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Check Out System Using Passive RFID Technology in Wholesale Supermarket

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***Abstract*—The aim of this paper is to improve reading accuracy and precision of passive tags on shopping cart. The proposed system, which is embedded on shopping chart, consists of a RFID (Radio Frequency IDentifier) reader. The reader temporarily records items that put in the shopping chart. At the check out counter, the proposed system transmits data to central server, while the RFID reader at the check out counter reads all items that pass to it. The central server then matches the data from the proposed system and the data obtained from check out counter. The checkout process is successfully done when both data are identical. Otherwise, a warning message is generated. Customer can monitor the total purchase by letting the reader identifies the items in the shopping chart. The results show that using the combination of both checking systems, the accuracy can be improved up to 18 percent by compared to that of using single checking system.**

***Index Terms*—Passive RFID ,Supermarket,RFID reader,RFID Tag,Check out counter,Accuracy.**

I. Introduction

As a commercial business, grocery stores, and similar shopping establisments play an important role in today's economy. [1] said, the supermarket sales in Indonesia are growing with rates of 13-15 % on 2012. With increasing purchasing power of consumers from year to year, producers face challenges in improving the customer's convenience. Problems in stock management and customer data have to be eliminated in order to improve the customer's convenience and ensure that the system can operate properly. According to [2], identification technique using bar code which is done for each individual item requires line of sight between barcode and reader. In contrast RFID identification technique allows automatic multi tag reading when the one or more tags enter the coverage area of the reader. Thus, implementation of RFID technology is expected to enhance the customer comfort and convenience when shopping in a supermarket.

Research on the implementation of RFID and Internet of Things (IoT) in supermarket have been done to improve the comfort and convenience when shopping [3]-[4]. Zhengshan studied the use of RFID technology in a supermarket [5]. The authors utilized the IoT and active RFID for searching position and monitoring availability of goods. At check-out counter, mobile payment was used for transaction. The goals of using mobile payment system is to reduced queue at the check-out counter. Monitoring goods informations using shopping cart which is mounted with RFID reader has been investigated [6]. In this research each shelf mounted with a reader to monitor the stock of goods. The system automatically updates the data to the central server when the items on the shelf have been reduced. Rong *et al*. [4] developed a guidance system in supermarket based on wireless technique and IoT. The system consists of active RFID tags on the shelf and hand held devices that is embedded with a RFID reader. The device receives product information when it is close to the tag.

The design and implementation of a new intelligent advertisement and shopping guide system for large supermarkets has been investigated by Ningyuan [3]. The wireless touch screen device is integrated in shopping cart. It can automatically broadcast the commodities advertisement when the cart is moving in large supermarket. Customer can easily search the commodity who they need with help of electronic guide services.

However, most researches do not pay attention on the accuracy and precision of the identification tags on product. A supermarket should ensure that is no fault occur during transactions on the check out counter. The tags that overlap with each other on shopping cart may be undetectable by reader and thus the products are not recorded to the system.

In this paper, double checking system is proposed. The aim of this paper is to improve reading accuracy and precision of passive tags on shopping cart. The proposed system, which is embedded on shopping chart, consists of a RFID (Radio Frequency IDentifier) reader. The reader temporarily records items that put in the shopping chart. At check out counter, the proposed system transmits data to central server, while the RFID reader at the cashier gate reads all items that pass to it. The central server then matches the both data. The checkout process is successfully done when both data are identical. Otherwise, a warning message is generated.

The reminder of this paper is organizedas follows. Section II describes the system overview of the proposed system. The experimentals and results are represented in section III. Section IV concludes the paper.

II. System Overview

The overall structure of proposed system is divided into three main layers which handle the entire task of the system as follows.

- First layer. This is client layer, which processes the data and generate the system output.
- Second layer. This is communicaton service layer, which is responsible for two-way communication between systems that use radio frequency data transmission and application on cashier.
- Third Layer. This is the data service layer, which is mainly responsible for providing the basic data for communication layer.

The proposed check out system aims to increase the accuracy of reading tag on goods and also improve the security in purchasing. Besbes [7] studied an intelligent check out system using camera at the cashier to determine the movement of customer if they already close to the gate cashier and selected puchase goods approach the checkout system. Thus, RFID reader is activated and identification of goods is started. According to that scenario, validation process of total goods and data items is executed only at cashier gate. Thus, the opportunity of items is not detected using the RFID reader is high as the selected purchase items are piled up on shopping cart. In the proposed system, double checking consists of the first checking system at the shopping cart for temporary selected purchase items and final checking system at the check out counter gate for final validation and transaction.

Every goods that is temporarily recorded on shopping cart will be compared with data obtained by RFID reader at cashier gate. This can be explain as follows. When the customer shopping cart passes through the cashier gate, system identifies each item by the RFID reader. At the same time the data is compared with data recorded in the system attached on shopping cart. Transaction can be completed when both data are identical. Otherwise, warning message is generated and the manual checking for the unidentified item should be done. Fig.1 shows the basic design of system.

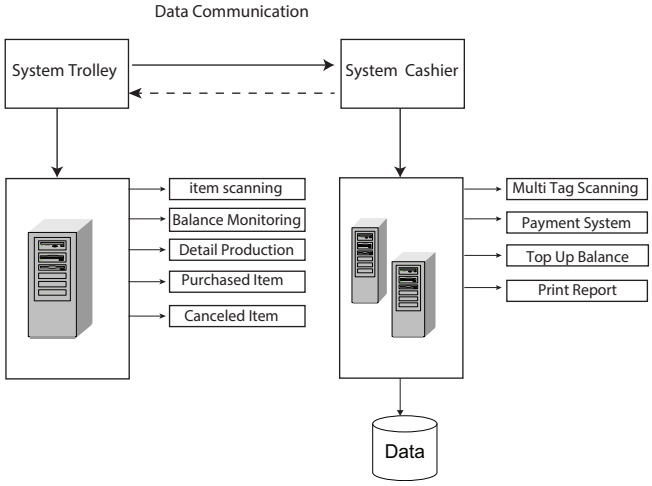

Fig. 1: Design of basic structure system.

III. Check Out System Design

A. RFID System in Shopping Cart

In the supermarket, every customer will take a shopping cart to transport the selected purchase items to the checkout counter during shopping. This research proposed a system with RFID technology embedded in the shopping cart. The embedded system will display the detail information when an item is handed in the vicinity of the RFID reader on the shopping cart.

Scenario of the proposed on shopping cart can be explained as follows:

- Customer enters the supermarket and selects one shopping cart.
- Embedded system on the shopping cart read the customer ID as appear in the customer card member. Customer ID and shopping cart ID will be used as parameters for every transaction. It is that assumed every customer have a card member for payment.
- Customer information and customer balance will be displayed when the card is read by the system.
- Each selected item has to be handed close to the RFID reader on shopping cart to record the temporary purchased items.
- When an item is read by system, detailed information such as a item description, producer, price, expired date, etc.will be shown in the monitor. The total of temporary purchased item is also shown in the monitor.
- When a customer wants to cancel the purchase of an item, she rescans the item to the reader and select the menu in the system for cancellation so the total temporary purchased item will be adjusted.
- Finally if the customer passes the check out counter. The system perfoms multitag reading using RFID reader to the items in the shopping cart and both data will be analyzed by the central server.

The workflow of embedded system on shopping cart is shown in Fig. 2.

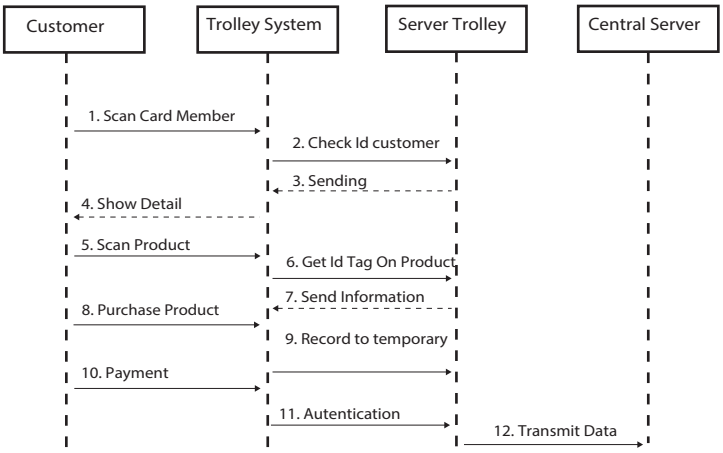

Fig. 2: Trolley system work flow

The advantages of using this system is not only for increasing accuration and security on cashier but also for improving the customer convinience. This system can monitoring directly the balance information at the shopping cart. Every goods that has been scanned will directly decrease balance of customer temporarily until they are ready to make a payment on cashier. With that way, customer can controlling their purchase goods by looking into information of last balance. Moreover customer can get detail information about goods which they want by scanning it on reader at shopping cart. After customer finish to select goods and ready for payment on the cashier, then shopping cart system will transmit data of goods which is recorded on temporary shopping list to central cashier system. Fig. 3 show the example of system on shopping cart.

Fig. 3: Shopping cart system [8].

B. RFID System On Cashier

Every item in supermarket is attached a tag that has unique identity. The system performs multi tag reading when shopping cart customer passes the reader. The proposed system uses RFD210P integrated ultra high frequencies(UHF)Gen-2 Reader Writer that work at 960MHz. This reader is an entry level reader that reads and writes electronic labels or tags and complies with ISO-18000-6B standard and EPC Class 1 G2. According the reader specification, mulitag scanning can be done with maximum read range up to 4 meters. Smart card is assumed to be used by customer for transaction in which the system automatically detects the customer ID and reduce the balance of customer during transaction. Specification of the smart card is Gen 2 blank UHF card with frequency of 860MHz-960MHz.

To avoid the phenomenon of lining up at check out counter waiting for payment, customers purchase the product through shopping cart and scan product to be recorded as temporary purchased items. After purchasing, when customer walk through the check out counter, the shopping cart will wirelessly transmits the data of temporary purchased items, customer ID, and shopping cart ID. The flow chart system on check out counter is shown in Fig. 4.

Both systems on shopping cart and check out counter have database to record any data related to the transaction process. Database at shopping cart system records the data of temporarily purchased items on shopping cart based on customer ID and shopping cart ID. The system read tags of

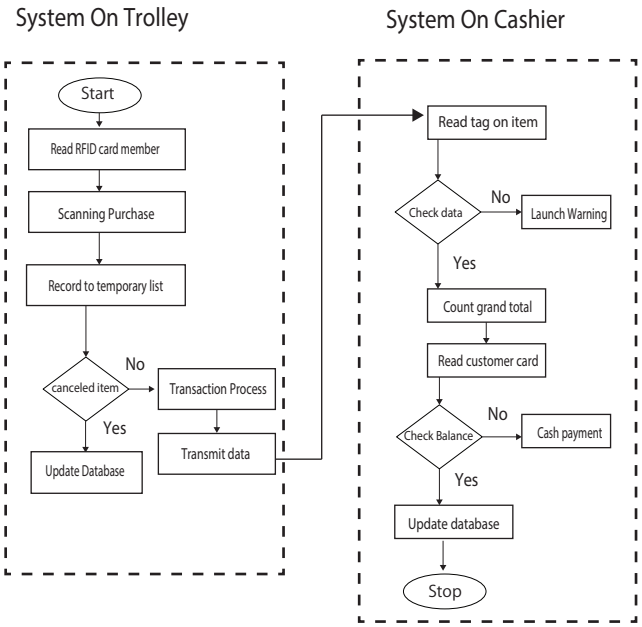

Fig. 4: Flow chart cashier system.

items on shopping cart and compare it with data from shopping cart based on the customer ID and shopping cart ID. If data of both system are matched, then field paid status on database set true. To avoid error occur if same customer purchase item in other time with same product and same shopping cart. System automatically check field that status paid is false. The scheme of comparing field is shown Fig. 5.

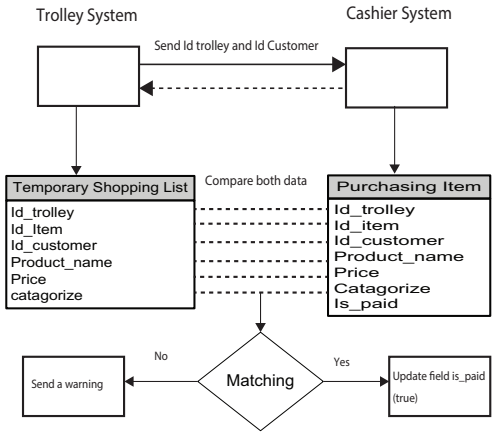

Fig. 5: Comparing data system.

IV. Experimentals and Results

A. Experiments of Single Checking System

To evaluate the effectiveness of the proposed system we will comparing single checking system and double checking system. The result will show which method is better. Some experiments are conducted including to estimate the maximum

capacity of shopping cart. According to the [9], the standardized shopping cart in hypermart has a maximum volume of 180 liters with 99.5 cm in length, 59 cm in width and 50 cm in height. In this experiment, the selected purchase items are assumed as a pile of boxes that has various size but not exceed the maximum capacity of the shopping cart. Maximum carried items that can be included in the shopping cart are calculated by dividing volume of the cart with a total volume of purchased item. The maximum number of tags on the shopping cart can be calculated as in Eq.(1).

$$Tag_{max} = \frac{L_t \times W_t \times H_t}{L_b \times W_b \times H_b} \quad (1)$$

$$L_t : Lengthtrolley, W_t : Widthtrolley, H_t : Heighttrolley$$
$$L_b : Lengthboxes, W_b : Widthboxes, H_b : Heightboxes$$

The volume number of shopping cart is $99.5cm \times 59cm \times 50cm = 293525cm^3$ and the volume of box is $30cm \times 25cm \times 35cm = 26250cm^3$ then the maximum capacity is

$$\frac{293252}{26250} = 11,185 \quad (2)$$

Based on result above, 11 tags RFID are used in this experiment as shown in Table I, experiment is conducted to determine the reading accuracy of RFID readerin a certain distance at the check-out counter gate.

TABLE I: ACCURACY EXPERIMENT

Experiments		
Distance (cm)	Time (s)	Accuracy %
50	4	100
100	22	81.3
150	55	56.2
200	65	43.8
250	73	25
300	78	18.75

As shown in Fig. 6, the reading accuracy decreases as the distance between the tag and reader increases. In order to improve the accuracy we propose the double checking system.

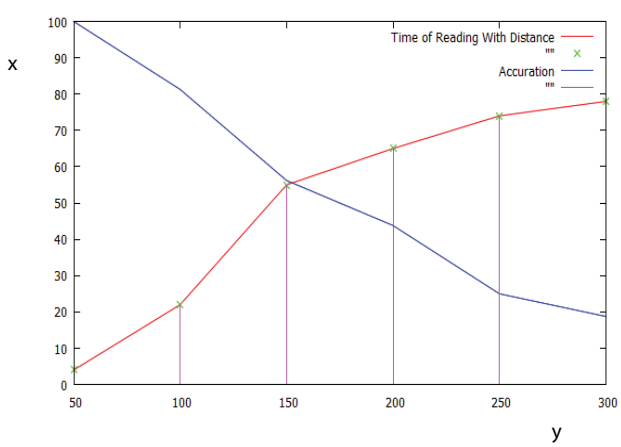

Fig. 6: Accuration reading tag based on distance.

B. Experiments of Double Checking System

In this experiment, the data recorded in the embedded shopping cart system will be compared with the data read at the check-out counter. If the RFID reader at the check-out counter can not detect all tags on shopping cart then the missed data will be copied from the embedded system on shopping cart. Scheme of adding the missed is shown in Fig. 7.

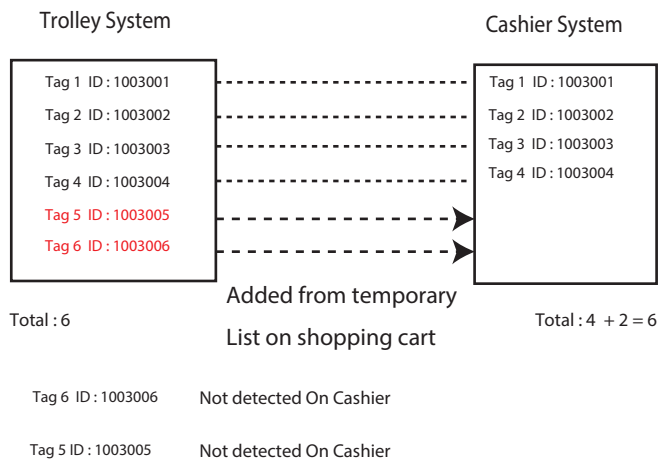

Fig. 7: Scheme of checking an adding unread items

Security and accuracy become an important part to measure reliabilty of the proposed system. The experiment scenario is explained as follows:

- In this experiment, it is assumed that 9 out of 11 tags on shopping carts have been scanned and recorded in the temporary database. However, 2 tags are not scanned and stored in temporary purchased items.
- Three boxes are used as barrier between tags where every box has width 30 cm, 25 cm, and 20 cm.
- Maximum distance is 50 cm and the experiment is conducted 50 times.

The result one checking system is shown in Fig.8.

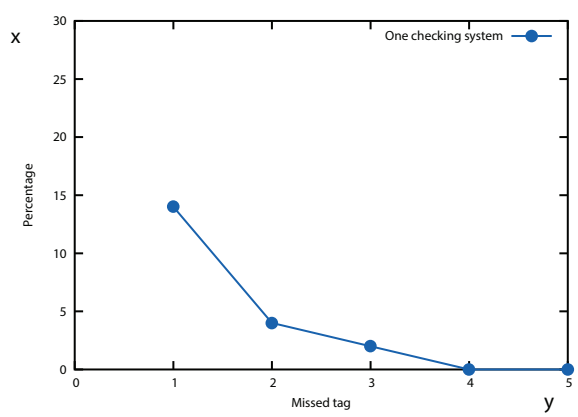

Fig. 8: Percentage of missed tag.

Fig. 8 shows that using one checking system, the reading accuracy is 78%. This come from 14% of 1 missed tags , 4% of 2 missed tags , and 4% of 3 missed tags.

With double checking system, missed tag is only 4% from 50 times experiments as shown in Fig. 9. Thus the reading accuracy from the double checking system is 96%. The result is shown in Fig.9.

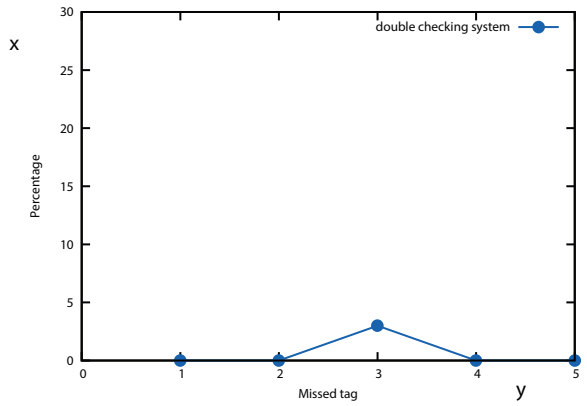

Fig. 9: Percentage of missed tag.

V. Conclusion

In this paper we have proposed double checking system to improve reading accuracy and precision of RFID tag on check out counter. The proposed system, which is embedded on shopping chart, consists of a RFID (Radio Frequency Identifier) reader and the reader temporarily records items that put in the shopping chart. At the check out counter, the proposed system transmits data to central server, while the RFID reader at the cashier gate reads all items that pass to it. The central server then matches the data from the proposed system and the data obtained from cashier gate. The advantages of the proposed system for customers are to monitor and controll amount balance during the shopping in supermarket.

According to the experiments with one checking system, accuracy of reading tag at check out counter is about 78% which is measured from 50 times experiments. The proposed double checking sytems reduce the percentage of missed tag about 18 % and thus the accuracy increases up to 96% compared with single checking system. In this study, shown that using double checking system is better than single checking system based on accuracy and precision to detected tag.

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