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Design and Implementation of Port Bulk Storage Management System Based on Internet of Things Technology

Yi Mao* **and Lei Zhang**

Chongqing College of Electronic Engineering
Chongqing 401331, China

ABSTRACT

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This paper builds the overall architecture of the warehouse material management system based on the Internet of Things (IoT) technology, and deploys the radiofrequency identification (RFID) data acquisition system that acts as the IoT perception layer. Furthermore, RFID middleware is structured. By analyzing the current status and management content of warehouse management, the design scheme of the IoT technology warehouse management system is proposed, and the hardware circuit design of the IoT is carried out, which provides ideas for the application of the IoT technology in the warehouse management system of bulk cargo terminals.

ADDITIONAL INDEX WORDS: *Internet of things, warehouse management system, port bulk cargo.*

INTRODUCTION

For products with a shelf life, warehouse management includes tasks such as quality inspection of products and storage zone management (Liu, Sun, and Yu, 2017). Statistics show that warehouse management costs account for the majority of a company's overall logistics operating costs. Therefore, adopting efficient and reasonable warehouse management measures to achieve effective management and control of materials is a key means to flexibly adjust the supply and demand of storage materials and reduce operating costs (Bito *et al*., 2017). With the rapid development of the Internet of Things (IoT), many new technologies are gradually being used in warehouse production (Xu, Kamat, and Menassa, 2017). The emergence of these technologies has provided strong technical support for solving the above problems. It is the best way to reduce the cost of warehousing logistics and improve management efficiency by transforming and optimizing the warehousing operation process through information technology (Zeng, Qiao, and Qu, 2017).

Compared with traditional systems, the warehouse management system based on the IoT is more complicated in collecting and processing various types of information. Therefore, such systems require more advanced information acquisition and processing equipment, and the integration of these different devices becomes a key technical issue for system implementation. Relevant scholars have used sensor technology, radiofrequency identification (RFID), and ZigBee technology to study the storage management system that can monitor the environmental temperature and humidity (Lee and Chuang, 2018). Some people have studied the remote security monitoring system on the basis of a low-power Bluetooth storage environment to realize real-time monitoring and fire alarm in the storage environment (Baptiste *et al*., 2017). Researchers have also studied a RFID-based intelligent electronic shelf system that enables real-time monitoring of online items on shelves (Esparza, Cerbán, and Piniella, 2017). At the same time, the introduction of identity authentication services and Windows Communication Foundation technology into the warehouse management system has been studied to improve the security of the system. The researchers studied an IoT warehouse management control system based on ARM microcontroller, emphasizing the high performance, low cost, and easy expansion of the system (Nandyal *et al*., 2017). The middleware technology is applied to the warehousing system to achieve rapid conversion of raw data to system business information. Some scholars have also studied the warehouse system modeling and automatic guided transport vehicle (AGV) scheduling control strategy, expounded the cause of the inefficient operation of the multi-AGV intelligent warehouse system and the frequent congestion deadlock situation, designed the multi-AGV intelligent warehouse logistics dispatching system, and carried out simulation (Innocenti *et al*., 2017). Combined with RFID positioning and sensing technology, the application of IoT middleware in an intelligent warehouse is discussed. The RFID positioning technology for intelligent warehousing is developed, which realizes the positioning management of warehousing goods.

WAREHOUSING MANAGEMENT SYSTEM DESIGN BASED ON IOT TECHNOLOGY

System Architecture

According to the three-layer architecture model of the IoT, the overall design idea of the warehouse material intelligent

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*Corresponding author: maoye@cqcet.edu.c

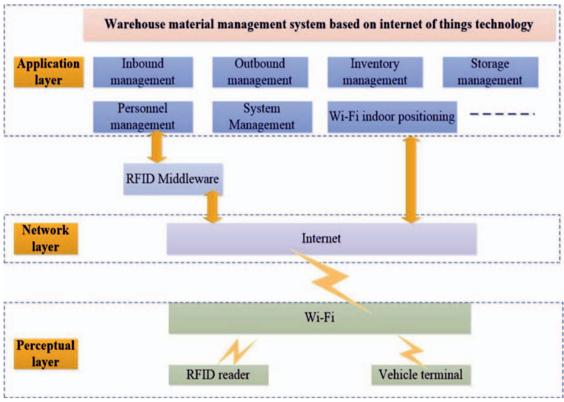

Figure 1. System overall design ideas.

management system based on the IoT technology is shown in Figure 1.

The first layer is the perception layer. It is the basis for information acquisition across the entire platform. The sensing layer mainly includes RFID readers, vehicle terminals, and Wi-Fi wireless access points (APs). The second layer is the network layer. In this level, the switch is used as the core of the network, and several wireless APs are deployed in the warehouse to achieve good Wi-Fi signal coverage in the storage area and establish a wireless network environment. The third layer is the application layer. This layer is primarily for system users. The database server is responsible for processing and storing the information transmitted by the network layer to the application layer and provides it to the application for query and processing.

According to the overall design idea of the system, the browser/server (B/S) software architecture is used to design the intelligent management system of warehouse materials on the basis of the IoT technology. The system architecture is shown in Figure 2. As can be seen from the Figure 2, in addition to the enterprise resource planning (ERP) system, the intelligent management system for warehouse materials based on the IoT technology consists of three parts: RFID middleware, Wi-Fi indoor positioning subsystem, and warehouse management system (WMS). The WMS system passes the application program interface and ERP system. Integrated in practical

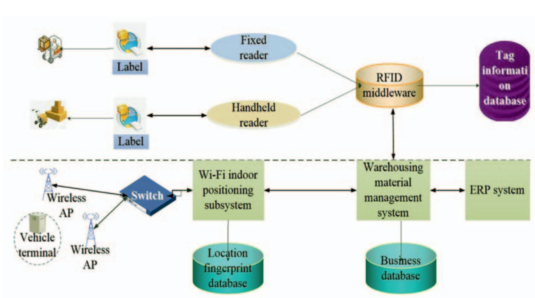

Figure 2. Schematic diagram of the overall system architecture.

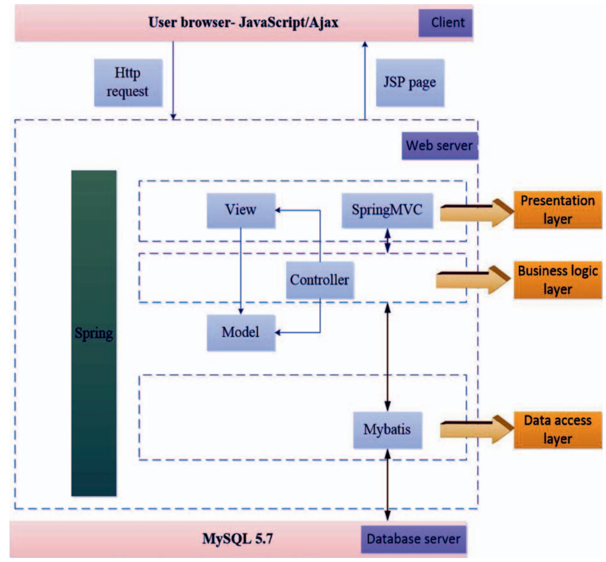

Figure 3. Technical architecture diagram of the warehouse management system.

applications, the system requires support from multiple different databases, such as those for RFID tag information, location fingerprint, and business.

System Technology Architecture

The system technical architecture studied in this paper is shown in Figure 3. The system combines a variety of hardware technologies and software technologies, including hardware tags and readers, network hardware, and vehicle terminals. The software system is designed on the basis of the B/S architecture and is mainly developed using Java enterprise edition technology. The advantage of adopting the B/S architecture is that the system resources can be more fully utilized, the client is only responsible for displaying the user interface, and the complex data calculation and input/output operations are performed by the powerful computing server.

At the same time, the warehouse management system will use the Spring + Spring model-view controller (MVC) + My Batis integration framework, which is based on the MVC pattern. It is a software design paradigm for web application development. The MVC pattern organizes code in a way that separates business logic, information data, and interface presentation from each other. In this mode, the business logic is encapsulated by components, so that the coding of the business logic part is not affected by the interface and user interaction code changes, which ensures the independence of business logic, information data, and interface display.

RFID Middleware Architecture

The RFID middleware is divided into four parts: device manager, event processor, control center, and gateway. Each part can operate independently and cooperate with each other to realize the function of RFID middleware.

The hardware manager is responsible for managing and controlling the behavior of the hardware device. By sending control information, the user can implement specific operations such as starting and stopping the RFID reader.

The main function of the event processor is to provide targeted services according to the customized information of the upper application. It structures the information from the hardware manager to make it available to the system and send it to the upper application.

The control center includes two modules: system management and configuration management. The former is responsible for system login, logout, and addition, deletion, and reinspection of information. The latter is responsible for the specific operation of the hardware manager and event handler.

Location Fingerprint Library Construction

In view of the uncertainty of received signal strength indicator (RSSI) caused by a complex indoor environment, this paper adopts a data preprocessing scheme that uses residuals to remove coarse errors.

When the RSSI is collected during the offline sampling phase, the scene layout, personnel movement, and changes in temperature and humidity will cause the collected RSSI to be unstable, so that the RSSI detected at the same location tends to fluctuate around a fixed value, and occasionally a data value with a large deviation occurs. To build an accurate and reliable location fingerprint database, the collected RSSI values need to be preprocessed to reduce the error before the fingerprints are entered into the database. The RSSI data collected during online positioning are also subject to coarse and random errors, so the same preprocessing is also performed on the RSSI data collected during the online positioning phase.

The coarse error is a large deviation from the true value because of strong pulse interference or environmental abrupt changes, and its most prominent feature is clearly beyond the normal error range. The coarse error has no regularity, and it can seriously affect the positioning accuracy. This paper uses the 3σ criterion and the Grubbs criterion to eliminate this kind of error.

RFID Data Acquisition System Deployment

Three RFID reader antennas are placed on the top, left, and right of the warehouse door to ensure that the goods in the warehouse can be identified by the fixed RFID reader when the goods enter and exit the warehouse. To make new RFID tags and recycle old ones, one desktop RFID reader is required.

A radiofrequency label printer is installed at the entrance of the warehouse, and the corresponding label is produced by the printer when the material without the RFID tag is encountered. Taking into account the cost factor, it is difficult to label each item with a RFID tag, so the materials on the same tray share one label. The material information on the tray is written into the label. The information includes the material code, quantity, supplier, and batch number. The warehouse administrator inputs the quantity, and the label can be recycled and reused after the material is delivered.

One RFID tag is installed on each shelf. The tag stores a number that uniquely identifies this store. The storage label only needs to be installed once, unless the label is damaged or a storage adjustment occurs. The RFID middleware system is configured to interface with the warehouse management information system. If one RFID handheld terminal is configured, the warehouse management personnel can use the terminal to scan and query the detailed information of the materials in the library at any time. An onboard terminal is arranged on the forklift for material positioning to help the forklift driver select the best route to pick up the materials.

DESIGN AND IMPLEMENTATION OF HARDWARE CIRCUIT FOR PORT BULK STORAGE MANAGEMENT SYSTEM

Yard Management System Design

Visual Design of Yard Operations

Transaction processing system (TPS) not only has measurement functions, data calculation, and dynamic deformation monitoring, but also real-time scanning and three-dimensional (3D) reconstruction. Using TPS to scan and 3D reconstruction of the stockpile, the TPS personal computer software can be embedded in the warehouse management system for monitoring the yard visualization. The image video data cable can be connected to a computer via the high-definition multimedia interface connector.

Design of Ground Settlement Observation Circuit

There are many methods for ground settlement observation, most of which are monitored by means of instruments and reference points, such as static load test piles, composite foundation loads, scale visual observation, and fixed rod settlement observations. Here, fixed settler is used because of its output signal type. It has the same output type as the total station, so its transmission line design method is similar.

Stack Temperature Detection

The temperature of the stack is detected by an infrared temperature detector. Infrared temperature measurement works in a noncontact mode and is easy to control automatically. The TN9 infrared temperature sensor is used as the temperature detection point, and four points are distributed around the yard. At the same time, the field data display and temperature value monitoring settings are added in the circuit design process, as shown in Figure 4.

Since the wireless transmission of data circuits using the ZigBee protocol is consistent with the design process in the text, no wireless transmission circuit diagram is given here. The internal temperature of the pile is monitored by the contact temperature sensor DS18B20. The number of monitoring points can be based on the nature and requirements of the specific material.

Silo Management System Design

The hardware circuit structure of the silo management system is in the specific circuit design. The temperature measurement circuit is consistent with the above design circuit. Here, the flammable gas concentration detection and humidity monitoring circuit is given, and the MQ-2 gas sensor is used to monitor the sensor. The MQ-2 gas sensor is ideal for the detection of methane, hydrogen, natural gas, and other combustible vapors. Its output signal is 0-5V analog. The SHT10 temperature and humidity sensor is used to monitor the internal air humidity of the silo. The circuit is shown in Figure 5.

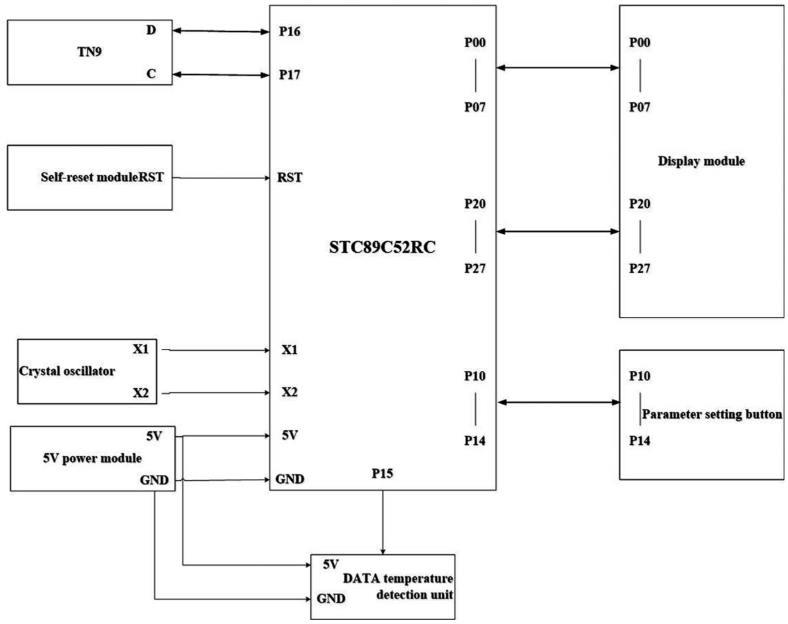

Figure 4. Stack temperature monitoring circuit.

CONCLUSIONS

Modern warehousing companies pay more attention to the four requirements of efficiency, speed, precision, and safety. However, with traditional warehousing methods it is difficult to meet such development needs, and the development of IoT technology has provided reliable technical support for improving the research of traditional warehousing. The hardware circuit designed in this paper is a good application of IoT technology in port storage management. It can realize automatic monitoring and processing feedback of various signals to the IoT port information platform. This not only improves the automation of the WMS, but also expands the ideas for the application of the IoT in port technology, enriches the logistics information, and achieves the real-time monitoring technical indicators of the IoT. The system designed in this paper not only provides warehouse management data for port companies, but also provides warehousing information for downstream logistics.

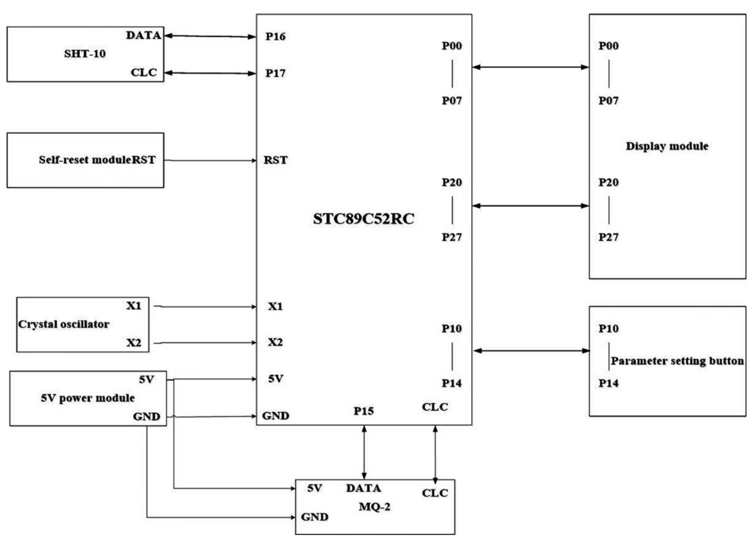

Figure 5. Combustible gas and humidity monitoring circuit.

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