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A RFID-based Material Tracking Information System

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Abstract **-** Radio Frequency Identification (RFID) is the next generation wireless communication technology applicable to various areas. For the beneficial features of RFID, we integrate RFID readers into the Material Tracking Information System. In this paper, we propose the function and solution architecture for the system. Two methods for the client application to communicate with the RFID readers are introduced, one of which is to build a RFID middleware server. The design of the RFID middleware is discussed. RFID reader and back-end database both help to automatically record and store the circulation history and current status of a tracked object, and they cooperate to synchronize the information flow and material flow. Prototypical intelligent RFID guided vehicle used in the warehouse is presented in the paper. Then the flowchart for one tracking subsystem is given and web server is built to provide convenient verbal and graphic interface for tracking.

Key Words – Material Tracking， RFID，Back-end Database

I. INTRODUCTION

Radio Frequency Identification (RFID) is the next generation wireless communication technology applicable to various areas such as distribution, circulation, transportation, tracing and tracking, etc. RFID is a non-contact technology that identifies objects attached with tags. RFID readers obtain the information of objects and surroundings through communication with tag antennas. Reader and tags can communicate in a wireless way. RFID can also identify mobile objects of high speed. And it can identify a certain amount of Tags simultaneously by its anti-collision mechanism. RFID is thought to be highly automatic.

Nowadays, low-cost RFID has been attracting more and more interests from both industry and academic institutes. [1] It has gained wide range adaptation for low-cost and ubiquitous computing applications, such as location tracking, access control and environmental conditions monitoring. In supply chain management, RFID tags are used throughout the supply chain to track products, from supplier delivery, to warehouse stock and point of sale. A RFID system consists of three parts: radio frequency (RF) tags, RF tag readers and the back-end database that associates records with tag data collected by readers. RF tags consist of a microcontroller, an antenna (either wire or printed using conductive carbon ink), and polymer-encapsulating material that wraps around the antenna and the chip. Readers interrogate tags for their contents through RF antenna and interface to back-end databases for more functionalities.

RFID, as an automatic technique of identification, is increasingly being used to identify and track objects through supply chain in industries and manufacturing process. Many manufacturing enterprises, are taking advanced technologies to ensure its ordered and correct product procedures.

To ensure the product quality, the raw material is required to be not mixed with another batch that does not belong to the same class. As a matter of fact, raw material has to be processed, packaged, labeled, preserved in the warehouse or in the temporary warehouse, transported to the workshop and produced into semifinished product. And the workers have to check the labels attached to the raw material packages at every procedure so as to minimize or diminish the errors and avoid product and band accident or loss. Nowadays, in most manufacturing enterprises, all of these procedures are finished manually. But errors are likely to occur for the workers are easily bothered or interfered by mood, spirit, and tiredness, etc. Once raw materials of different classes are mixed together, for instance, the excellent one is mixed with a passed or inferior one, the whole excellent batch will be polluted or degraded, which is not what the enterprise and its customers expect.

RFID, as an attractive and relatively effective technology, is widely and successfully used in manufacturing process. So we want to apply RFID technology to solve this special problem. We built up a distributed client/server architecture which can be used by the administration department of the product plan, the raw material workshop, the warehouse management department, and the semifinished product workshop and other department related with material or product circulation. In addition, browser/server architecture works as an additional solution. Automatic identification and material tracking are adopted to ensure the purity of the raw material batch and trace and track materials or products of different classes.

This paper is organized as follows. The architecture of the material tracking information system (MTIS) is firstly proposed in section II. Then our detailed design and implementation are introduced in section III. In this section, two kinds of methods for data gathering are stated. Then, how to integrate the RFID reader, database and application is presented and the tracking mechanism is detailed.

II. ARCHITECTURE

In order to realize the system at a lower cost and compatible with existed intranet and database, we build the system as 3-level client/server architecture. MTIS is a system which is composed by tags, fixed readers, portable readers, workstations, a certain mount of application severs, a RFID middleware server, a web server and a database server which are distributed in different places. Fig. 1 is the diagram of MTIS with RFID technologies for a manufacturing enterprise.

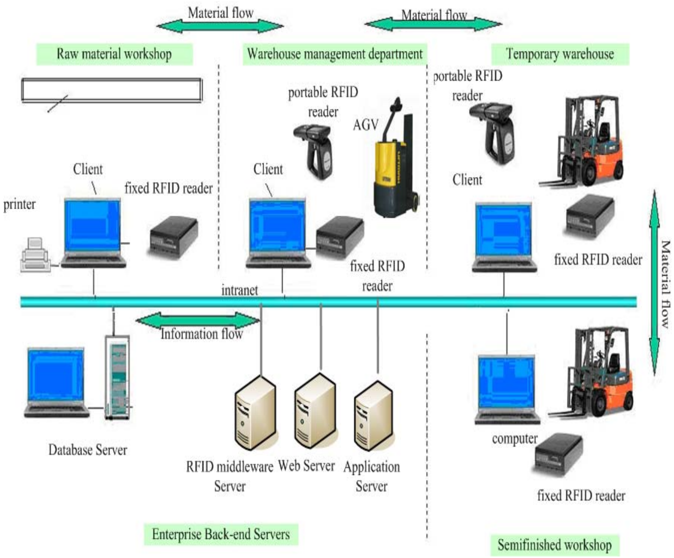

Fig. 1 Material Tracking Information System for Manufacturing Enterprises.

To satisfy different demands of different departments, we design six main subsystems. They are as follows:

Raw material subsystem: It is employed in the raw material workshop. The program reads the product plan, and gathers the related data such as the net of each package full of raw material, the current date and so on. After the raw material is processed(e.g. cleaned, weighed or checked) and packaged, the program write necessary data into the tag, and the processing record is also conserved into the back-end database. The rack location, scheduled by the application server, is also written into to the tags to guide the forklift to place the packaged material in the right rack location.

Warehouse monitoring subsystem: It is used in the warehouse. When the forklift goes through the gate-in, the reader reads the tags on the forklift, and then the identification information is passed to the subsystem by RFID middleware server. If the packages on the forklift belong to the same batch, the subsystem will give "passed" signal, the scheduled place for the coming packages and update the current status of the tracked material in the database. Otherwise, an alert message will be displayed and human interference is needed to ensure the purity of the batch. A RFID-guided Vehicle will place the package in the right position. And the warehouse administrator can check the tag information by portable RFID reader. At the gate-out, the similar procedure is designed.

Temporary warehouse subsystem: The function of this subsystem is like that of the warehouse monitoring one, but they work at different places.

Semifinished product subsystem: This is deployed in the semifinished product workshop. It checks whether the materials belong to the same batch, and then give a passed or alert signal. If necessary, human interference will help to adjust.

Material tracking subsystem: It provides users a query interface in text and graph. The concerned material attached with tag will be located and traced in graphic user interface.

System administration subsystem: This module is in charge of initialization configuration, authorization administration, product plan administration etc.

The MTIS can provide automatic check and material tracking in every related department of manufacturing enterprise. Fig. 2 shows the solution architecture.

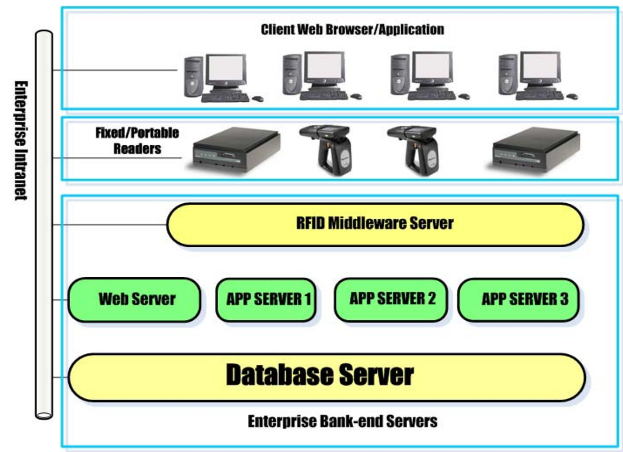

Fig. 2 Solution Architecture of MTIS

To use RFID in our system, our application should communicate with hardware device, not with an application. So something is indispensable to interpret requests and responses by the control of hardware between RFID devices and user application software. General RFID system consists of devices, application and middleware. [2][3][4] To ensure the system robustness, the backup solution works if the RFID middleware server fails. We design extra program to connect RFID readers to the client application not via middleware server but by calling the functions of the native dynamic link library.

III. Design And Implementation

In this section, the main design and implementation of MTIS will be discussed.

A. Communication Between Application and RFID Readers

There are four types of RFID devices in terms of working frequency. The operation of RFID is regulated by local government which controls electromagnetic spectrum resource. Most RFID devices work in Industrial-Scientific-Medical bands which are freely available for use by low-power, short-range systems. Table I shows the features of the four types of RFID devices.

Tags of 915MHz can not be read through most materials, and the working environment of manufacturing enterprises is relatively complex, so RFID devices of 915Mhz are not suitable to be used for tracking objects in manufacturing enterprises. If the processing speed and spectrum permitted region are taken into account, RFID readers of 13.56MHz is the most suitable one.

In our work, the modules of the fixed RFID readers we select are the S6500 Long Range Reader Modules made by Texas Instruments (TI) which can handle all RF and digital functions required in order to communicate with **Tag-it™** HF,

Tag-it™ HF-I (ISO 15693 compliant) and all other ISO 15693 compliant transponder from various suppliers. [5] We use two methods to communicate with the readers.

TABLE I
DEFERENT FEATURES CONTRAST OF RFID DEVICES

	LF	HF		UHF	Microwave
Frequency	125-34KHz	13.56MHz	JM13.56MHz	868-915MHz	2.45-5.8G Hz
Communication range	1.2m	1.2m	1.2m	4m(USA)	15m （USA）
Processing speed	slow	moderate	very fast	fast	very fast
Directionality	free	free	free	partly limited	limited
Spectrum permitted region	Global	Global	Global	EU, USA	Non-EU countries
ISO standards supported	11784/85, 14223	18000-3.1/14 443	18000-3/2 15693,A,B,C	EPC C0,C1,C2 G2	18000-4
Applied area	safety check，gas，laundry	library，product tracking	post，medicine，tobacco	shelf，truck or trailer tracking	toll gate, container

One is that the application software on the client computer communicates with S6500 reader by calling functions of native dynamic link library. TI provides program libraries, feisc.dll and fecom.dll, which help to integrate RFID reader into MTIS and support the functionality of the reader. The fecom.dll supports the serial interface communication. Together with fecom.dll, feisc.dll makes it possible to run all the protocols of the reader.

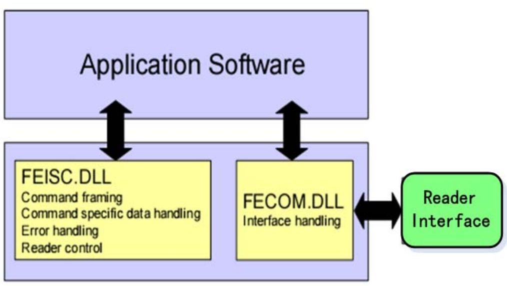

Fig. 3 Application serial interface communication

The client application is written with Visual C++ on the Microsoft Windows platform, so we copy feisc.dll and fecom.dll into the Windows system directory, feisc.lib and fecom.lib into the project or LIB directory, and feisc.h and fecom.h into the project or INCLUDE directory [6]. When the application works, it open the serial port and initialize communication parameters, then it creates a reader object which can control the reader and gather data from it.

The other is that we set a RFID middleware sever to link the readers and client applications. The above dynamic link library files(fecom.dll and feisc.dll) are written with Microsoft Foundation Classes, and JavaBeans is a good choice to design middleware, so we decide to use java by calling native methods which are written with visual C++ and accord to Java Native Interface(JNI) standard. And these native methods can directly use dynamic link library files (fecom.dll and feisec.dll). The RFID middleware is based on three components: reader interface component, event management component, application management component.

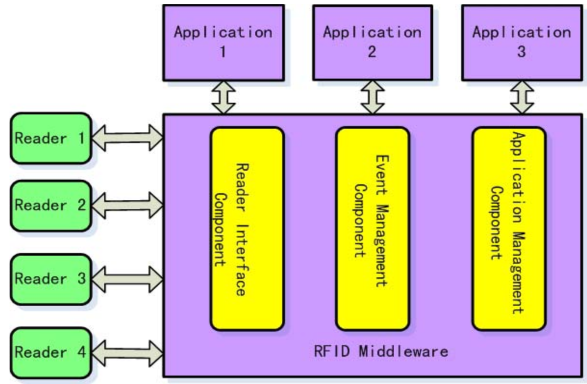

Fig. 4 RFID Middleware

Reader interface component should support many types of RFID Devices, and it should be component-oriented and provide uniform function interfaces. Reader interface component is composed of reader profile, protocol processor, connection management, event generator. Reader profile manages the data on the registration of the readers deployed. Protocol processor functions like protocol interpreter between different readers and middleware. Connection management helps to ensure that RFID middleware access to a certain reader via network by the interface of RS232 or TCP/IP. Event generator defines different status of each tag and different events that are generated when the status of a tag changes.

Event management component performs filtering, aggregation, and routing events generated by reader interface component, and then transmits the event message to the connected application.

Application interface offers interfaces to the applications so that they can control RFID readers and access data from them. This component listens and receives requests from application by communication protocols such as Web-Services and XML-RPC, analyses the order and then passes it to reader interface component. The reader interface component sends it to the reader and then passes the returned message to the application who called service.

Applications communicate with RFID readers via RFID middleware server, which can support distributed and networked application. And it enables heterogeneous RFID readers from different vendors to work uniformly, and makes the application independent from specific hardware and language environment.

Portable RFID readers are adopted to read and check the information stored in the tags. Portable RFID device is composed by RFID reader module and smart terminal. They communicate by RS232 or other interface.

B. Synchronization of Information Flow and Material flow

Modern logistic management requires that the material flow should be recorded in the information system so as to be synchronously fused with the information flow. Material flow is the most important activity for manufacturing enterprise.

Now RFID can identify the specific material, and is able to connect the material and information flow.

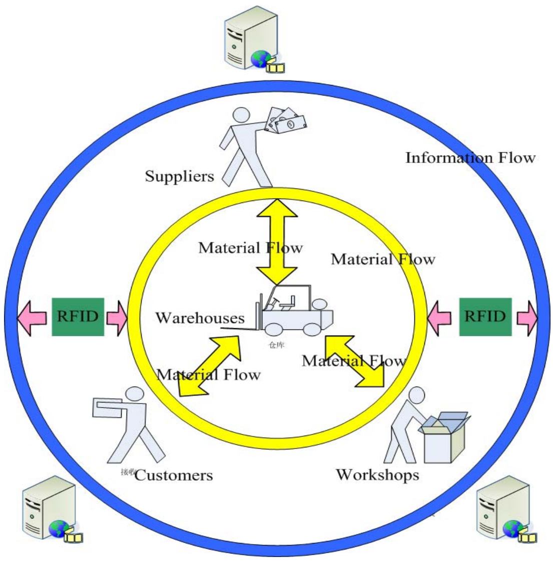

Fig. 5 Synchronous Fusion of Material and Information Flows

To track the tags and objects that are attached by tags, we must record their circulation history, which aims to synchronize the material flow with information flow. In MTIS, we design three important tables that are closely connected with their circulation history and current status. These tables are Tags, Tracked Materials, Operation-History. Information flow is strictly synchronized with Material flow. As for the tracking information that Electronic Product Code (EPC) can not include but the users concern, we can utilize the rest memory of the tag, for EPC needs 64, 96, or 256 bits and there may be memory left available for tracking or other specific use. While the tracked materials are transported, processed, the information system will store these real-time changes on location and time, etc.

To balance the network workload and make updating and maintenance more convenient, we set an independent database server. As is shown in fig. 2, database server works at the data layer of the 3-level client/server architecture, and browser/server is also available.

C. *Intelligent RFID Guided Vehicle in the Warehouse*

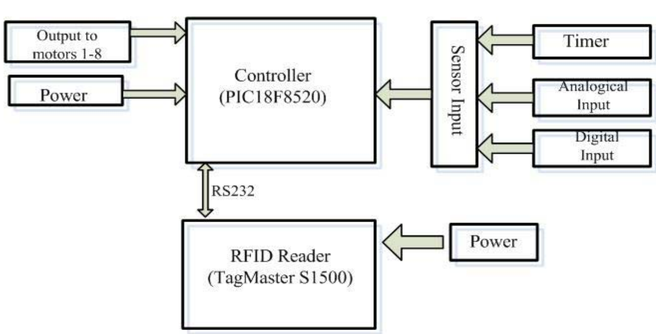

Fig. 6 RFID Guided Vehicle

RFID can also be used to guide the robot, we design a prototypical RFID guided vehicle (RGV) to transport the material in the warehouse. RFID reader is used as a sensor which can communicate with the main controller.

RFID tags are orderly deployed on the ground of the warehouse. As is shown in fig. 6, the main controller can output different motor control orders such as to move forward, backward, stop, turn left, or turn right according to the acquired unique serial number of the tag along the vehicle's moving direction.

D. *Material Tracking*

When the object to be tracked is attached with a tag, the basic information on the package is stored both in the tag and in the back-end database. In the system, we offer two methods to tracking the objects and tags. One is that the MTIS will give an alert message when the packages of different classes or batches are mixed or placed together going through the RFID readers' reading zone. The other is that client web browser can trace the circulation record and current status of objects and tags in verbal and graphic user interface.

i) automatic check procedure

The fixed reader gets the serial number of a tag, and the application gets the number via RFID middleware server or the dynamic link library interface. Then the application queries the related information such as batch number from the back-end database. If all the packages on the container have the same batch number, the application displays a passed message on the client screen, or else an alert message is given. In our research, we find that in a manufacturing enterprise that every batch consists of 65 packages. The passing rule is that packages of one batch or the rest packages of one batch and the packages of another batch are permitted. And the warehouse monitoring subsystem works according to the flowchart in fig 7.

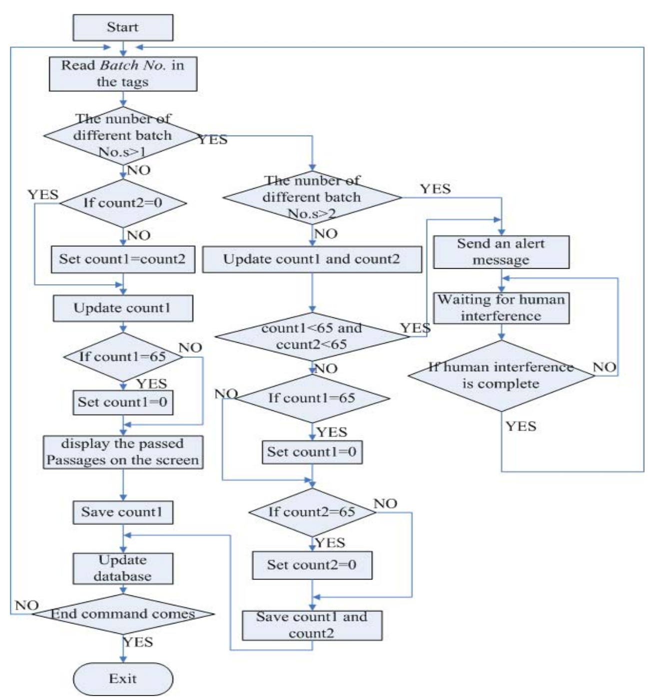

Fig. 7 Flowchart of warehouse monitoring subsystem

ii) graphic user interface for tracking

A Web service is an interface that describes a collection of operations that are network accessible through standardized XML messaging. The interface hides the implementation details of the service, allowing it to be used independently of the hardware or software platform on which it is implemented and also independently of the development language [7].In addition, some smart terminals have not installed application software but a web browser. In MTIS, not only client application but also portable RFID reader devices need to track the tags and object materials. So we build a web server to offer graphic interface.

RFID reader can easily get the unique serial number of the tag; the web server can query detailed information on its history, current status and position. This information can be transmitted and displayed in web browser. We plan to combine this verbal information with the picture of the enterprise map. So the user can get a visual result of the tags and objects concerned. For instance, the concerned tag and package will be highlighted in the map. The packages of the same batch will be displayed in the same color, so if there are more than one kinds of color shown in one closed area, there may be an error and more attention should be paid.

IV. CONCLUSION

This paper puts forward a solution of material tracking information system that integrates RFID readers, database and application. It can be used in most manufacturing and circulation enterprises. And our future work is to construct a public RFID service platform, which can support different technologies such as bar code and sensors and be shared by different types of enterprises along the supply chain.

ACKNOWLEDGMENT

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