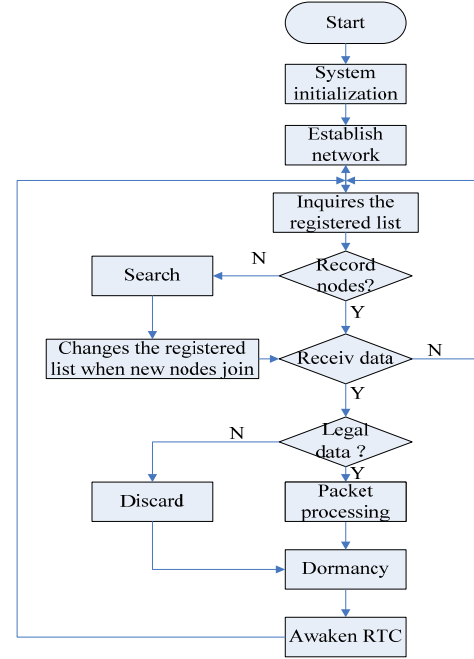


Fig.9.Wireless gateway flow chart

## VI. CONCLUSION

A books tracking system based on RFID combined with ZigBee is proposed in this paper in order to solve a series of problems, such as readers intentionally keeping library books of their owns, putting the books on the wrong frames, checking large amount of books, etc. The system is innovatively blended with RFID technology which replaced library bar coding. In addition, the virtual routing algorithm is used in the system to realize ID positioning and together with ZigBee wireless network technology to transmit the real-time tracking data to PC. Simulating experiments is carried to prove its feasibility. This system not only can detect the position of bibliography in real-time, but also realizes the wireless short-distance communication of less power-consuming and lower cost. Besides, the system is expansible and open as CC2520 can be connected with various MCU. With the rapid development of ZigBee, RFID and other electronic technology, it is certain that the system with a good developing space is a scheme worthy of studing.

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