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Positioning of Logistics Based on RFID and Integrated Sharing System

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Abstract

As logistics system becomes more complex, identifying and tracking a certain product or pallet in the whole process based on RFID in a real-time manner has played an important role. This study is focusing on identification, locating, tracking and dynamic management on logistics by using RFID technology. Firstly, an innovative scheme for the identification of an individual physical object through Web service is proposed. Then, an anti-collision framed slotted Aloha algorithm for the multiple tags simultaneously sensing is discussed. In addition, a selection sequence optimizing model via RFID technology is developed, and numerical analysis is made to explain the model. Finally, an RFID-based framework of dynamic logistics management system is put forward in order to realize logistics processes automatically verified and operation optimized.

Keywords: *RFID, tracking, positioning, dynamic sharing*

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1. Introduction

Supply chain logistics is the control and management of the process involving supply, demand, raw material procurement, production, inventory, distribution and other activities. To realize management optimization, various activities happened in this process require timely and adequate information. As to existing supply chain activities, however, due to bullwhip effect and high inventory caused by invalid information and inefficient asymmetric sharing mechanism. Therefore, effective identification and real-time management of logistics information throughout the whole process is more favorable and tends to improve effectiveness and validness of opertaions.

RFID, namely Radio Frequency Identification, is a non-contact technology for automatic identification, data collection and tracking of products. Traditional RFID is composed of three parts which includes Tag, Reader and Application system (Application Interface, Transmission network, Business applications and management system). When tags of product are exposed to reader magnetic field, it will receive RF signal emitted by the reader through energy produced by induced current to send the product information stored in the tag chip (Passive tags) or take the initiative to send a signal (Active tags). After reading and decoding the information you get, it will be sent to application system for data processing [1]. Compared with the traditional bar code technology, RFID can dynamically identify fast moving objects even a number of electronic tags at the same time, thus adapting to a variety of environments. Logistics process based on RFID includes identification, tracking and positioning, real-time storage, distribution, sales, handling return and after-sales service. Through application of RFID technology, data flow of activities throughout the supply chain can be obtained, which enhance accuracy of information transmission along supply chain and supply chain management transparency so as to realize increase of distribution turnover rate and reduction in logistics costs [2]. In the context of inventory storage and distribution process, in this study, i the supply chain logistics operation processes based on RFID technology which focuses on automatic recognition algorithm of multi-tag information and goods identification method based on Web services technology are analyzed, and then a distribution model to track the locations is established, and finally dynamic real-time supply chain logistics management system architecture that is mainly used for exchange of supply chain logistics information based on

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RFID technology is developed in order to arrive at dynamic visualization and sharing of supply chain logistics information as well as efficient logistics operations.

2. Analysis of Logistics Operation Process based on RFID
2.1. Invetory Storage Process based on RFID

In the process of warehouse management, when RFID tags attached to pallets or containers are located within RFID reader magnetic induction region, the RFID reader will automatically capture information from tag code and transmit it to the warehouse management system (WMS). For example, a hybrid-product (SKUS) tray is equipped with multiple products, and all the information of these products can be read into tags through the reader. And next, systems enable to make arrangements for the storage locations in accordance with cargo information and inventory records as well as goods storage distances. In storage process, through the application of automatic anti-collision function of RFID identification system, a number of different tags can be read and products can be traced, which ensures the goods have been placed at their right places, warehouse operation processes have been adjusted, inventory turns has been effectively controled.

2.2. Distribution and Selection based on RFID

An RFID tag will be installed on each cargo in warehouse of distribution center, besides; cargo or handling forklift will be bundled with RFID and then entered into the database. The entrance to the warehouse is installed with RFID reader and the information of RFID tags can be captured and transmitted to WMS and finally arrangement for the storage location by the system in accordance with cargo information. Selection area of warehouse requires being installed with identification systems, the information of selected goods will be read or written into RFID tags of turnover box or forklift which is connected with WMS. When sorting the cargo, automatic double check of delivery cargo from warehouses can be complete [3-4]. Forklift RFID recognition system will recognize the RFID tags carried on the tray so as to locate and track them in accordance with the information.

2.3. Replenishment based on RFID

In RFID supply chain inventory management system, by virtue of identifying the electronic tags, inventories of raw materials and parts enables to be counted so as to determine when and how much of replenishment are needed. By use of information sharing platform, production suppliers can accurately understand detailed needs of the customer and timely identify and trace raw materials, components or semi-finished and finished goods through RFID production systems so as to keep abreast of the progress of production, enhance the quality of tracking and monitoring and achieve rapid and timely as well as accurate replenishment. In addition, RFID technology can be applied in procurement, transportation, retail and other sectors, in order to realize vehicles configuration determine the possible optimal routes. What's more, electronic tags directly reflect the types and quantity of consumer demand which makes supply chain operations highly visual and feasible. Each node enterprise enables to master the most accurate demand trends and reliable forecasts, leading to optimal supply chain logistics operation and effective decision-making.

3. Identification of Logistics Information based on RFID

Supply chain logistics operation is composed of a variety of links throughout upstream to downstream, regardless of which, logistics information such as inventory information, sorting and distribution information need to be firstly identified. Therefore it can be said that the identification of logistics information is the first priority throughout the entire supply chain. Currently, there is a variety of goods identification technologies like the Universal Product Code (UPC, also known as bar code), Electronic Product Code (EPC), etc. Among them, the bar code is a serial number of 12 digits or characters which is combination of different width of bars and spaces according to encoding rules translated by a bar code reading device. Bar codes greatly improve the speed and efficiency of acquisition of information of goods and items and enhance the level of supply chain management, however, there are some defects cannot be overcome, such as reading only one tag at a time, limited amount of data, poor adaptability to environment, the same goods with the same bar code, which limit the efficiency of the supply chain. While RFID technology overcome the shortcomings of the bar code and provide more effective technical support for the effective positioning and identification of the products and real-time visualization management.

3.1. Access to Information in Logistics System

Supply chain system is a distributed system, the product information on the supply chain can be accessed at any time, any place when the location of product information server with RFID tags is known and relevant access rights are recognized. However, the technology needs to have the product information mapped into the address of the server. The usual method is to use the ownership mechanism in application (such as directory services, database queries, product name services, etc.) [5]. This approach often results the difficulties in software development, promotion, maintenance and permission to use, which leads to time-consuming, laborious and inconvenient when access to information.

This paper presents a finite-bit character encoding method to identify the object, and by use of the method, products of supply chain can be uniquely identified. Through the Internet and web services technology, at any time and place, the information which identifies the object tag can be directly read from a designated server which is specified by IP address stored in the code [6]. Product identification method based on web services involves with a start bit part and a data part. Data part is composed of two basic structures: One is unique identifier of tag items; the other one is specific server's IP (Internet protocol) address which is defined as “start bit+IP address item ID”. In which, EPC can be used as item identification code composed of 96-bit character including a 8-bit characters of starting part and three sets of data section. Among the three sets, one is identifier of manufactures, one for identifier of the type of product, and another one for serial number of given type of product, for example:

02.0006A66.56271F.0003476AB
8 bits.28 bits.24 bits.36 bits
Header. Enterprise. Product. Serial Number

In this way, product code based on web services can be defined as:

02.IP.0006A66.56271F.0003476AB
8 bits.IP.28 bits.24 bits.36 bits
Header. IP Address. Enterprise. Product. Serial Number.

Through the way of identification mentioned above, as to supply chain information management system with Web service functions, if the Web server's address is known, SOAP can be used as the communication protocol between the user and the specified server which allows the application sending an XML message to another application. Therefore, the information in the tag indentified can be transmitted through Internet and RFID tags can be read through computer network and then information will be obtained and immediately displayed on the screen. The following program is for request-response after SOAP sents a message to the server:

```
<soap:Envelope xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
  <soap:Body>
     <GetAItemFromList xmlns="http://tempuri.org/">
     <aCode>string</aCode>
     </GetAItemFromList>
   </soap:Body>
</soap:Envelope>
<soap:Envelope xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
     xmlns:xsd="http://www.w3.org/2001/XMLSchema"
     xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
   <soap:Body>
```

```
        <GetAItemFromListResponse xmlns="http://tempuri.org/">
        <GetAItemFromListResult>
        <Code>string</Code>
        <CompanyName>string</CompanyName>
        <Product>string</Product >
         <ObjectSerialNumber>string</ObjectSerialNumber>
        </GetAItemFromListResult>
        </GetAItemFromListResponse>
   </soap:Body>
</soap:Envelope>
```


Assuming that the Web server's IP address is 202.120.148.1, the process of server to accept the tag information can be programmed as:


```
 <?xml version="1.0" encoding="utf-8" ?>
<Item xmlns:xsd=http://www.w3.org/2001/XMLSchema
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://tempuri.org/">
      <Code>02. 202.120.148.1.0006A66.56271F.0003476AB </Code>
      <IP>202.120.148.1</IP>
      <CompanyName>Donghua Company </CompanyName>
      <Product>Apparel </Product>
      <ObjectSerialNumber>1234</ObjectSerialNumber>
  </Item>
```


Goods identification method based on Web services enable to realize information of the supply chain logistics operation can be obtained directly from a specified server. The method of identification and access to product information does not rely on special or specialized hardware and software, the information server can be located anywhere in the supply chain network, and the product information can be read in the RFID tag through the network so as to realize products identification and information sharing.

3.2. Multi-tag Information Identification in Logistics System

Due to the fact that similar RFID tags work under the same frequency, so when multiple similar products with RFID tags are located within work scope of the reader, tags will send the same signal to the reader and will inevitably cause interference with each other, resulting in tags information collision that the tag information cannot be correctly identified[7-8]. For this reason, we conduct a research on algorithm called dynamic frame slotted ALOHA which dynamically adjust the frame length according to the actual number of tags and maximize average throughput of the signaling pathway, to prevent the collision of the tag information and realize automatic identification and access to information through quickly and successfully reading multiple tags.

3.2.1. Anti-collision Dynamic Frame Slotted Working Mechanism

When a tag with a serial number (UID) is placed in magnetic induction region, the reader will send anti-collision UID number of instructions, and all tags response to return the UID number. If the reader does not receive any signal shows that goods are not tagged in the induction area.

If the reader receives one complete UID signal, which means there is only one tag in induction region and no collision happens; If the reader receives the return signal of the tag but return signal cannot pass through signal calibration, which means and there happens a collision and the reader should continue with the anti-collision recognition.

One frame comprises a certain number of time slots and data stored in tag is sent at one of time slots. Firstly, the initial number of time slots is set and a slot collision probability p can be calculated in accordance with the maximum throughput of the system. And then collision number of tags can be estimated based on collision probability, namely the number of tags that failed to be identified.

3.2.2. Multi-tag Identification Model

Assuming that the number of time slots is s (length of frame), the number of tags within a certain time slot is q and the number of tags not identified is n, then the probability that all the q tags choose the same response time slot follows binomial distribution, as follows (1):

$$P(q) = (nq)(\frac{1}{s})^{q}(1-\frac{1}{s})^{n-q} \tag{1}$$

The probability that all q tags choose the same response time slot can be calculated, and mathematical expectation should be:

$$E = s \times (nq)(\frac{1}{s})^{q}(1-\frac{1}{s})^{n-q} \tag{2}$$

Step 1: When q=0, it is called empty time slot that there is no tags within magnetic induction area of reader. The mathematical expectation of the probability is s_0:

$$s_0 = s \times (\frac{1}{s})^{0}(1-\frac{1}{s})^{n} = s \times (1-\frac{1}{s})^{n} \tag{3}$$

Step 2: When q=1, it is called identification time slot that there is no collision within a time slot and the data has been sent successfully. The mathematical expectation of the probability is s_1:

$$s_1 = s \times n \times (\frac{1}{s})(1-\frac{1}{s})^{n-1} = n \times (1-\frac{1}{s})^{n-1} \tag{4}$$

Step 3: When q≥2, it is called collision time slot that more than one tag send data at a time slot and they cannot be identified. The mathematical expectation of the probability can be denoted by s_n:

$$s_n = s - s_0 - s_1 \tag{5}$$

We can further calculate the tag identification rate:

$$\beta = \frac{s_1}{s} \tag{6}$$

After reading each tag, we enable to properly estimate the number of tags that identified and not identified according to the (3), (4) and (5) and dynamically adjust the frame length so as to maximize the throughput of the information pathway as well as automatic identification rate of multi-tag.

4. Tracking and Positioning Optimization Model of Logistics System based on RFID

After automatically products information in supply chain system is identified and accessed an important part is how to use the information to track location of the supply chain logistics activities to support the optimization of supply chain processes. In the context of logistics selection process, we explore the selection of route selection and positioning method. As a major component of logistics, the rational design and configuration of the process for the selection of goods is essential. The application of the method in this section can provide uninterrupted delivery of goods location information to support the identification and tracking of all items, enhancing distribution plan to improve the turnover of the distribution center, distribution capacity, reducing distribution costs, improving the modern logistics and distribution management efficiency.

4.1. Tracking and Positioning Optimization Model

In supply chain logistics system based on RFID, goods are selected, located and tracked, and their determinants are selection distance and selection sequence, repectively [9-10]. We define selection distance as the distance shuttling among different warehouses to pick up goods due to the different types of goods and locations. Selection sequence refers to selection of different goods according to order. Goods information and position information stored in warehouse can be read by several readers placed in warehouse and then sent to supply chain logistics real-time management system based on RFID. When implementing selection, the information can be sent to handling equipment (such as forklifts) that equipped with a RFID device [11-12].

Assuming the location information of goods and selection of handling equipment can be represented by coordinate data. Setting goods to be chosen as p, and its position coordinates in the warehouse is $p_i(p_{ix}, p_{iy})$; Forklift can be represented as f and coordinate is $f(f_x, f_y)$; Warehouse roadway can be represented a_i; The distance between goods p_i and p_j can be denoted as $d_{pi,j}$, and the mathematical model of minimal moving distance of goods selection is as follows:

$$Min \quad s = \sum_i \sum_j d_{p_{i,j}} x_{i,j} \tag{7}$$

$$x_{i,j} = \begin{cases} 1 \\ 0 \end{cases}$$ When forklift or other equipment i pick item j, $x_{i,j}$ is otherwise 0.

$$d_{p_{i,j}} = d(p_{ix}, p_{jx}) + \min \begin{Bmatrix} d(p_{iy}, a_{1y}) + d(a_{1y}, p_{jy}) \\ d(p_{iy}, a_{2y}) + d(a_{2y}, p_{jy}) \\ d(p_{iy}, a_{3y}) + d(a_{3y}, p_{jy}) \end{Bmatrix} \tag{8}$$

Where $\sum_i x_{i,j} = 1, \quad j = 1,2,3$

The result calculated from the model is the shortest moving distance in selection process and thus selection sequence can be obtained. In this process, through reading selection and handling information by the RFID system, selection, tracking, verification of goods and access to real-time location can be realized so as to achieve the correct positioning of the distribution.

4.2. Numerical Simulation

Assuming there are three warehouse roadways in distribution center, their lengths are a_1=180m, a_2=100m, a_3=75m, respectively. An order requires selecting three kinds of goods, their locations are p_1 (95,120), p_2 (46, 82), p_3 (68, 60), respectively. Initial position of the forklift f is f (45, 10). Initial positions of goods and forklift as well as road network are shown in Figure 1; meanwhile, all possible routes can be obtained:

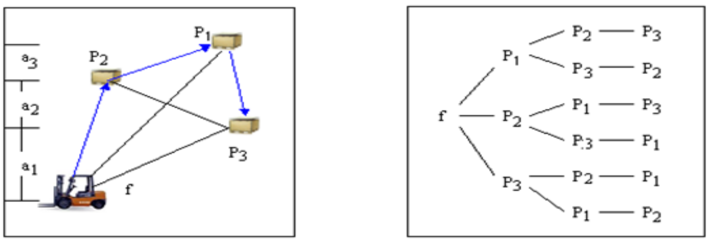

Figure 1. Route Network and Possible Routes

First, calculate the distance from p_1 to p_2 by the formula (8).

$$d_{p_{1,2}} = d(p_{1x}, p_{2x}) + \min\{d(p_{1y}, a_{iy}) + d(a_{iy}, p_{2y})\} \quad i = 1,2,3 \tag{9}$$

Substituting distances that forklift moves through three different roadways into formula (9), we get the shortest distance from p_1 to p_2:

$$d_{p_{1,2}} = (95-46) + \min\begin{Bmatrix} d(p_{1y}, a_{1y}) + d(a_{1y}, p_{2y}) \\ d(p_{1y}, a_{2y}) + d(a_{2y}, p_{2y}) \\ d(p_{1y}, a_{3y}) + d(a_{3y}, p_{2y}) \end{Bmatrix} = 49 + \min\begin{Bmatrix} |120-180| + |180-82| \\ |120-100| + |100-82| \\ |120-75| + |75-82| \end{Bmatrix} = 87 \tag{10}$$

Similarly, we can calculate the distances between products and products as well as the distances between forklifts and products. According to the formula (7), we can obtain all distances of all the selected routes and finally determine optimal route and the order of selection of products.

Table 1. All Selection Routes and Distances

Two-point route	Two-point distance (m)	All routes	Total distance(m)
$f \to p_1$	120	$f \to p_1 \to p_2 \to p_3$	331
$f \to p_2$	33	$f \to p_1 \to p_3 \to p_2$	321
$f \to p_3$	***53***	***$f \to p_2 \to p_1 \to p_3$***	***197***
$p_1 \to p_2$	87	$f \to p_2 \to p_3 \to p_1$	234
$p_2 \to p_3$	124	$f \to p_3 \to p_2 \to p_1$	264
$p_1 \to p_3$	77	$f \to p_3 \to p_1 \to p_2$	217

From the Table1, the optimal route is the shortest one: $f \to p_2 \to p_1 \to p_3$. The sequence of optimal route is that the forklift firstly selects goods p_2 from initial location and then p_1 finally p_3, which complete 197(m). Similarly, if the Logistics Center has multiple handling equipment, such as multiple forklifts, we can determine which device is called to select is optimal according to the initial position of the forklift, thus promoting the optimal allocating decision-making.

5. Integrated Logistics Information System based on RFID

The above method and models used for automatic identification and optimization of selection and positioning in supply chain logistics process is based on RFID integrated supply chain logistics real-time management system, so this section gives the structure of the system and discusses the real-time management methods.

5.1. Integrated Logistics Real-time Management System based on RFID

The integration of real-time management system involving hardware and software which include passive tags, active tags, readers, selection optimization subsystem, inventory management subsystem, data acquisition and processing subsystem as well as servers, etc. It can be categorized as four parts, namely RFID physical layer, data layer, business logic processing layer and presentation layer, shown in the Figure 2.

In Figure 2, the first layer is physical layer. In this layer, the reader is placed on the shelves, forklifts, or turnover box facilities. The reader contains the antenna, which is used to identify and read into RFID tag information, and send it through the Edge Server and RFID middleware to data acquisition and processing subsystems in the second layer for information processing. As for the volume tag information of RFID tag, physical markup language (PML) is used to descript goods, while the ONS to provide location information of the EPC code. When RFID middleware needs to query or save the server network address of goods information, the ONS server provides EPC numbers and EPC information Server control functions.

Typically, assuming that the reader that can set IP address is only controlled by an edge server, the server embeds anti-collision dynamic framed slotted ALOHA algorithm to prevent tag collisions, eliminate duplicate operations and automatically filter reading information. RFID middleware connects the RFID reader hardware module database and application software, through communication with ONS (Object Name Service), to find only RFID tagged ID number and continuously query data from the EPC (electronic product code) database as well as communicate with external systems through the gateway in the firewall.

Layer 2 is called data acquisition and processing layer which is responsible for resolving and processing the raw data collected from the physical layer reader and conformed to the provisions of the agreement, as well as data processing and validation.

Layer 3 is called integrated business logic processing layer, which is mainly responsible for logistics optimization allocation and management. In this layer, picking and positioning optimization model is integrated to optimize route planning and selection order and adjust the distribution process, achieving accurate positioning of goods. Besides, it communicates with order management system, warehouse management system, to check the selection of goods, quantity, SKU and other information, as well as timely review and update inventory information.

Layer 4 is called application presentation layer, which aims at transforming data into a unified data representation format to support management decision-making of corporate executives. Exchange of information can be realized by using XML technology, while Web presentation can be designed through http request-response format. If having RFID tag information, position information displayed or applied in decision-making and statistics report generation, personalized business needs can be done to facilitate the registration, query, and interactive information services.

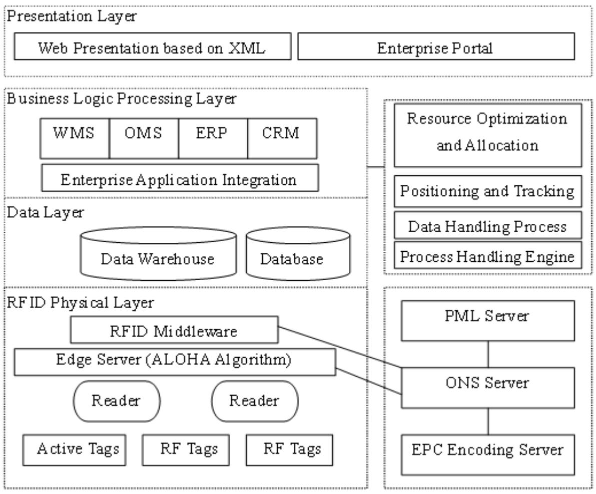

Figure 2. Integrated Real-time Management System Framework based on RFID

5.2. Integrated Logistics Management Workflow based on RFID

In the system shown in Figure 2, the RFID reader placed on the handling equipment (such as forklifts), while RFID passive tag is affixed to each unit of goods, such as crates or pallets of goods, and all tag information is stored in system database. Forklift is equipped with computer terminals and active RFID tags. When forklift is executing picking operations, the order information will be sent via Order Management System (OMS) to the business logic processing subsystem. The subsystem enables to obtain virtual location information of goods requires being selected according to actual position information of goods in warehouse, so as to work out to optimal selecting path and allocation sequence scheme. The program can be displayed in the computer terminal of forklift so as to guide its correct movement. When selecting goods, the forklift reader will read tag information on the carton or pallet of goods as forklifts move. The information like which forklift the selected goods are put in, goods information and the changes of status of movement location can be written to active tags on the forklift, and sent through RFID middleware to the data processing subsystem and business logic processing subsystem. RFID middleware is responsible for collecting and storing EPC information the reader sends and taking corresponding actions like updating data of WMS.

WMS is to decide whether replenishment is needed, if so, the replenishment information will be promptly sent to the suppliers. In this way, the supply chain is to achieve the automatic identification of the logistics of goods, position determination and dynamic tracking and management.

6. Conclusion

In this paper, supply chain logistics operations process model based on RFID is firstly analyzed, and then implementation of dynamic management of application of RFID technology on supply chain logistics operation process is discussed from view of supply chain automatic identification, tracking and positioning and real-time information management. The article uses a limited character encoding method to identify objects, and access and read information that identifies the object tag directly from the server via Web services technology. As for multiple RFID tags into the same range of the reader, through the application of dynamic frame slotted ALOHA anti-collision algorithm, multi-tag identification model which dynamically adjust with the actual number of tags is established to have the average throughput of reading information maximized, so that the RF tags can be read quickly and automatic identification of the product information enables finally be achieved. For selecting and tracking logistics products, an optimization model for selection and positioning is built to calculate the shortest distance of handling in selection process and optimal sequence, to realize reasonable positioning of distribution. Finally, RFID integrated real-time management system framework is put forward for optimization.

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