A Study on the Application of RFID to Container Transportation System

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Abstract  This paper focuses on the extended application of RFID to container transportation systems. Based on an overview of common applications of RFID technology to containers, this paper studied the possibility of RFID applications to container transportation systems. We categorized the application of RFID to container transportation into four hierarchies from the angle of cost and application area. It then analyzed four basic modes of container RFID applications. According to the problems analysis and the actuality of container transportation, several RFID application development trends were deduced.

Key words  RFID, container transportation, application mode

1 Introduction

Radio Frequency Identification (RFID) is a type of automatic identification technology, which has been increasingly adopted since the 1990s. Due to its technical advantages, RFID technology is adopted in many areas, including assets/equipment management, animal tracking and tracing, supply chain/retail management, doorway control, logistics, and transportation, etc., which can be generally categorized into two basic application modes: the closed loop application and the open loop application.

At present, closed loop RFID applications, such as asset management, have drawn more attention in the business circles, due to their relative mature application mode and easy implementations. However, in the areas of supply chain/retail management with more open loop characters, the development trend of RFID application seems to have met many challenges. Despite the leading retailer such as Wal-Mart and Metro have been promoting the adoption of RFID technology in their business networks to improve their supply chain transparency and efficiency and their agility of supply chain management, the absence of sophisticated application modes for open loop applications is thought to be the major reason for this status.

Container transportation systems, the backbone of modern logistics industry, is a typical open loop system with millions of freight containers moving worldwide via multimodal transportation networks. Apart from the research of small scale application (such as solutions for container depots), it is very important to improve the overall efficiency and security of the container transportation system, so as to meet the ever increasing requirements of the logistics service quality provided to the shippers. One of the possible ways of doing so is the adoption of RFID technologies. Therefore, it is necessary to study over this challenging topic.

2 RFID and container transportation system

2.1 RFID technology

The components of an RFID system may differ depending on different RFID applications. However, an RFID system generally consists of three basic modules: the tags, the readers, and the data processors. Its working principle can be explained by Figure 1.

The tag: a non-contact IC card, which can further be divided into two types, the active tag (often with battery as power supply to enhance communication and information process capacities) and the passive tag (often with no power supply). An RFID tag can be attached on an item, carrying its information including its ID information, which can be read and updated by authorized RFID readers.

The reader: a fixed equipment or a handset communicating with RFID tags by reading data carried by them and/or writing new data into them. Communication between reader and tags should conform to certain air interface protocols ratified by certain standardization organizations.

The background PC(s): computer(s) connected with RFID reader(s), to process the information read
from, or to be written into the tags. Certain software interface protocols should be abided by the communication between the PC and the Reader connected to it. If appropriately integrated into the Management Information Systems, the technical predominance of RFID can be well materialized.

Figure 1 Working Principle of a RFID System

Through the comparison of RFID with other currently used auto-identification technologies, showed in Table 1, it is safe to draw the conclusion that is in favor of RFID: RFID has higher accuracy, better acclimatization and anti-jamming capability, also better operation agility.

Table 1 Comparison of Several Common Auto-ID Technologies

<table>
<thead>
<tr>
<th>Auto-ID techs</th>
<th>Main advantages</th>
<th>Main disadvantages</th>
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<tbody>
<tr>
<td>Bar code</td>
<td>Low costs</td>
<td>Easy worn-out,</td>
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<tr>
<td></td>
<td></td>
<td>limited data storage,</td>
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<tr>
<td></td>
<td></td>
<td>invalid in darkness</td>
</tr>
<tr>
<td>Magcard</td>
<td>Low costs</td>
<td>Easy worn-out,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>limited data storage,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>magnetism needs to be maintained</td>
</tr>
<tr>
<td>Contact IC card</td>
<td>Better data storage,</td>
<td>Easy worn-out,</td>
</tr>
<tr>
<td></td>
<td>Better data security</td>
<td>limited data storage,</td>
</tr>
<tr>
<td>RFID tag</td>
<td>Low requirement for working environments,</td>
<td>Comparatively higher costs,</td>
</tr>
<tr>
<td></td>
<td>high accuracy and efficiency</td>
<td></td>
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</table>

2.2 RFID system for container transportation

Technically the RFID tag is a better choice for container identification compared with other technologies, as is manifested in the last section, due to its performance in relative inclement working environments tally with that of freight containers. This provides us with the technical fundamentals for the possible application of such technology in container transportation system.

On the other side, requirement of the overall efficiency improvement for container transportation is concrete as there are several bottle necks within the system, one of which is information management efficiency. Currently bar code and image recognition techniques are widely adopted by container docks/yards/freight stations to identify containers, with manual labor as a supplement. However, due to its capacity and accuracy limitations, the conventional way of container identification has become a bottleneck in the whole container transportation system, in which many related parties’ container operation management have been highly computerized.

The adoption of RFID tags in container transportation system can be divided into four hierarchies shown in Figure 2 depending on different utilization degrees of RFID in each hierarchy. Higher hierarchy needs higher RFID implement costs and difficulties accordingly.
Hierarchy-Ⅰ is the basic application of RFID technology, which system structure is exactly the same as was shown in Figure 1. In this condition RFID tags are utilized as a simple substitute for conventional identification technologies such as bar codes. Apart from basic equipments installations, to implement RFID on this level requires modification on the software interface between RFID system and the PCs connected to it for container identification purpose. For a container terminal or container freight station (CFS), gate operation efficiency could be improved by this level of RFID application.

Hierarchy-Ⅱ integrates the RFID system into the user’s management information system, and some extended functions of RFID can be developed based on its combination with MIS. Take a container terminal again for example: functions such as container storage blocks allocating, containers locating in the yard and other storage operations can be developed.

Hierarchy-Ⅲ requires the cultivation of RFID users’ clusters within the container transportation industry. Through the inter connect (via EDI or certain RFID container information platforms) of the MISs of ports, liner companies and other related parties, more powerful information management coordination can be realized among the RFID users’ clusters. The overall efficiency of container intermodal transportation system is expected to be significantly improved. Using the container RFID tag number as the key information, authorized users can check their containers information such as the location and the logistics operation records of them. Statistics data could also be drawn from the platform or network more easily and accurately.

Hierarchy-Ⅳ is the most advanced application of RFID to container transportation. As the western countries are working on security trade lanes, safety issue is attached top importance to, by top container cargo importer countries such as the US. Smart electronic seals based on RFID technology have been developed to serve as new electronic equipments for container and cargo safety monitoring and data recording. Nevertheless, to run RFID application systems on this hierarchy requires great recognition and the clasp cooperation of all trading countries. If this hierarchy were to be achieved, the customs’ functions could be better performed by introducing “green trade lanes” for those normally operated containers to upgrade the general working efficiency, while carefully inspect those containers with abnormal records in their RFID tags to prevent danger factors.

3 Analysis on the application of RFID to container transportation

3.1 Application modes and development route

In correspondence with the four hierarchies demonstrated above, the application of RFID to container transportation could also be classified into four modes.

3.1.1 Mode one—quasi closed loop application
A container terminal or a container yard (CY) or CFS is more likely to implement this RFID application mode in the first place within the container transport industry. As the container terminal is the most dynamic node full of container logistics activities, the implement of RFID within the terminal or yard could become of substantial benefits include but not limited to the following aspects:

- facilitating gatehouse operations through better container identification efficiency;
- keep improving the container storage management via real-time data updates;
- checking container logistics operations to minimize operation errors.

3.1.2 Mode two—container shipping route application

This mode can come into being only when at least two terminals have implemented RFID systems so that the container shipping routes between the ports can be integrated into their systems, forming lines of RFID application routes. It is expected to bring about the following benefits:

- facilitating the liner companies with their container scheduling and management;
- better container tracking and tracing functions.

3.1.3 Mode three—RFID container application clusters

Based on well implemented RFID within the shipping/port realm, other operators related to container logistics within the multimodal transportation systems can be further integrated into the existing container RFID application clusters. This step is essential to the whole container transportation system’s efficiency improvement since the information of the containers within the clusters can be transmitted efficiently and timely. Information distortion can be eliminated significantly in intermodal container transportation chains.

- satisfying container tracking and tracing functions;
- comprehensive and prompt statistics.

3.1.4 Mode four—comprehensive application

Along with the roll out of RFID application to the container transportation, under proper international standards, the internationally compatible application can be expected in container transportation. This is the ultimate application of container RFID. If it is going to happen in the future, the following extended functions of container RFID system may be realized:

- public container data platform implementation for international customs organization, to monitor the container transportation and international trade security;
- the efficiency perfection of the entire container transportation system.

3.2 Main challenges of container RFID implementation

The roll out of RFID application to container transportation should take steps from the low-grades to high-grades, i.e. from Mode-one to Mode-four as a whole. During this process, many challenges may emerge, just as in any other new technology’s popularizing process. Analyzing the possible challenges to container RFID system, the following aspects are evident:

i. The container RFID tags installation. This issue involves in quite a few problems such as who does this job, what type of tags are suitable and what technical standards are needed for the readers and tags, and the overall cost are unpredictable.

ii. The appropriate application mode selection. Container transportation system is a huge open loop system, in which container flows appear to be stochastic. This makes the control of containers extremely difficult compared to those closed loop assets management applications.

iii. The development of RFID software interface, and the standards to be obeyed. Application software is the crucial element for the success implement of RFID; good RFID applications can fully integrate its technical advantages with the management systems, which can help upgrade the management level greatly.

iv. The technical follow-up with the logistics technical progress. For example, double (even fourfold) trolley container cranes are increasing used in container terminals, how to ensure the container identification remains as a challenging problem for RFID system.

4 Development trends
Based on the analyses in section 3, some deductions are drawn as follows:

Currently, the container transportation industry is still in the elementary stages of its RFID applications. Trial projects similar to Mode-one and Mode-two can be seen within the industry. However, the essential steps towards Mode-three are still to take through the effort of the whole industry. The lower mode’s success is helpful for higher mode’s implement.

The RFID applications to the container transportation are not exactly the same as the RFID applications to the customs requirement. In transportation and logistics realm, information management accuracy and efficiency is more important with a relative low system cost. However, the customs need more security guarantees. This is why the customs are working on smart container e-seals to achieve their goals. Given the gap between the container transportation industry and the customs, it is very likely that two types of RFID applications will coexist: one is logistics tag for the transportation applications, and the other “e-seal”, when necessary, would be added to the exporting container.

So far, for the RFID tags in container transportation field, it seems that the container manufacturer is one of the most suitable parties for container RFID tag installation, for the manufacturer is the source of containers, which has the precedence to gain an economic of scale and technical standards establishment and implement. China now possesses more than 90% of the world’s container manufacture capacity, so there is great potential for China to work on this issue.

The best practice of “e-seal” operation modes are still under discussion. It is difficult for the customs to do this because of the huge workload required. Hence the installment and collection of such devices could be done by some third-party agencies through their global service networks, such as authorized ship classification societies and RFID technical providers or other notary agencies in logistics industry. This could be a business opportunity for such 4PL organizations, if appropriate service modes and financial plans are designed.

National governments and international organizations are suggested to promote the establishment of uniform RFID technical standards, so as to eliminate the technical barriers for container RFID development.

5 Conclusions

By analyzing the possibility of RFID applications to container transportation, the following conclusions are available:

1. Based on the cost and application level of RFID, the application of RFID to container transportation can be categorized into four hierarchies: Container identification, improving the identifying efficiency and accuracy; Combined with MIS and EDI: Improving enterprise-level logistics efficiency; National/regional RFID platform: improving industry-level logistics efficiency; Combined with GPS and sensor technologies: “smart container” for international customs.

2. Corresponding with the above four hierarchies, there are four basic modes of container RFID applications. They are quasi closed loop application, container shipping route application, RFID container clusters application and comprehensive application.

3. By the actuality of container transportation, the paper gave several developing trends of RFID application, relating to container manufacturers, logistics service providers and the government bodies.

References


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