Postal RFID Application Model and Performance

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ABSTRACT— In this letter, we suggest a postal RFID application model and system architecture that can be used for real-time trace and tracking system implementation of parcel processing and pallet management. This letter also shows the tag recognition performance of parcels and pallets by speed and mounting tag materials such as cans, water, and paper using an implemented postal RFID system for postal logistics.

Keywords—RFID application model, postal RFID system architecture, tag recognition performance.

I. Introduction

Radio frequency identification (RFID) technology has broad applicability to the automatic identification and data capture (AIDC) industry in item management, and its applications cover multiple levels of industrial, commercial, and retail supply chains, including freight containers, returnable transport items, transport units, product packaging, and product tagging [1].

As the technology matures and applications proliferate, RFID will facilitate global commerce and spur innovation and competitiveness.

But the performance characteristics of devices (tags and interrogation equipment) may vary drastically due to application factors as well as the particular RF air interface (frequency, modulation, protocol, and so on) being supported. Of key concern is the matching of the various performance characteristics to user applications. Additionally, in an open environment, users of such technology demand multiple sources for these devices from technology providers. A key challenge is a method of evaluating the differences between various technology providers' products in a consistent and equitable manner [2].

This letter details how RFID technology is used for parcel processing such as registration, collection, sorting, distribution, sending, arriving, delivery, and real-time trace and tracking of pallet management in postal logistics environments.

In section II of this letter, we suggest a postal RFID application model and architecture that can be referred to for adoption of RFID technology in postal logistics environments. In section III, we show the recognition performance of a parcel tag by speed and tag mounting material such as water, paper, and cans using an implemented RFID application system for postal logistics. We conclude with a summary and suggestions for further study in section IV.

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II. Postal RFID Application Model and Architcture

1. Postal RFID Application Model

To minimize trial and error for the adaptation of RFID on postal environments, to check the problem of an RFID application system on postal logistics environments, to find an RFID adaptation model, and to find the application

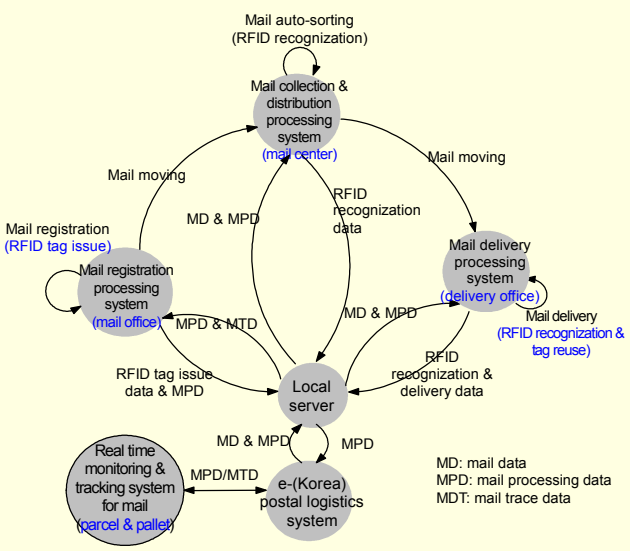

Fig. 1. RFID application model for postal logistics.

requirement profile of RFID on postal logistics environments before establishing a real RFID system on a postal field, we need to design a postal RFID process and application model, RFID tag data structure and code, and postal RFID application system. Figure 1 shows the postal RFID application model that was proposed for the adoption of RFID technology in postal logistics environments.

A. Mail Office

A mail office that can conduct parcel registration through issuing an RFID tag and label printing sends parcel issue data such as a postal code and address automatically using an RFID reader with an Internet connection to a postal logistics system via a local server. The mail office also receives mail trace data such as parcel processing and delivery data from a local server after the registered parcel has moved to the mail center.

B. Mail Collection & Distribution Center

A mail center that can conduct RFID tag recognition at docks and has a sorting machine for the auto-sorting, sending, and arrival processing of parcels and pallets sends RFID tag recognition data of the parcels and pallets, such as mail center code and parcel processing data, automatically using an RFID reader with an Internet connection to a postal logistics system via a local server. The mail center also receives mail trace data such as parcel processing and delivery data from the local server after the parcels and pallets have moved to the delivery office.

C. Delivery Office

A delivery office that can conduct RFID tag recognition for the delivery of parcels and a tag data reset for the reuse preparation of parcel and pallet tags sends RFID tag recognition data of the parcels and pallets, such as delivery office code, delivery person's ID, and delivery data automatically using a hand-held RFID reader with wireless LAN and CDMA connection to a postal logistics system via a local server. The delivery office also receives processing data such as parcel registration and sorting data from the local server after the sorted parcels have moved to the delivery office.

D. Monitoring Center

The monitoring center can do a real-time trace and tracking of parcel processing and pallet management via a local server and postal logistics system. The monitoring center can also check how many parcels are registered in real time, how many pallets with parcels have moved among mail centers, and how many empty pallets are stored in each mail center. This is also important for the effective use of parcel and pallet management, customer service parcel upgrades, and for knowing which mail center has a problem with parcel processing and pallet management.

2. System Architecture

Figure 2 shows the system architecture of a postal RFID system for parcel processing and pallet management. There are six major subsystems including a parcel registration system, parcel takeover process system, parcel sorting process system, parcel sending and arrival process system, parcel delivery system for real-time trace and tracking of the parcel process, and pallet management. There are also a local server and postal logistics system for postal-processing data management and parcel registration and delivery data management, and a monitoring system for real-time trace and tracking of parcels and pallets via a local server. Each subsystem on the postal RFID system has an RFID interrogator interface module for inter-working between middleware and RFID reader, and a legacy system interface module for inter-working between a local server and RFID controller. This architecture can be referred to in order to develop a postal RFID application system.

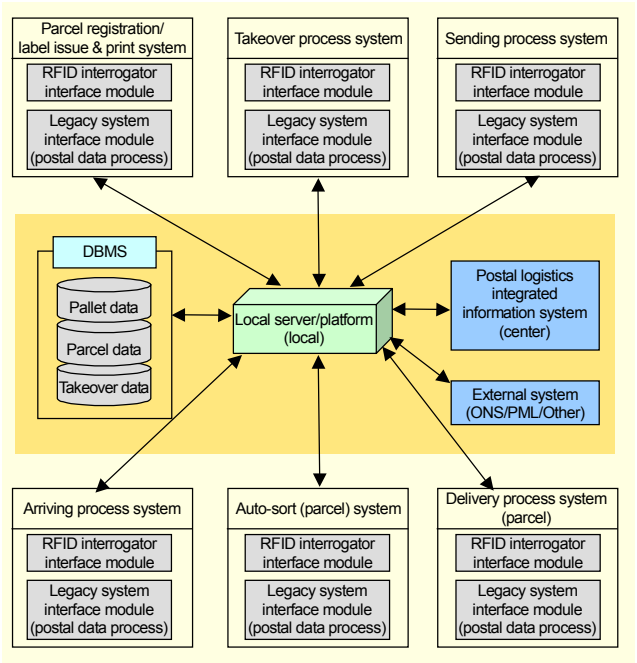

Fig. 2. Postal RFID system architecture.

A. Registration Processing System

The registration processing system is for the registration of parcels through a flat base antenna and on-table RFID reader. The system consists of an RFID controller for the interface of postal data between the RFID reader and postal data processing module, parcel processing terminal with user interface window, which can be used for data input of parcel registration, a parcel tag label printer for printing the label of the registered parcel,

and a legacy system interface module for inter-working with postal data between the RFID system and legacy postal system. Input of parcel registration data such as postal code and address, printing of parcel tag labels, and the uploading of parcel registration data to a local server and postal logistics system via TCP/IP all proceed concurrently.

B. Takeover Processing System

The takeover processing system is for a registered parcel in a mail office and a sorted parcel in a mail center through type 2 ceiling antennas and an RFID reader. The system consists of an RFID controller for the interface of postal data between the RFID reader and postal data processing module, parcel processing terminal with user interface window that can be used for confirmation of parcel tag recognition, and legacy system interface module for inter-working with postal data between the RFID system and legacy postal system. The system compares the recognized data of a parcel tag with the loaded parcel data on a postal logistics system in real time via TCP/IP, and feedbacks the results to a local server, which can confirm normal operation of the parcel process.

C. Sending and Arriving Processing System

The sending and arriving processing system is for the sending and arrival of parcels at docks in a mail office or mail center through overhead type 4 antennas and RFID reader. The system consists of an RFID controller for the interface of postal data between the RFID reader and postal data processing module, parcel processing terminal with user interface window that can be used for confirmation of parcel and pallet tag recognition, and legacy system interface module for inter-working with postal data between RFID system and legacy postal system.

D. Auto-Sorting Processing System

The auto-sorting processing system is for auto-sorting of parcels using a parcel tag including the zip code through tunnel type 2 antennas and RFID reader in a mail center. The system consists of RFID controller for interface of postal data between RFID reader and postal data processing module, parcel processing terminal with user interface window that can be used for confirmation of parcel tag recognition, and legacy system interface module for inter-working with postal data between RFID system and legacy postal system.

E. Delivery Processing System

The delivery processing system is for delivery of parcels at a delivery office through a hand-held RFID reader. The system compares the recognized data of multiple parcels with the loaded parcel data on a postal logistics system in real time via a wireless LAN, and feedbacks the results to a local server, which can confirm normal operation of the parcel process.

III. Performance Evaluation

In order to prove the tag recognition performance based on the implemented postal RFID system and find the best installation solution of the system in postal logistics environments, we tested the tag recognition rate of parcels by tag mounting material, tag orientation, and moving speed using a postal RFID application system. The recognition rate of pallets and boxes by antenna type and tag position was also carried out in postal logistics environments. We use only a UHF linear and circular antenna (Intermac) with RFID tag (ISO 18000-A, SAMSys) for the performance test based on our implemented and installed system in the field.

1. Recognition Rate of Parcel on Pallet by Tag Position and Speed and Tag Mounting Material

Figure 3 shows how we attached the tags on parcels for a multiple recognition rate test by tag mounting material using a postal RFID system [3]. Figure 4 shows the recognition rate of parcels by tag mounting material and speed. The recognition rates of paper and aluminum are about 90% and 80%. The recognition rates of cans and water are about 50% and 35%. There is also a small difference of recognition rate of paper by moving speed, slow, medium, and fast, and by tag orientation. Medium speed means that the walking speed for passing the installed system and RFID antenna from a 5 m front area to 5 m backend area is 8 seconds, while slow is 14 seconds and fast

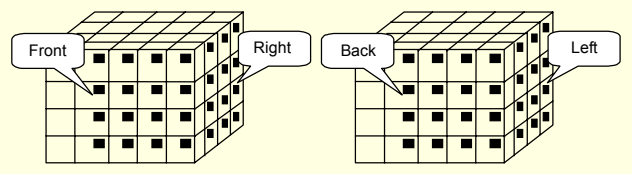

Fig. 3. The attached tag view of material for multiple reading tests.

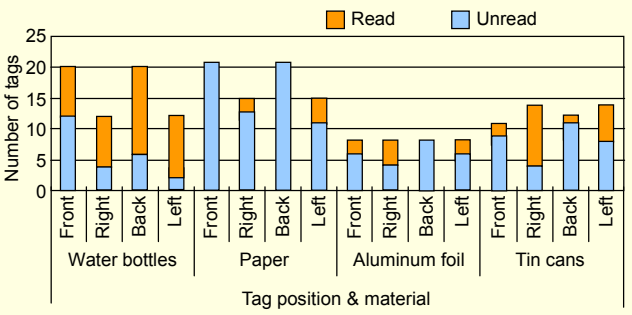

Fig. 4. Recognition rate of parcels on a pallet by tag position and tag mounting material at medium speed.

is 4 seconds. We also installed an antenna 130 m high in an overhead type RFID system for testing the reading rate of water bottles, 170 m high for paper, 150 m high for aluminum foil, and 73 m high for tin cans.

2. Recognition Rate of Boxes on a Pallet by Antenna Type and Tag Position

To find a postal RFID application requirement profile such as antenna type and direction for registration, takeover, and sending and arrival of parcels, we performed a field test by box tag orientation on pallet and antenna type using an RFID testbed [4]. Figure 5 shows the recognition rates of box (plastic) tags on a pallet by antenna type and tag position. A circular and ceiling type (CC) antenna with a maximum 98% reading rate is better than a circular and stand type (CS) antenna with maximum 44.3% reading rate, or a linear and stand type (LS) antenna with maximum 62% reading rate. Figure 5 also shows that the best recognition rate of box tags on pallets occurs when we attached the tag under the box. And it shows that the maximum recognition rate of multiple boxes on pallets is 20 box tags. Based on this preliminary field test, we consider antenna type, tag orientation, optimal number for multiple parcels, and pallet recognition in postal logistics environments as necessary parts of an application requirement profile. For parcel and pallet management using RFID, the best situation is a flat type antenna for parcel registration, circular-overhead type antenna for parcel takeover, circular and ceiling type antenna for sending and arrival of multiple parcels, and a pallet with 20 tagged boxes.

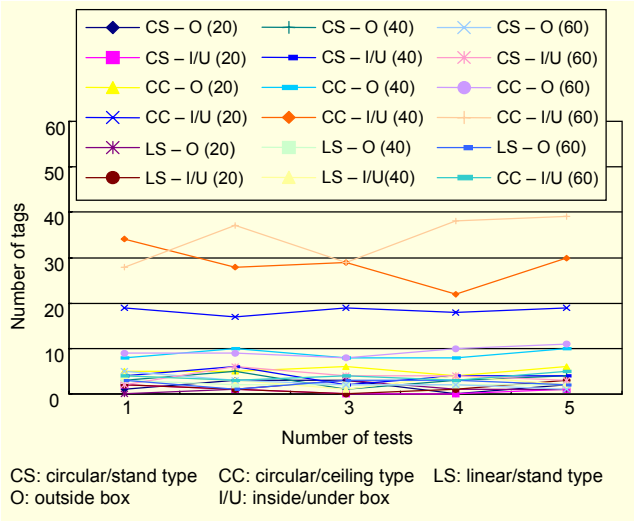

Fig. 5. Recognition rate of box tags on pallets by antenna type and tag position.

3. Recognition Rate by Power and Distance

The reading distance of a tag depends on the field conditions, electric conditions between tag and reader, the reader's power, and so on. The minimum value for normal operation of a tag that has to get signal power from an RFID reader is 35 μW. So we can calculate the maximum reading distance of a tag from the RFID reader signal using the following formula:

$$R_{\max} = \sqrt{\frac{P_{EIRP} \cdot G \cdot \lambda^2}{(4\pi)^2 \cdot P_{Chip}} \cdot Loss},$$

where EIRP reader power (P_{EIRP}) is 4 W, reading distance (R_{max}) is 7.56 m, tag antenna gain (G) is 1.64 dB, operation frequency (f) is 912.5 MHz, received tag power (P_{chip}) is 35 μW, and mismatching and tag antenna loss (Loss) is 3 dB .

We also tested the reading distance by RFID reader power using a postal RFID system in postal logistics environments. At the test, the received power of a tag decreased according to the distance and became 35 μW at 7.56 m, which is the maximum reading distance. The measured values were almost the same as the calculated values using the above formula.

IV. Conclusions

In this letter, we suggested a postal RFID application model and system architecture that can be used for real-time trace and tracking of parcel processing and pallet management. This letter also showed the recognition performance of parcels by speed and tag mounting material such as water, cans, and paper in postal logistics environments. However, there are still some considerations for adaptation of RFID technology in postal logistics environments such as multiple tag recognition rate by speed, distance, content, and environment; interference problem of antennas; visibility problem of recognized multiple parcels; visibility of non-recognized parcels; visibility of RFID tag data; reuse of RFID tags and labels; specific label type design problem for parcels and pallets; postal code development for postal logistics; and a new standard postal logistics process and platform development based on RFID.

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