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Abstract:

This paper describes the research and development of a radio frequency identification (RFID)-based personal shopping assistant (PSA) system for retail stores. RFID technology was employed as the key enabler to build a PSA system to optimize operational efficiency and deliver a superior customer shopping experience in retail stores. We show that an RFID-based PSA system can deliver significant results to improve the customer shopping experience and retail store operational efficiency, by increasing customer convenience, providing flexibility in service delivery, enhancing promotional campaign efficiency, and increasing product cross selling and upselling through a customer relationship management (CRM) system. In this study, an RFID value grid for retail stores is proposed that allows managers to use RFID technology in stores to add value to the shopping experience of their customers. Four propositions are presented as the research agenda for examining the ability of RFID technology to improve the operations management of retail stores.

Keywords: Radio frequency identification (RFID), retail store management, retail industry, customer relationship management (CRM)

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I. INTRODUCTION

Radio frequency identification (RFID) is increasingly gaining prominence as a technology with significant potential to deliver business benefits. The technology is used in many business and industry sectors, including the airline industry [O'Connor 2006], food safety management [McMeekin et al. 2006; Kelepouris et al. 2007], healthcare [Collins 2005], logistics [Ngai et al. 2007], manufacturing [Swedberg 2006], supply chain [Bose and Pal 2005], and transportation [Caputo et al. 2003]. In this study, RFID technology was used as the key enabler to build an RFID-based personal shopping assistant (PSA) system to optimize the operational efficiency of retail stores and deliver a superior customer shopping experience to customers

To sustain business growth, retailers need to continuously increase their competitive edge when it comes to attracting new customers and sustaining repeat visits to their retail stores. Many retail stores strive to better use innovative technology (such as RFID) to bring added value to the shopping experience of their customers, and to continuously improve the shopping experience and service quality. However, some stores confront certain fundamental challenges in managing and operating their business.

Inefficient Customer Shopping Process. Except for the checkout service, most of the activities in the traditional shopping process mainly involve customers only. Customers are required to search for their items throughout the store area. They may wander into a store by chance, and discover the discounted and promotional items they favor. Little interaction between the customers and retailers is established to encourage product sales and enhance the shopping experience. This kind of shopping process is inefficient, and the shopping experience is far from satisfactory.

Non-interactive Product Cross Selling and Upselling. Most stores traditionally advertise products in a non-interactive manner, with product marketing messages displayed through the mass media or in store aisles. Hence, the target marketing segments are neither very specific nor personalized. Imagine if retailers could know precisely their customers' purchase history, favorite products, and so forth. While customers were wandering along the store aisles and selecting products, interactive and powerful cross-selling and upselling promotions could be presented to the customers to influence their buying decisions and maximize their total bucket value. However, most stores lack this marketing competence, and thus fail to achieve or exceed their sales targets.

Inflexibility in Service Delivery. The "do-it-yourself" mentality has created customer demand for more self-service. However, most checkout and payment services in stores are not automatic, and are performed manually. In addition, seldom do stores provide product search services so that customers' required items can be easily located and customers need not wander throughout the store to find their items. As such, traditional service delivery is inflexible and time consuming.

A research question arises from these challenges. Can RFID be used to overcome the challenges facing the retail industry? With this question in mind, we propose RFID technology to be used to keep track of customers' shopping history and provide data for the retailers to implement individualized marketing strategy and services. The retail industry has become one of the main sectors for conducting RFID pilot studies (e.g. Wal-Mart, Tesco, Target, and Albertson have all carried out pilot studies [Kinsella 2003]. In this regard, the adoption of RFID technology has become a key issue for retailers in many countries [Jones et al. 2005]. Customer Relationship Management (CRM) is increasingly being used in the field of sales and marketing. The RFID-based PSA can be used to automatically capture customers' behaviors and can effectively track these behaviors without having the customers answer questionnaires. Effective product recommendations toward the right consumer can be made via personalized PSA and a CRM system. We believe that the use of RFID in retail stores can improve the customer experience and exploit captured data to give a store a significant competitive advantage.

Despite the potential benefits of the adoption of RFID in retail store, Bose and Leung [2008] point out that the application of RFID is still limited to the upper stream of the supply chain with very little application to the lower stream or the client management side. CRM has become widely recognized as an important business strategy. Although there is no universally accepted definition of CRM, it is commonly defined as the corporate objective to learn more about customers' needs, preferences, and behaviors in order to serve customers better and develop quality relationships with them [Ngai 2005]. In current competitive business environment, we can gain better insight into customer behavior and activities by implementing RFID technology in a retail store. We believe that there is a need for a better understanding of an RFID-based PSA system to support CRM in the retail industry.

Given the motivations behind our research, we used a system development approach in a retail store to

1. examine how RFID technology via an analytical CRM system could shed light on customers' behavior and optimize the operational efficiency of retail stores;
2. design and develop an RFID-based PSA prototype system to
   - improve the business operation and management efficiency of retail stores;
   - increase product cross selling and upselling through the enhancement of the promotional campaign efficiency via an analytical CRM system;
   - increase customer convenience and improve efficiency in the shopping process; and
   - empower and facilitate customers to use in-store self-services.
3. propose an RFID value grid that can be used by researchers who seek to measure the value and impact of an RFID system in the retail industry; and
4. extend the empirical study by presenting propositions for future research.

The rest of the paper is organized as follows. In the next section, we provide a brief overview of previous RFID applications to sales and marketing or CRM. Then, we describe our development of a PSA prototype system. Next, we propose an RFID value grid for retail stores and suggest some directions for future research in the form of four propositions. Finally, we present a conclusion and discuss some of the limitations of the study.

II. LITERATURE REVIEW

With the rapid development of RFID technology, academic researchers have become more interested in studying how RFID technology is developed and implemented in organizations. An increasing number of RFID-related publications have appeared over the last few years. However, there are relatively few academic publications related to the application of RFID to sales and marketing or after-sales service [Ngai et al. 2008].

Kärkkäinen [2003] investigated the potential of utilizing RFID technology to increase efficiency in the supply chain of short-shelf-life products in an RFID trial conducted at Sainsbury's stores. Kourouthanassis and Roussos [2003] described the design and implementation of a prototype system catering to consumers on the move, which uses a wirelessly connected cart with a display device and an RFID sensor that detects the objects placed in the cart. They presented the results and implications of the front-end and formative evaluation studies they conducted of the second-generation retail system. Smith and Konsynski [2003] explored the applications and future commercial impacts of RFID technology. They summarized the ways in which organizations and academics are thinking about these technologies to stimulate strategic thinking about their possible uses and implications. Jones et al. [2004] examined some of the issues facing retailers in terms of the widespread use of RFID tags and the privacy concerns that are linked to data capture and data usage by retailers and third parties. Jones et al. [2005] provided a brief and accessible outline of the RFID developments in food retailing, and suggested that RFID has the potential to offer food retailers a reduced labor cost, and improved customer service while facilitating compliance with traceability protocols and food safety regulations. Prater and Frazier [2005] examined the market drivers that are leading to RFID implementation in the grocery industry, and proposed a research framework that includes research using modeling techniques, RFID implementation, and the impact of RFID on daily operational issues. Lee et al. [2007] presented a simulation model using system dynamics to show the importance of trust issues involving RFID technology, and provided insight into the development of consumer trust in RFID-based e-commerce and policies to increase consumer trust in e-commerce. Bose and Leung [2008] discussed the potential use of RFID in CRM by integrating the technology with enterprise information technology infrastructure, and suggested some further research directions in these areas.

According to Violino [2003], CRM projects fail for a number of reasons, one of the most cited being the lack of real-time customer data. RFID technology can help companies deal with the issue of real-time data capture and provide a wealth of information to managers about customers' needs and behaviors through data mining. Although CRM is an attractive area for research because of its relative novelty and explosive growth [Ngai 2005], few academic research and empirical studies have addressed the integration of RFID and CRM technologies. Therefore, in this paper, we address the design and development issues of an RFID system and describe our experience of developing an RFID-based PSA system and how these technologies can be integrated and handled through the development and evaluation of the system.

III. RESEARCH APPROACH

With the rapid development of RFID technology, academic researchers have become more interested in studying how RFID technology is developed and implemented in organizations. An increasing number of RFID-related publications have appeared over the last few years. However, there are relatively few academic publications related to the application of RFID to sales and marketing or after-sales service [Ngai et al. 2008].

In this paper, we describe the design and development of an RFID-based PSA system to support CRM in the retail industry. This research neither tests nor validates a theory, but aims to understand the role of RFID technology by building a PSA system in the retail sector. As the academic study of RFID applications in the retail industry is at an embryonic stage, we can describe this study as being explorative in nature. We chose a case-based approach, which is particularly appropriate when research and theory are still in their early, formative stages. Benbasat et al. [1987, p. 13] also argue that such an approach is appropriate for “sticky, practice-based problems where the experiences of actors are important and the context of decision is critical.” They go on: “Case study is clearly useful when a natural setting or a focus on contemporary events is needed.” Furthermore, Eisenhardt [1989] pointed out that “building theory from case study research is most appropriate in the early stages of research on a topic or to provide freshness in perspective to an already researched topic.”

IV. THE CASE STUDY

Since an RFID system is new to most retail practitioners, the developed RFID prototype system can help them to understand how it can help business operations and support the CRM system. According to Nunamker et al. [1990], an ideal research problem cannot be tested either mathematically or empirically. It is necessary to develop a system to validate the concept underlying the research study. Once the prototype system has been designed and built, we can study the research issues in order to gain better insights into the study problem.

The company that we examine here is a supermarket chain operator in Hong Kong that has been in the retail industry for more than 50 years. The senior management has a strong motivation to keep abreast of the latest technology to remain competitive. They recognize that they need to know more about RFID technology and the possibility of applying RFID in their retail operations as RFID could be used to replace barcode technology in the future. From our site visits and discussion with the management, we obtained a clear project scope for the development of this RFID-based PSA system prototype. The prototype system was demonstrated to the senior management and three of the retail store managers, and their opinions about it were sought. An interview was conducted with the retail store managers after the prototype demonstration. In the following section, we outline the architectural framework of a PSA system for the retail stores.

Architectural Framework of the PSA System

First, we provide an architectural overview of the system and of the five cross-sectional layers of the system. Then, we describe the six stages in the design and development of the proposed system, namely business process analysis, requirements analysis, system architecture, system design, implementation, and testing and evaluation.

Architectural Overview

Figure 1 depicts an overview of the architectural framework of the system. It comprises five layers. We use a layered architecture as our design pattern to decompose the system functionality of the PSA system into groups of sub-functions such that each group can achieve a particular level of abstraction. A layering application design pattern allows a complex application to be broken into smaller, more manageable pieces and for the implementation details to be hidden from other layers. This can simplify not only the intra-application communications among different layers within a PSA system, but also the inter-application communications between the PSA system and other existing legacy applications. As the interfaces across layers are relatively stable, late source code changes to the PSA system should not ripple through the entire application, and thus the subsequent application maintainability can be more cost effective.

Data-Capturing Front-End System. The first layer provides the RFID data-capturing front-end system. It contains three components: transponders, readers, and antennas. Each shopping cart is embedded with a transponder with an RFID tag inside. Each tag contains the cart ID and store information about the items inside the cart. In addition, each item is also equipped with an RFID tag, which contains the product ID and major data (characteristics) of the product. Readers equipped with antennas are placed at fixed locations within the retail store to read or write information onto the RFID tag. When customers move the tagged shopping cart or pick up a product in the store, the tag information can be retrieved and sent to the next layer for processing.

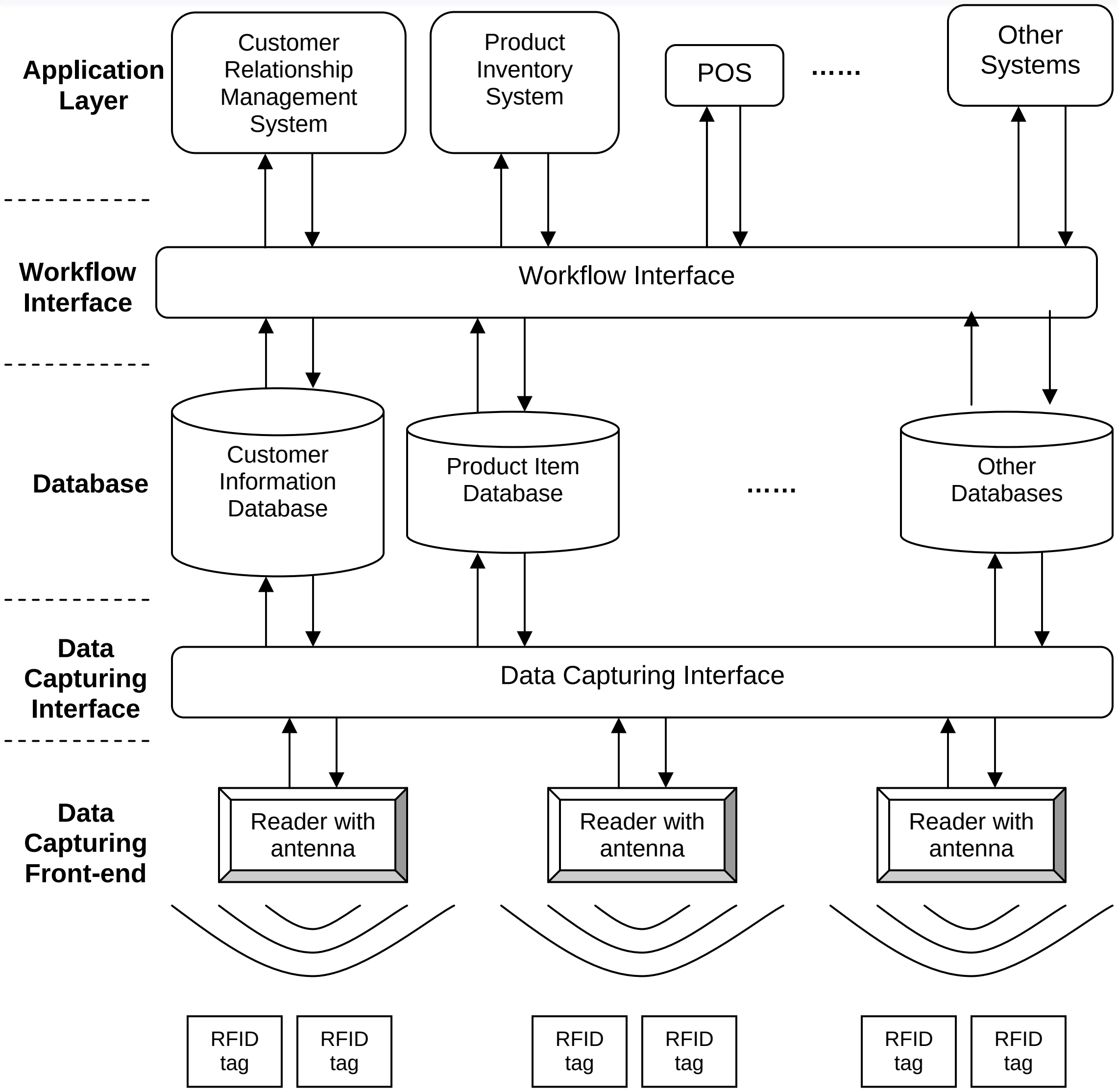

Figure 1. Architectural Overview of the PSA System

Data-Capturing Interface. The tag and the system have different formats and standards, so an interface is needed to enable communication between them. This interface converts the tag information into data that are readable in the system, and vice versa.

Database. The captured data are fed into a well-designed database. This data repository provides the essential information to run various applications and supports the data mining processes at the upper levels. The data can be extracted and updated by various applications.

Workflow Interface. This layer is used to manage, coordinate, and integrate the processes and the data flows within the application systems. A middleware interface is needed to communicate with the database. The middleware has built-in business rules that monitor the data stream and direct the data into the appropriate application systems.

Application Layer. Application systems such as a product inventory system and customer management system are developed to enhance the operations and improve the service quality of the retail store. These systems are integrated with the existing legacy systems, such as the customer relationship management (CRM) system and point of sale (POS) system, because the workflow interface provides a standard application program interface (API) for the applications to communicate with the database.

Design and Development

Our architectural development process comprises of six stages and is structured as a cascade of stages, where the output of one stage constitutes the input to the next one. Each stage, in turn, is organized as a set of activities that can be executed by different functional or specialist teams accordingly. We describe each stage following.

Stage 1: Business Process Analysis. A business process refers to the way in which a particular business is conducted. It is related to the business rules, strategies, and unique ways in which an organization coordinates work, information, and knowledge [Laudon and Laudon 2002]. Grover et al. [1994] indicated that information technology can play a significant role in facilitating business process reengineering. In this connection, an RFID technology is proposed in this study as an enabler that can affect business process changes.

Figure 2 illustrates the RFID-enabled shopping process in a retail store. First, the process validates the customer's identity based on a customer loyalty card that contains basic customer data for identification purposes. After successfully verifying the customer's identity, the shopping journey starts with a shopping cart, and the following four subprocesses come into play.

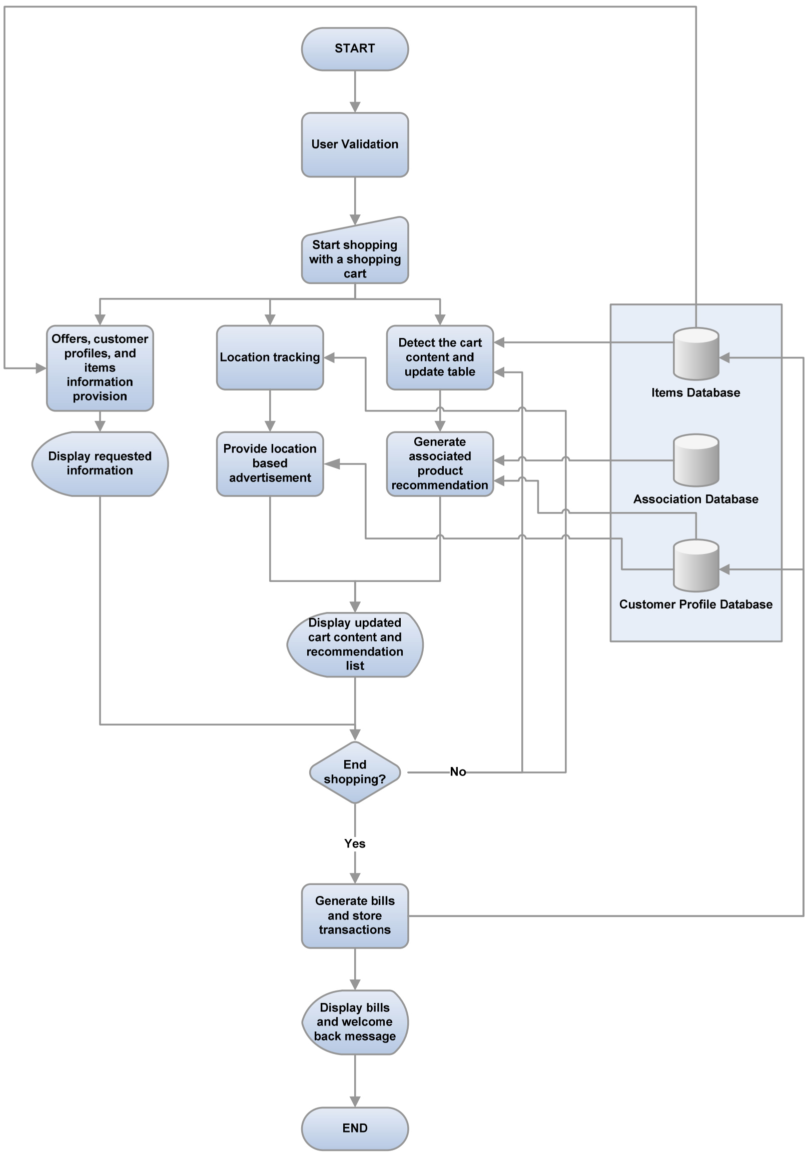

Figure 2. Flow Chart of the RFID-Based Shopping Process

Product Selection Subprocess. When an RFID antenna detects the in-and-out movement of the items in the shopping cart, it retrieves the product pricing information from the system databases to instantly calculate and update the total amount of all items inside the cart. This helps customers monitor and check whether the items or number of items are within their budget. In addition, when customers select an item, other brands or associated products can be presented to them using an intelligent user interface so that a wide range of products can be offered to the customers and the store can better cross sell other relevant products.

Product Promotion Subprocess. When customers successfully log in to the system, their prior shopping behavior and favorite items are retrieved and analyzed. Based on the analytical results, the store can effectively market personalized product sales. To achieve this, RFID antennas are installed storewide to detect the location of customers within the store. When they walk through particular product areas or pick up items that have been recorded as their favorites, the system can alert customers of other new or similar products.

Customer Management Subprocess. In the system, customers can view and update their personal information, favorite products, product purchase history, and so forth. Then, the store can better understand an individual customer's shopping habits and needs, and shopping services can be customized accordingly to improve the customer shopping experience and customer loyalty. Furthermore, if a customer needs in-store assistance, he or she can press a button on the PSA screen, and the store assistant can immediately locate the customer's position and approach the customer to offer help.

Product Checkout Subprocess. Having finished selecting the products they wish to purchase, customers can move their carts to a self-checkout machine. The system then transfers the data of the chargeable items to the checkout machine and a shopping invoice is generated. When the customers confirm the invoice, their accounts can be debited accordingly. The product(s) purchased and the transaction data are transferred to the database for storage and analysis. The shopping journey ends after showing the customers a "Thank You, Welcome Back" message.

Stage 2: Requirements Analysis. Having acquired knowledge of the business process and learned the operational environment of the retail store, we analyzed the store's business needs to define the specific, unambiguous, and testable requirements with regard to the user, hardware, and software. After discussing matters with the key stakeholders, we analyzed and summarized their key functional requirements for a PSA system. These requirements are shown in Table 1.

Table 1. Requirements of the Key Stakeholders

Stakeholders	Requirements for a PSA System in a Retail Store
Store Owner	• To provide an effective way to market products • To facilitate product cross selling and upselling • To enhance the shopping experience and service quality • To enable personalized product sales • To improve customer loyalty and relationship
Customers	• To provide a service to search for and locate an in-store product • To provide fast and self-service checkout service • To alert customers to their favorite items and recommend to customers other related items • To enable customers to view products in the shopping cart and keep track of the total purchase amount
System Owner	• To provide user friendly interfaces • To provide accurate, consistent, and up-to-date shopping information throughout the entire store • To offer ubiquitous and instant access to product information

Stage 3: System Architecture. System architecture development is the initial process of identifying the subsystems and establishing a framework among subsystem controls and communications [Sommerville 2007]. The system architecture provides an encompassing and integrated environment for both logical design and physical implementation [Tung, Keim, and Ramirez 1992]. The mapping between the system and business processes is used to guide the application development and ensure integration takes place in the right way. It defines the functionalities of the components and describes how they communicate with each other.

An overview of the system architecture is shown in Figure 3. The figure depicts a PSA system consisting of five key components: (1) PSA client; (2) database server; (3) self-checkout server; (4) shopping cart embedded with an RFID tag; and (5) the RFID reader. All of them are linked up through a wireless network (WLAN).

We describe each of the key components following.

PSA Client: This provided the graphical user interface to customers. It was equipped with an RFID reader that detected the in-and-out movement of items to and from the shopping cart.

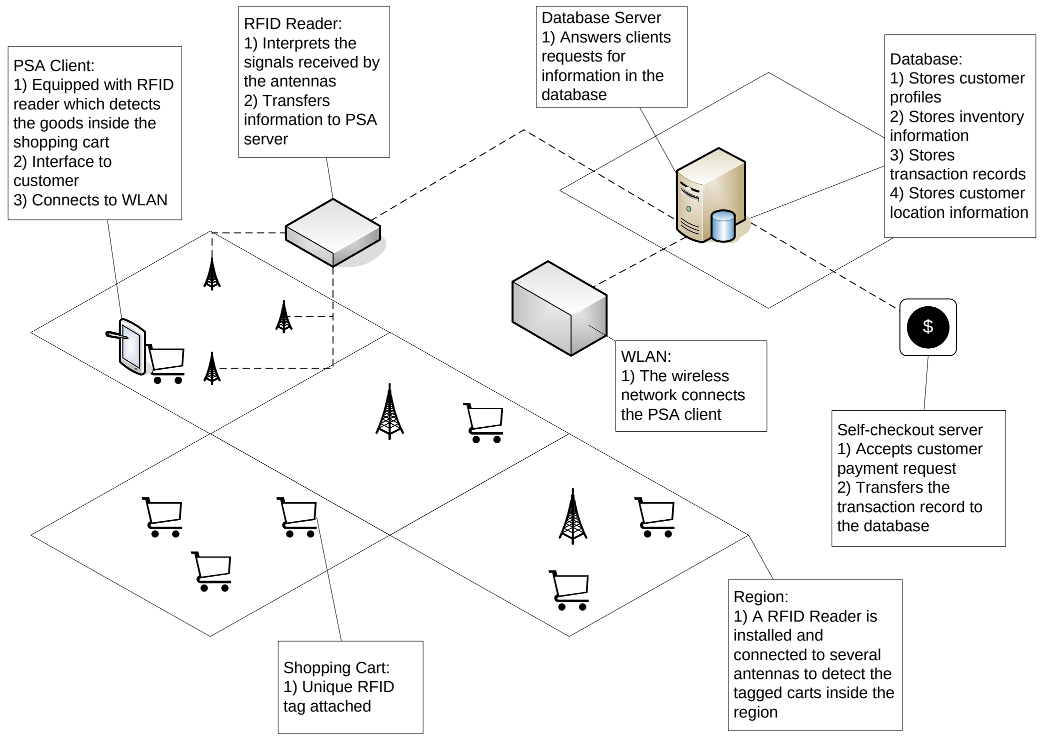

Figure 3. Overview of PSA System

Database Server: The database server consisted of various specific databases including customer data, product information, inventory data, transaction management information, and RFID information. For the execution of a query, the databases were accessed through an open database connectivity (ODBC) gateway.

Self-checkout Server: This processed the product checkout via self-service, computed the checkout amount, and accepted the payment from the customers. The transaction data were transferred to the relevant databases for record keeping.

Shopping Cart Embedded with an RFID Tag: A tiny RFID tag was embedded into each shopping cart. The tag information could be either read or written by an RFID reader to retrieve and update the product information in the cart.

RFID Reader: RFID readers were placed at fixed positions in the retail store and connected to several antennas to detect the flow and location of the shopping carts and products.

Stage 4: System Design. System design is an important aspect of system development. It involves an understanding of the domain being studied, the application of various alternatives, and the synthesis and evaluation of a proposed solution [Nunamaker et al. 1990]. In this phase, we identified the necessary system requirements of the prototype. We used data flow and entity relationship (E-R) diagrams to help effectively design and model the system. The PSA system consisted of three primary components: (1) the PSA client application; (2) the checkout server application; and (3) the PSA database. We describe each of the subsystem functionalities following.

1) PSA Client Application. This component contains four underlying modules, including an RFID module, product recommendation module, and enquiry module.

RFID Module. This module handles all RFID-related processes as shown in Figure 4.
The store is divided into several regions in which RFID antennas are installed to detect the flow of the shopping carts. Each shopping cart is attached with an RFID tag. The RFID antennas transfer the data to the server after receiving the signal from the RFID tag on the shopping cart. When a tagged shopping cart moves into a region, the antennas capture its signal. The signal received is then interpreted by the corresponding RFID reader and transferred to the PSA server. The server can therefore determine the location of the shopping cart. In addition, each shopping cart is installed with a PSA client that is connected to the server through the wireless network.

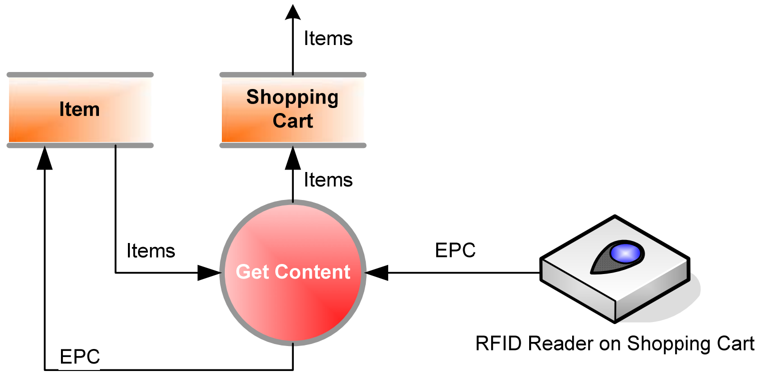

Figure 4. Data Flow Diagram of the Cart Content RFID-Related Process

The RFID reader on the shopping cart captures the in-and-out movement of products to and from the cart. When an item is put into or taken out of the cart, its electronic product code is captured. By referencing the relevant databases, the item is identified. This cart content information is then stored in a database, and the recommendation module accordingly generates upsell and cross-sell items to be advertised to the customers.

Product Recommendation Module. This module recommends items to the customers as shown in Figure 5.

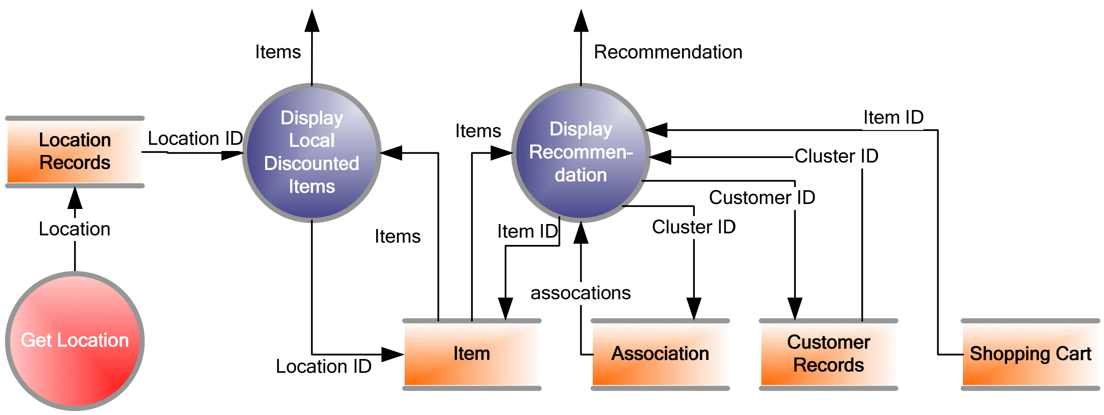

Figure 5. Data Flow Diagram of the Recommendation Generation Process

Data mining techniques such as association rule mining and cluster analysis are used to generate promotional items. The recommendation of the promotion items is based on customer segments and association rules.

Recommendation Based on Customer Segments. Market segmentation divides a larger market into smaller markets based on customer profiles. Clustering analysis is therefore adopted to segment a market [Changchien, et al. 2004]. Clustering analysis identifies clusters embedded in the data, where a cluster is a collection of data objects that are similar to one another. In other words, customers with similar values of demographic attributes are grouped together to form a smaller market segment to which the retailer promotes products different from those promoted to another segment. In our study, the k-means partitioning method is used [Han and Kamber 2001].

Algorithms Employed. Figure 6 shows the pseudo-code k-means algorithm. The basic strategy of the k-means clustering algorithm is to find k clusters in n objects by first arbitrarily finding a representative object for each cluster. Each remaining object is clustered with the medoid to which it is most similar, based on the distance between the object and the cluster mean. Then, the new mean for each cluster is computed. The process iterates until the criterion function converges.

Recommendation Based on Association Rules. The correlations among products should be analyzed in order to promote products by cross selling, and therefore an association mining technique is adopted to discover the product associations for cross selling. Changchien et al. [2004] suggested this technique can be applied to all customers' transaction records, cluster-wide transaction records, and individual transaction records. In our study, association rules are not mined from all customers' and cluster-wide transaction records, because of a number of constraints and the costs involved. Exact matches can require infinite capacities. All products were promoted to the customers according to their current context.

```
var customer_chain() as customers                    /* list of customers */
var k as integer                                     /* number of clusters */
var cluster_matrix()() as customer                   /* matrix of customers */

/* Select initial medoids */
for i = 1 to k do
        cluster_matrix(i, 1) = customer_chain(i)     /* set initial mean to list*/
loop

/* Assign customer to cluster */
var temp() as real                                   /* distance between mean and customer */
var temp_mean() as real                              /* mean of each cluster */
var change as boolean

for i = 1 to k do
        temp(k) = calculate_similarity(cluster_matrix(i))
loop

do
        change = FALSE
        for each customer in customer_chain() do
                for i = 1 to k do
                        /*calculate similarity of customer to the cluster mean */
                        temp(k) = calculate_similarity(cluster_matrix(i, 1), customer)
                loop
                /*add customer to list */
                add_customer(cluster_matrix(getMinimum(temp)), customer)
        for i = 1 to k do
                        if temp_mean(i) = calculate_cluster_mean(cluster_matrix(i))
                                change = FALSE
                        else
                                change = TRUE
                loop
        loop
until change = FALSE
```

Figure 6. Pseudo Code of the k-Means Algorithm

Input:
1. L, frequent itemsets in D
2. Minimum confidence threshold, min_conf

Output:
1. R, association rules from L

Method:
1. for each itemset $l \in L$
2. S_l = subset_gen(l) /* generate all nonempty subsets of l */
3. for each subset $s \in S_l$
4. if $\frac{support\_count(l)}{support\_count(s)} \geq min\_conf$ then
5. add "$s \Rightarrow (l - s)$" to R;
6. return R;

Figure 7. Pseudo Code of the Algorithm for Generating Association Rules from Frequent Item Sets

Algorithms Employed. The a priori algorithm shown in Figure 7 gives the steps needed for generating association rules from frequent item sets. As is common in association rule mining, given a set of item sets (in this case, items bought by customers in the supermarket), the algorithm is designed to find association rules in the data that are common to at least a minimum number C (the cut-off, or confidence threshold) of the item sets.

Enquiry Module. This module provides the capability of information on demand, ranging from item searching to customer profile modification, as shown in Figure 8.

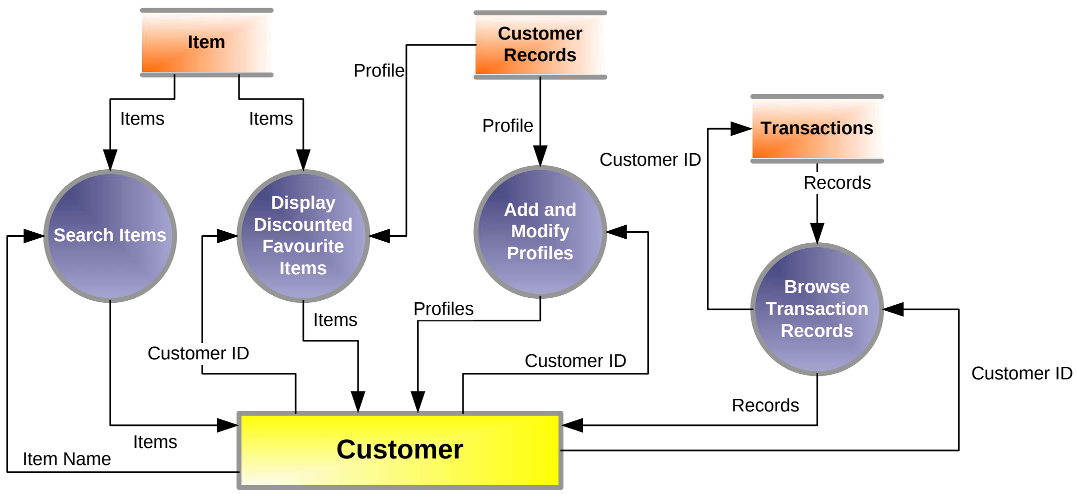

Figure 8. Data Flow Diagram of the Enquiry Process

Through the PSA client, customers can initialize and issue different enquiries, including product searches, discounted favorite item queries, personal profile viewing, transaction history browsing, and so forth. When the system receives an enquiry from a customer, this module accesses the relevant databases, and retrieves and presents the required information for the customer on a real-time basis.

2. Self-checkout Service Application When approaching the self-checkout area, a customer can trigger the self-checkout request using the PSA client. Then, the product checkout and payment service at the self-checkout machine can be invoked remotely via the wireless network. The machine displays all the product information sent from the PSA client, and computes and generates the shopping invoice. When the customer confirms the invoice on the PSA client screen, the machine debits the customer's account and settles the invoice instantly.

3. PSA Database This database is responsible for storing all of the data for the PSA system, including product information, customers' personal data, transaction information, and so forth. The PSA clients can use the JDBC driver to connect to the database server through the wireless network to access the required information in the data repository. Figure 9 shows an E-R diagram of the PSA database schema, which specifies the relationships among the various entities.

Stage 5: System Implementation. Prototyping is a quick way to demonstrate a solution to a problem. In the system implementation stage, a prototype system was built using a low-cost throw-away prototyping approach [Sommerville 2007]. We therefore developed the prototype of PSA system according to our architectural and system design. HyperText Markup Language (HTML), JavaServer Pages (JSP) and Javascript, and Macromedia Flash programming languages were selected for the development of web-based interfaces, as they were portable and compatible with most web browsers. In addition, we used Java and Java Servlets for developing modules in the middle tier, such as session tracking and flow redirecting, because most of the current application servers like Tomcat widely support these kinds of Java components. Finally, a structured query language (SQL) was used for writing statements and queries in the rational database management (RDBMS) system. The open database connectivity (ODBC) protocol was selected for communication between the database server and the application server. Both SQL and ODBC are compatible with a variety of RDBMS databases.

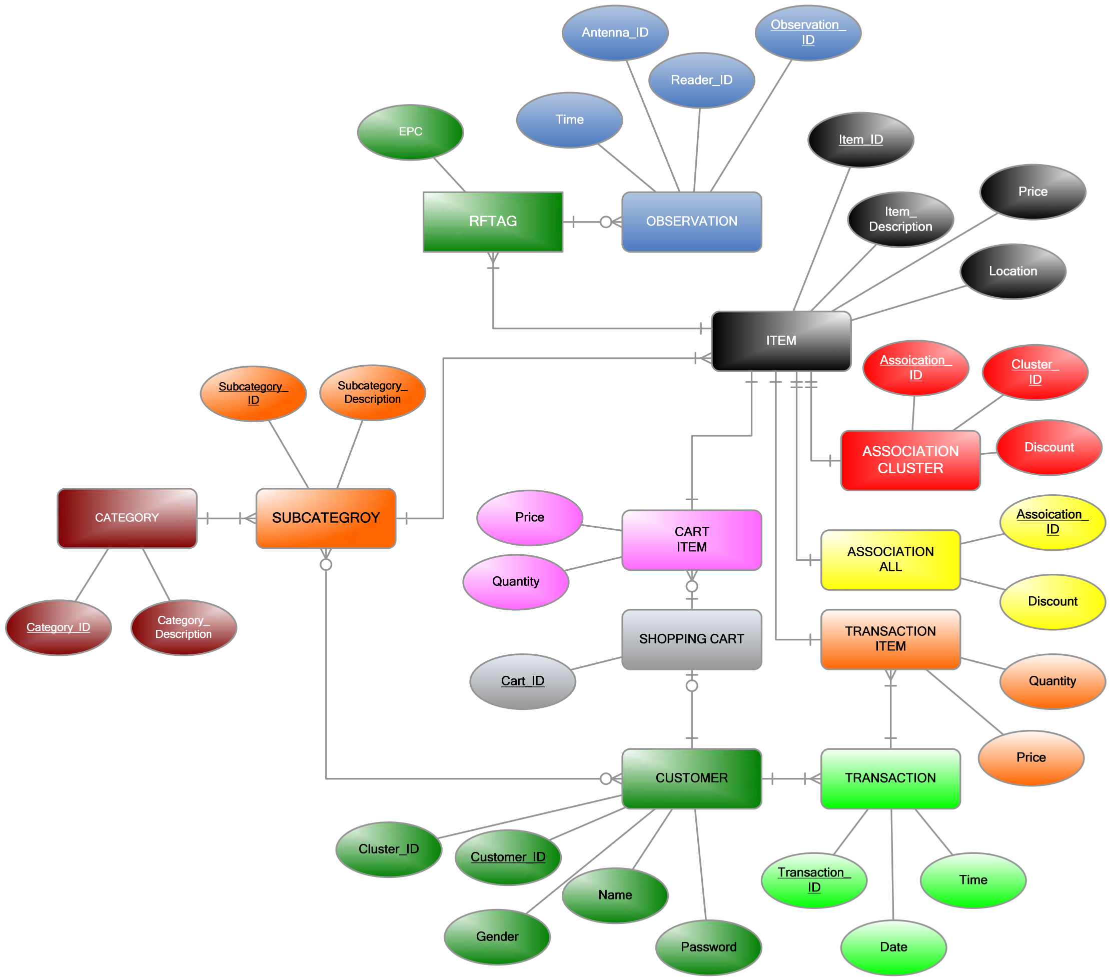

Figure 9. E-R Diagram of the PSA System

Stage 6: System Testing and Evaluation. Having developed the system prototype, we conducted testing and evaluation processes to ensure that the prototype conformed to its specifications and met the business needs of this stage [Sommerville 2007]. A set of formal tests, including module tests, integration tests, functionality tests, and performance tests, were performed to show that the prototype was free of bugs and errors. We employed a user questionnaire to document responses to the system testing. To obtain comprehensive feedback, 34 retail practitioners i.e. store supervisors and potential customers, and 10 retail store managers were invited to participate in the evaluation. At the evaluation session, the system prototype was demonstrated and the respondents' feedback was solicited through structural discussion and by using an evaluation questionnaire form. The questionnaire, which contained both closed and open-ended questions, had two sections covering: 1) the effectiveness of the prototype system, and 2) the usability of the prototype system. The respondents were asked to rate, on a five-point scale (1 = strongly disagree, 3 = undecided, and 5 = strongly agree), the two main aspects of the prototype system: its effectiveness and its usability. The results of the questionnaire analysis showed that the respondents rated the system highly in terms of the above two aspects, with a mean score of at least 3.6 on a five-point scale. From the customers' perspective, "customer convenience was improved," "enhancing promotional campaign efficiency," and "in-store self-service such as the checkout system was facilitated" that all evidenced from the one sample t-test using test value "3" was conducted on these items. We have ensured that the values of our mean responses were statistically significantly different from "3" i.e. the neutral values of the scale ("undecided") as well. The mean values for these three items in the questionnaire are larger than 3.00 and significant at a 5 percent level. The viability of the RFID prototype via an analytical CRM system in a retail store has been ascertained by positive feedback obtained from the questionnaire evaluation.

Table 2 summarizes the findings from the personal interviews with the 10 retail store managers regarding their perception of the value added by RFID technology to their store. Most of the interviewees agreed that RFID technology has a potential in various areas of retailing to help them to improve their operational efficiency and support an analytical CRM.

Table 2. Findings from the Personal Interviews with the 10 Retail Store Managers Regarding Their Perception of the Value Added by an RFID-Based PSA to Their Store

Interviewee	Excerpts of information on RFID-based PSA in a retail store
Interviewee A	I see this is a global trend to use RFID technology to enhance the business operations and that it can be used to better understand the customers' wants and their behaviors through a back-end CRM system in order to create a competitive edge. Wal-Mart is piloting RFID and some big retail store in Europe is trying it. I think it will come to Asia soon. It is certainly beneficial to both customers and retailers as it helps to improve the effectiveness and efficiency of business operations.
Interviewee B	With an RFID system, the inventory of products can be managed more easily and accurately. With real-time data, we can replenish products as soon as possible without the problem of stock-out. Employees can have real-time information that will enable them to better perform inventory management.
Interviewee C	I heard about the concept of RFID in a seminar and am glad to see that this RFID system can support a retail store. The system looks very intelligent and can enhance customers' shopping efficiency and retailers' operational efficiency. It also enables one to track every tagged element and customer purchase behavior. It certainly adds value to both customers and retailers.
Interviewee D	From a customer's perspective, it can improve customer convenience and accelerate the buying process. I like that it can provide more "personalization" in the shopping process and I can easily find what I want. From a retail store manager perspective, I find it is much easier to understand buyers' behavior and enables one to obtain real-time data that can prevent stores from running out of stock of a particular product.
Interviewee E	I am not optimistic with this technology but I do have hope that it can be used to replace bar-code technology in the future. Automatic data capturing adds the value to beyond bar-code technology. However, I see there will be resistance from the local community regarding the private issues.
Interviewee F	The system looks like it can do a lot of things for consumers and marketers. I believe it can benefit both customers and marketers, and improve the effectiveness and efficiency of business processes in a retail store. However, I am concerned about privacy issues.
Interviewee G	A real-time data acquisition system is difficult to get and I see that RFID technology can help. Theoretically, it can help a retail store with inventory management and can save the time spent on checking the availability of items on shelves. Obtaining real-time data can assist retail managers to make their decisions more easily and quickly.
Interviewee H	CRM is not a new concept to me but RFID is. The new RFID system has useful system functions and it can understand customer needs and product preference via the backend CRM system. Capturing what customers need and want is wonderful. So it can provide product recommendations to potential customers.
Interviewee I	The benefits of using an RFID system for a retail store are huge to both customers and the company. It can reduce the time that customers spend lining up at the checkout counter, and it can interact with customers through a CRM system. As managers, we can improve the decision-making process by analyzing the captured data through some data-mining technique.
Interviewee J	It is nice to see what is happening to each item in the store and what each customer's buying behavior is like. A real CRM system would help improve customer satisfaction, interact with the customers, and develop customer loyalty and relationships.

V. RFID VALUE GRID

Regarding the practical value of RFID-based PSA prototype, it is important to evaluate the potential of such IT artifact in solving the challenges the retail industry faces. Therefore, on top of the formal system testing and evaluations in stage 6 of the "system design and development", we proposed to develop the RFID value grid to assess the potential of RFID-based PSA prototype in producing value and enhancing organization's competitive advantages in a retail store. Based on the studies of Riggins [1999] and Hammer and Mangurian [1987], as well as the results of our interviews with the 10 retail store managers, we develop an RFID value grid that includes an impact/value framework which can be used to assess the value of the RFID technology to the retail industry. In constructing this grid, we considered four dimensions of competitive factors (time, relationships, interaction, and product) and three benefits of value creation (efficiency, effectiveness, and innovation) that are crucial to enable a retail store to compete in the retail industry. Riggins [1999] commented that efficiency benefits accrue when a retail store uses RFID technology to perform the same tasks, while other strategic benefits accrue as the RFID infrastructure facilitates a new way of doing business for a retail store [Riggins 1999]. RFID can achieve better information accuracy than barcode technology in retail operations. Based on the idea of the "electronic commerce value grid" proposed by Riggins [1999] and Hammer and Mangurian [1987], Table 3 presents the value grid for a retail store as generated by RFID technology.

Table 3. RFID Value Grid for a Retail Store

Value Creation / Dimension	Effectiveness	Efficiency	Innovation
Time	Enable instant checks and auditing of inventory from store room to store floor to eliminate human error, avoid stock-outs and avoid auditing costs	Improve customer convenience and flexibility in the shopping process to accelerate the business process and enhance customers' shopping efficiency	Create service excellence by empowering customers to use self- and automatic services to enhance shopping efficiency and reduce in-store labor requirements
Relationships	Capture customers' actual purchase behavior and preferences to enable one-to-one marketing and relationship management	Enable more sophisticated and personalized in-store service by offering improved in-store promotional campaign efficiency	Create a unique shopping experience and atmosphere to develop customer loyalty and relationship
Interaction	Collect customers' in-store shopping path movement to better understand their shopping needs and product preferences	Provide interactive product recommendation information to facilitate customers' purchase decision making	Build closer interactions and increase customer intimacy to create a more competitive edge for a store
Product	Accelerate change of product information and management of product recalls to improve product's information visibility and tracking	Improve product availability on the store shelves to eliminate stock-outs, and promote in-store cross selling and upselling to boost sales	Improve inventory forecasting and product tracking, prevent stealing, and foster compliance to achieve better store operations and management

Emerging Research Propositions

To better understand whether, and if so, how retailers will adopt RFID in their retail stores, we present four research propositions, which are based on the theoretical framework of the RFID value grid and the results of the interviews with the participants (10 retail store managers) of the prototype system. We believe that future empirical studies in this area should further investigate RFID's ability to support the effective management and operations of retail stores. The following discussion explores the reasons why we posit these propositions.

Proposition 1: The business values that are generated by using RFID technology can improve customer service delivery and satisfaction in a retail store via an analytical CRM system.

RFID technology can significantly improve customers' shopping experience. It enables a self-checkout service in the store and empowers customers to use this service to shorten their checkout lining-up time. Use of RFID technology, in addition, can make shopping easier. It allows ubiquitous and instant access to in-store product information and enables an interactive product recommendation service to customers. Customers can more wisely choose their products and make purchase decisions that maximize their total basket value. Through the collection of information about customers' shopping behavior patterns and preferences, retailers can easily data mine customers' shopping habits and patterns, allowing the provision of more personalized services to boost customer satisfaction and loyalty via an analytical CRM system. In our interviews with the 10 retail store managers, Interviewees A, H, I, and J perceived that RFID technology can improve customer satisfaction and help retain existing customers in a retail store via an analytical CRM system.

Proposition 2: Through the RFID intelligence built into the retail store management system, in-store shop floor operational management can be used to improve the effectiveness and efficiency of business operations.

Through the RFID intelligence built into the retail store management system, customers can pre-input their shopping lists via the Internet or a mobile network into the system. Upon customers' arrival at the store and their logging into the system, the retailer can proactively iterate through their shopping lists to ascertain the on-shelf product availability, identify the shelf level stock-outs, and alert store assistants if timely and responsive replenishment is required.

RFID technology also improves in-store promotional campaign efficiency and on-shelf product availability. It enables more sophisticated and personalized in-store service to be offered, and better accuracy of inventory. It also improves store security and helps reduce inventory auditing costs and labor requirements.

Use of RFID technology can also enable more in-store self- and automatic services. This will help reduce staff workload and staff headcount, for example, at the checkout counters, giving store managers the flexibility to redeploy resources to other key areas. Product-level tagging helps not only eliminate the need for manual stock checks and thus reduce inventory auditing costs, but also to prevent theft by setting off an alarm if the product is taken outside the store. Interviewees A, B, C, F, and G perceived that RFID technology can make business operations more effective and efficient.

Proposition 3: RFID technology can provide product information and recommendations to customers, particularly across various customer-contact points, via an analytical CRM system in a retail store.

As each shopping cart in a store is also equipped with an RFID tag, in-store readers can record the movement of the carts and provide a more complete picture of customers' shopping paths. These devices can collect information about customers' purchase behavior patterns and shopping path movement to enhance in-store information visibility. Product-level tagging data also helps instantly pinpoint recalled products and get them removed from the distribution chain. Each product in the store is embedded with an RFID tag, and each tag stores the information about the product ID, price, expiry date, and other information. Readers equipped with antennas are placed at strategic locations within the store. When a customer takes a product from the shelf, the reader nearby can read the product tag information and send it to the store management system. The system can proactively provide more useful and relevant product information to customers. Through an intelligent client interface, the system can provide interactive product recommendations to customers. When customers have finished shopping, the information on items they have purchased can be collected in order to analyze their shopping behavior and preferences. This will enable the personalization of the relationship with the customer and the broadening of the retailer's response to the customer's needs. Furthermore, these data can be used to support strategic customer information provision and customer knowledge acquisition. Unlike barcode technology, product-level tagging allows the RFID reader to track an item without requiring the item to be physically scanned. RFID technology allows for more personalized promotions to be disseminated in-store. Interviewees A, H, I, and J perceived that RFID technology can provide product information and recommendations to customers and can help to develop better relationships through an analytical CRM.

Proposition 4: Through RFID technology, there has been a major paradigm shift to offering more self- and automatic shopping services in retail stores in order to enhance shopping service quality, satisfaction, and efficiency, and to create a competitive edge for stores.

The use of RFID technology enables flexible and available in-store self-shopping services. These kinds of services provide shopping convenience, a better choice of product selection, and a differentiated shopping experience and atmosphere for customers. We believe that this can improve shopping service quality, satisfaction, and efficiency. In addition, through the RFID readers, customers' shopping habits and preferences can be collected and analyzed. This information is valuable for facilitating closer interaction and increased intimacy with customers in order to create more benefits for both customers and retailers. Such customer relationship management not only encourages more potential and actual customers to share shopping preferences in order to maximize the value of their shopping experience, but also gives retail stores a competitive edge in the retail industry (refer to Table 2: Interviewees A, B, and G).

VI. CONTRIBUTIONS OF THE STUDY

We design and develop an RFID-based PSA prototype system and evaluate it as a proof of concept. The contributions of this research are the design artifacts—RFID-based PSA system (a system architecture and its implemented prototype system). In addition, we develop an RFID value grid that includes an impact/value framework which can be used to assess the value of RFID technology in the retail industry. The grid can be used to benchmark one organization's retail store against that of another. Furthermore, based on our proposed conceptual framework of the RFID value grid and interviews with 10 retail store managers, we have presented four propositions which can be empirically tested in future research. Future empirical and conceptual research could work to refine and validate our propositions. We believe that this study provides a theoretically grounded basis upon which future research about the RFID systems implementation can be built.

VII. CONCLUDING REMARKS

This paper has described the research and development with regard to an RFID-based PSA prototype system that can be used to extend CRM in retail management. RFID technology can be used for real-time determination of product availability and customer movement, enabling dramatic improvements in operational efficiency and customer service. In this study, we demonstrated that RFID is a promising technology that can be used in the retail industry to support analytical CRM in a retail store. From the customers' perspective, customer convenience is improved and in-store self-services are facilitated, such as the purchase of items at a self-service checkout, thereby empowering customers.

There are certain limitations to this research that may suggest some opportunities for further investigation. We designed and developed the RFID-based PSA system based on a single retail store. Our sample size of ten retail store managers was small (and Hong Kong-based), and selected using a convenience sampling approach. This study should be considered as only the beginning of research in this promising area.

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