RFID APPLICATION FRAMEWORK

FOR

THEME PARK MANAGEMENT SYSTEM:

SUNWAY LAGOON THEME PARK

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By

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DECLARATION

I certify that all the work described in this dissertation was undertaken by myself (unless otherwise acknowledged in the text) and that none of the work has been previously submitted for any academic degree. All sources of quoted information have been acknowledged through references.

Chong Kon Ming
May 2008

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ABSTRAK

Teknologi Pengenalan Frekuensi Radio (RFID) membolehkan data ditransmisikan oleh alat kecil yang mudah alih dipanggil “Tag” yang akan dibaca oleh pembaca RFID and diproses mengikut keperluan tertentu. Teknologi sedemikian hanya mula bertapak di pasaran dunia baru-baru ini. Analisis menjangkakan bahawa RFID akan mencetuskan revolusi terbaru dalam bidang industri seperti Pengurusan Rangkaian Pembekalan (Supply Chain Managment (SCM)), Pengurusan Perhubungan Pelanggan (Customer Relationship Management (CRM)) dan perniagaan runcit (retail business) melalui pengurusan stok yang lebih sempurna dan justeru itu, mengurangkan kos. Thesis ini mengfokus ke atas penggunnaan rangka teknologi RFID di dalam Sistem Pengurusan Taman Tema (Theme Park Management System).

ABSTRACT

The technology for Radio Frequency Identification (RFID) enables data to be transmitted by a tiny portable device, called a tag, which is read by an RFID reader and processed according to the needs of a particular application. It is only recently that the technology has begun to take off in the mass market. Analysts predict that RFID will revolutionize areas of industry, such as Supply Chain Management (SCM), Customer Relationship Management (CRM), and the retail business, for example by reducing costs with better stock management. This paper focuses on the application of RFID technology framework in Theme Park Management System.

ACKNOWLEDGEMENTS

A special acknowledgement is for my supervisor, Dr Mohd Syazwan Bin Abdullah @ Pathmanathan and all my Professors, lecturers for their kindness, time and effort offered in providing guidance, meaningful and valuable knowledge and information during all my study. Also, full respect for Associate Professor Dr Norshuhada Shiratuddin as lecturer for the subject (TIV 6043). The encouragement and support from all my classmates and external sources like Internet does help a lot in completing this project.

Lastly, I would also like to express my honor appreciation to my wife, Esther Wong Pei Ying, for support that she had offered which never stop from times to times.

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1.1 Sunway Group Background

The Sunway Group stands as one of Malaysia's foremost, well-diversified conglomerates in leading position in several industries.

Since its foundation in 1974 as a tin mining company, The Sunway Group has continuously aimed at excellence in every field of its operations as it diversifies and grows in tandem with national progress. This, the Group has made possible through strategic alliances with the government and private sector both on the home front and internationally.

Figure 1: Sunway Group Attraction

The Sunway Group is made up of three public listed companies, each consisting of divisions and classified by the nature of the business. They are Sunway Holdings Incorporated Berhad (SunInc), Sunway City Berhad (SunCity) and Sunway Infrastructure Berhad (SunInfra).

Sunway City Background

SunCity Group's key business segments are as follows:-

a) Property Development

b) Property Investment

c) Leisure and Entertainment

d) Hospitality

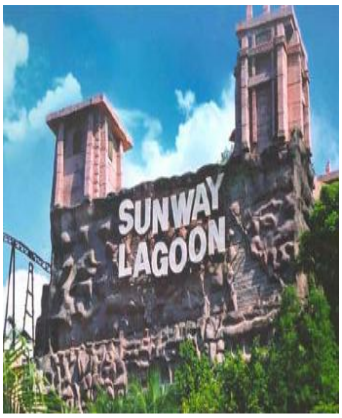
e) Healthcare

Figure 2: Sunway City Key Business

ABOUT SUNWAY LAGOON (Leisure & Entertainment)

Sunway Lagoon Stands as Malaysia's Premier Theme park. Officilly opened on April 29, 1993 by Prime Minister YAB Dato' Seri Dr Mahatir Mohamad, Sunway Lagoon is Malaysia's Premier Theme Park and has become the most visited tourist destination in the country.

Sunway Lagoon is strategically located in the township of Bandar Sunway in Petaling Jaya. Spanning 80 acres, the Lagoon draws fun seekers from all over with its reputation as fascinating land of fun and excitement.



Sunway Lagoon is separated into 3 major themed lands, each boasting their own exciting attractions. Find entertainment, adventure and excitement all in place. A place will bring back more than just memories.

Figure 3: Sunway Lagoon Theme Park Attractions

Sunway Lagoon, Malaysia premier theme park has over 1.2 Million guests visit yearly. Being one of the largest wet and dry Theme Parks in the South East Asia, Sunway Lagoon has the need to manage visitors, guests, sales and all other assets efficiently using technology.

Some processes of the existing workflow in Sunway Lagoon that needed to improved by introducing and to acquire new technology. Currently greatly relies on manual process to identify visitors in entering parks that they purchased barcode hand tag. Barcode is based on open standards -ISO 15426-1 that having:

- a line-of-sight requirement,
- the constraints of limited,
- static data
- problems caused by inconsistent print quality on barcode Tag
- need for a particular orientation.

The existing workflow of the process area requires enhancing by introducing or adapting new technology –RFID.

1.2 PROBLEM STATEMENT

Sunway Lagoon are currently greatly relies on barcode manual process to identify visitors when entering parks after purchased ticket. In the other hand, visitors needed to hire lockers to store their valuables as well as cash. In the tube rental area, cash transactions are the only valid payment method. In such situation, problems are generated in both the admission and the park area. Most of the existing systems are not linking together. Technically, databases are not centralized and there is no data analysis system for Customer Relationship Management and Marketing as figure 4 and figure 5 attached.

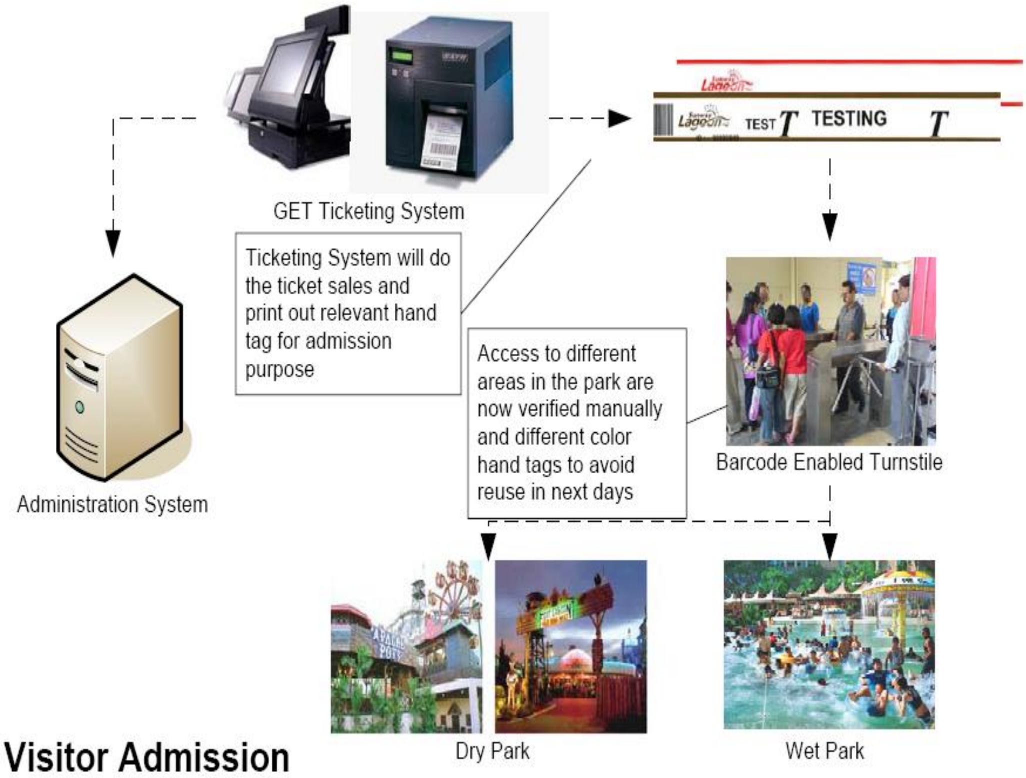


Figure 4: Current Workflow Visitor admission

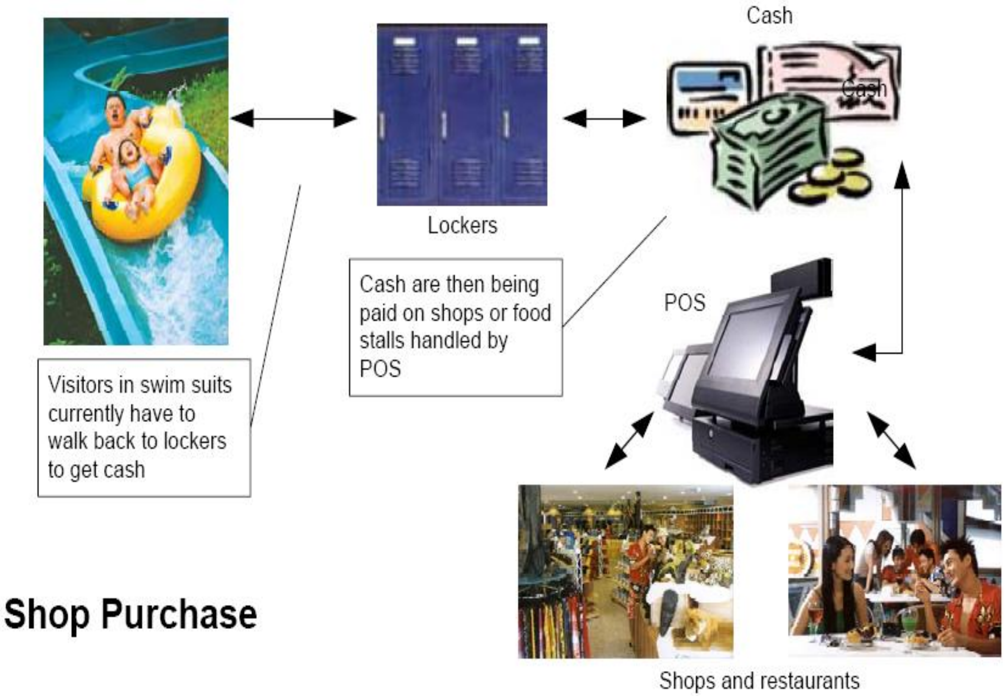


Figure 5: Current Workflow Shop Purchase

As shown in the above figures, that creates some possible problems on current situations.

Front End:

- Security guards need to identify each visitor's hand-tag to differentiate wet/dry park visitors manually. This labor intensive might lead to human errors or other administration problems
- Current visitors needed to hire lockers to store all valuables as well as cash. In the tube rental area, cash are the only payment method and also handled manually. In such situation, problems are generated in both the admission and through the park area.
- Visitors in swim suits cannot carry cash easily throughout the park. Inconvenience in cash carrying leads to low intention on shop purchase.

Moving to backend:

- All the databases or existing systems are not well linked together. Technically, databases are not centralized and there is no data analysis system for Customer relationship Management and Marketing.

- No analysis tools available, thus no Customer relationship Management (CRM) systems handling visitors data such as the visiting trend, age group, nationality, etc and hence, there is not sufficient data for marketing or for future planning.
- From users' feedback/data collection, the existing reporting function is non-flexible and non customizable that lead to difficulties of marketing analysis and planning.

This Project is attempted to provide viable solution in addressing the problems above.

1.3 OBJECTIVES

The main objectives of the project as listed below:

To propose and design model for RFID application to be used in Theme Park Management System.

The objectives can be further divided into the following sub-objectives:

1. At The Front End:

   To implement RFID Reader enable to all the front-end POS terminals, including Ticketing POS, F&B POS, Retail POS and Tube Rental POS Entrance with prepaid value store immediately in the system according to RFID hand-tag that enhance business processes

2. At the Back End:

   To produce Centralized Administration System for all POS via LAN to the backend Server that manage provide Data in real time, Customer Relationship Module (CRM) analysis relating to the prospects visitors data such as visiting trend, age group, nationality and inventory relating to better planning and decision making.

1.4 SIGNIFICANCE OF STUDY

The significance contributes by this project are:

Single Integrated System (Ticketing, Retail, and F&B), coupled with powerful (CRM) Customer Relationship Module, with cutting edged RFID technology in place to increase the operation efficiencies in term of lead time, accuracy and better customer experience.

1.5 SCOPE AND LIMITATION

This project was limited by several factors that have to be taken into consideration. One of critical factor is RFID tag vulnerable to viruses. If certain vulnerabilities exist in the RFID software, an RFID tag can be (intentionally) infected with a virus and this virus can infect the backend database used by the RFID software (IDG, 2007). From there it can be easily spread to other RFID tags. Indirectly, an RFID buffer overflow bug could infect RFID Database for baggage, and also to obtain valuable information.

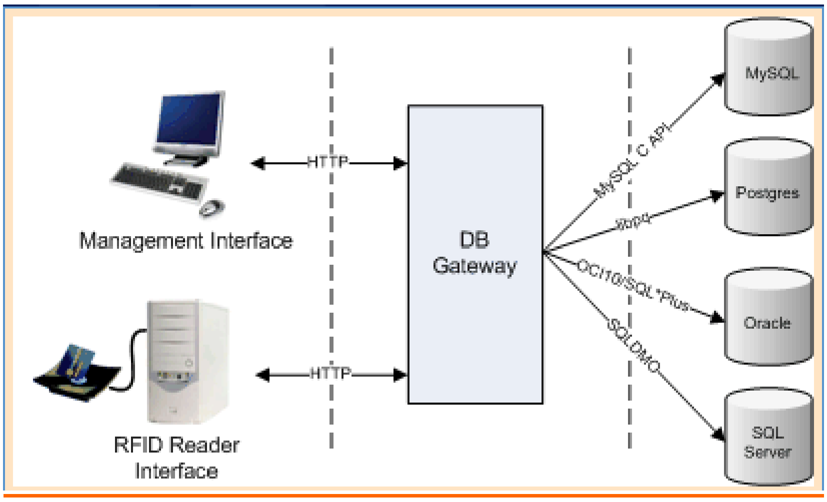


Figure 6: RFID Vulnerability (IDG, 2007)

Therefore designers of RFID systems should take into consideration of the deployment of the vulnerable systems.

OTHER IMPLEMENTATION FACTOR CONSIDERATION

DATA PRIVACY

One of the major issues with implementation RFID is more of a social issue than a business problem. When a product that is tagged with a bar code leaving a department store, the information for the product has been collected and the tag is essentially dead. However a RFID tag continues to emit signals containing information. This becomes a privacy issues because the product can be tracked even after the sales is complete and essentially throughout the life cycle of the product.

A possible solution could be disabled the RFID tag when the item is sold. This would ensure that the last stage of information gathering occurs at the checkout counter.

Another solution could be having the RFID tags in tear-away labels. For example: Wal-Mart does not have to implement RFID disabling procedures at every checkout counter.

In trial implementation, Tesco used RFID technology primarily as a theft prevention measure. This test run was heavily protested by privacy advocates. Wal-Mart also conducted trials in which they more focused on inventory tracking of pallets and bins.

CHAPTER 2: LITERATURE REVIEW

In this chapter, will discuss on the technological changes have influenced the various industries. Speed and automated processes to the consumer on time have become a major push to manufactures, grocers and retailers increase margin profitability. Radio Frequency Identification (RFID), tags, barcode and cost-benefits will be discussed as to the influence of Theme Park industry and getting improved results from Theme Park Management System.

2.1 RFID Theme Park Management System

Theme Park Management System (TPMS) is designed base on passive RFID tag technology appear with 13.56 MHz carrier frequency range capability with the following observation and conclusions that include the following components:

At the Front-end

- FRID Enabled Ticketing System with POS
- RFID Store Value Hand-Tag for Admission
- RFID Readers Installed to Turnstiles, Retails POS and F&B POS
- RFID Enabled Retail Shop POS
- RFID Enabled Food and Beverage POS
- Automatic Store Value Deduction Payment System for POS
- Tube Rental POS

At the Back-end:

- Centralized Administration System for All POS
- Customer Relationship Management Module linked to the Centralized Administration System
- Inventory Management System linked to Shop
- Event Order Management System linked to Inventory System for Budgeting
- Optional Handheld Terminal Module linked to Inventory for Stock-In/Stock-Out/Stock Take purpose

RFID offers many more superior capabilities to barcode:

Summary Comparison of Barcode and RFID Technologies		
	Barcode Technology	**RFID Technology**
Contact for reading	Requires line-of-sight. This is generally considered a disadvantage as where precise targeting is required (RFID IEE, 2005) .	No line-of-sight required (Boss, Richard W, 2004, 2005). This tends to be an advantage for systems that aim to eliminate human intervention, e.g. baggage handling and document inventory systems. RFID has an advantage in dirty or harsh environments where a barcode would become obscured.
Speed of reading	Barcodes are scanned one at a time. (RFID IEE, 2005)	Depending on technology used, up to several hundred RFID tags can be scanned in a single second by one reader (Bylinsky, 2000).
Read or write	Once printed, a barcode cannot be modified. (RFID IEE, 2005)	Some (not all) RFID tags allow information to be modified. Typical capability is 100,000 write operations with a 10 years data-retention lifespan (Bylinsky, 2000).
Security	Data on barcode could be encrypted; however, they provide no protection from being copied. (RFID IEE ,2005)	RFID tags allow more sophisticated forms of data protection.

Table 1: Barcode & RFID Technology Comparison

2.2 Technology

2.2.1 Barcoding

Traditionally, retailers, manufacturers and logistics have used bar coding as a quick and easy way to track inventory. Bar coding uses several symbologies (digital languages) to digitally encode data so that it may be read optically by a computer-based scanner. Bar coding has distinct advantages over keyboard data entry in terms of data accuracy, data transfer speed and versatility. (SystemID Warehouse, 2001)

The disadvantage of bar coding is that each item (unit, batch, truck, etc) must be scanned manually. There have been several attempts to automate barcode scanning with mixed results. Barcodes can only store a limited amount of information. Once a tag is printed, the information contained in that tag cannot be changed. The tag must be changed when information is modified. Degradation of barcode tags is a big issue as well. A dirty or damaged tag cannot be read. And protecting these tags in harsh environments is a challenge.

2.2.2 RADIO FREQUENCY IDENTIFICATION (RFID)

2.2.2.1 THE HISTORY OF RFID

RFID is making headlines now, but it is the product of a decades-long process of technological evolution. RFID found some of its first applications in the military. It is now being taken up by business. In the future RFID will be adopted by individual private users (Shrouds of Time, The history of RFID, 2001)

One way to think about the evolution of RFID is to follow the evolution of three major uses: vehicle tracking, container tracking, and object tracking (see Figure 7).

RFID as a Tracking Technology, 1945-2010(Institute for the Future, April 2005).

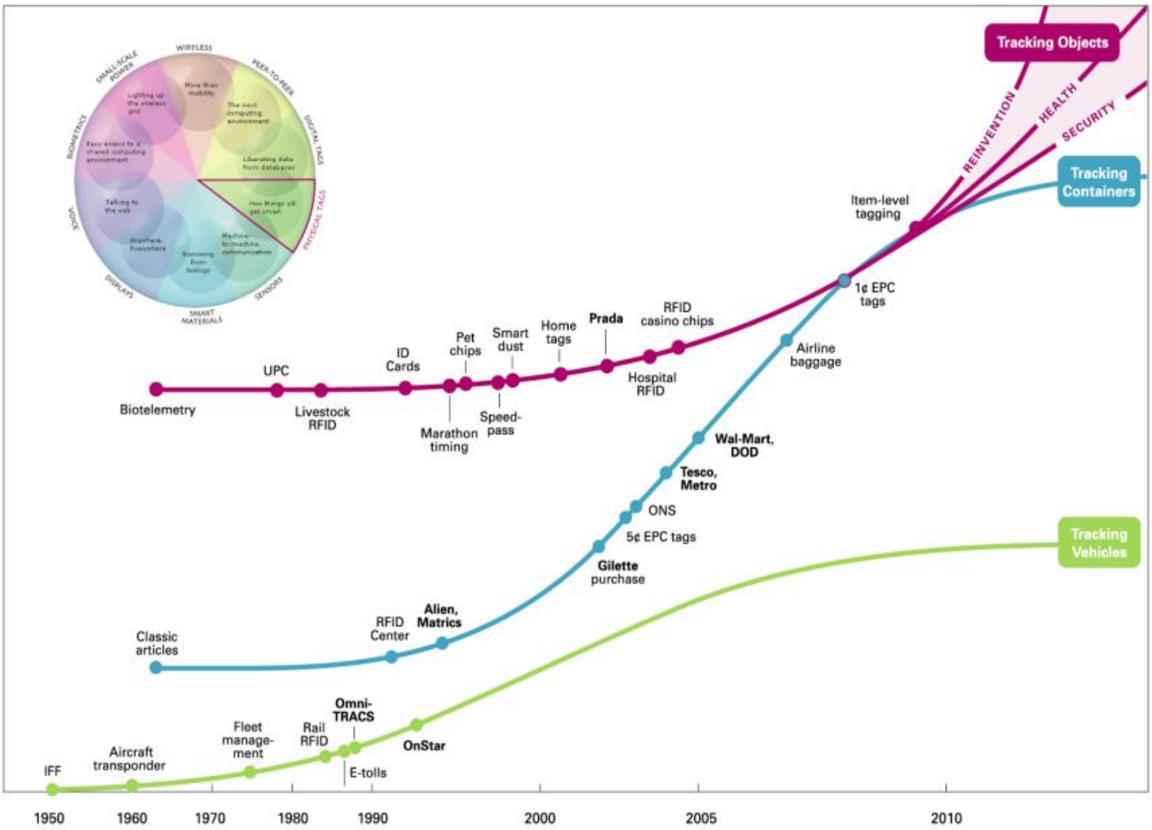


Figure 7: RFID Tracking Technology (Institute for the Future, April 2005)

2.2.2.1.1 VEHICLE TRACKING

The first RFID-like technologies were used in World War II, in IFF (Identification Friend or Foe) systems. The transponders installed on the aircraft, which broadcast a signal that could be read by fire-control crews. In 1960, government required civilian aircraft install the transponders, to assists air traffic controllers keep better track of aircraft. In the 1970s, in fleet-management systems used on railroads and trucks. OmniTRACS, a leading fleet-management system company, opened in 1989. RFID begin to make its way into private autos in the late 1980s. The first electronic toll systems, used by commercial vehicles and private autos, appeared in 1988 in Europe, and spread to the United States within a couple years. In 1996, GM launched OnStar, which uses GPS (Positioning Satellite System) and wireless technology to provide drivers with emergency roadside assistance, remote unlocking, directions, and concierge services (Institute for the Future, April 2005).

2.2.2.1.2 CONTAINER TRACKING (Institute for the Future, April 2005)

Container tracking was discussed as early as 1960s, but the technology didn't take off until the early 1990s, with the opening of MIT's Auto-ID Center, and similar laboratories in Cambridge, Switzerland, Australia, Japan, and China. Container tracking is the epicenter of RFID today and its adoption curve is primed to take off now. The ONS (Object Name Service) was opened in early 2004. In 2005, Wal-Mart and the U.S. Department of Defense will require suppliers to use RFID on pallets and cases of goods, and a number of other retailers are following suit. All these projects are focused on improving warehousing, delivery, and inventory control. There are also container-level experiments using RFID as a security technology. The first state laws mandating use of RFID for drug safety purposes go into effect in 2005. Several airlines and airports are also experimenting with RFID-enable baggage tagging.

2.2.2.1.3 OBJECT TRACKING

Object tracking has been around since the early 1960s, when biologists first used radio transponders to track large mammals. (This practice really took off in the late 1960s and early 1970s.) But as with container tracking, there has been a long lag time between early adopters and the mainstream. The 1990s saw the emergence of RFID in a variety of object tracking application: contact less ID cards, marathon timing system (in which RFID tag worn on runners shoes activate an electric mat at the start and finish lines), implantable pet ID systems, and rapid payment systems used in gas stations and toll booths. Around 2000, a few companies also begin to sell keychain-sized radio frequency tags that can be attached to PDAs, remote, and cell phones. More recently, libraries have adopted systems that use RFID tags embedded in books to speed up book checkout and shelf inventory (Institute for the Future, April 2005).

2.2.2.2 Classification of RFID tags

RFID tags can be active, passive, or semi-passive.

Characteristics	Active	Semi-Passive	Passive
Power Source	Battery	Inductive	Inductive
Memory	up to 288kg	Variable	up to 288kg
Read Range	< 1,500 feet (500m)	< 100 Feet (30m)	< 15 to 30 feet (10m)
Class	0 (read only) 3 (write once, read many) 4 (multi read / write)	3	0 (read only)
Frequency	Low (125, 134 KHz) High (13.56 MHz) Ultra High (868 to 930 MHz) Microwave (2.4 GHz)	915 MHz 2.4 GHz	Not Applicable 303, 433 MHz

(RFID Technology, RedPrairie)

Figure 8: RFID Classification

2.2.2.2.1 Passive

Passive RFID tags rely on the energy of the incoming signal to power their responses, and therefore the distances they can be read are much shorter because the energy used is much less (from about 10mm up to about 5 meters, but typically a few centimeters) and can only transmitting limited amount of information. Yet, the lack of power supply gives passive tags their unique and main selling point, that they can be very small in size. One of the smallest passive RFID chips, Hitachi's µ-Chip is only 0.4mm x 4mm in size and barely visible with the naked eye. It contains a unique 128 bit number that is written onto the chip during the manufacturing process and cannot be changed. (World's smallest and thinnest 0.15 x 0.15 mm, 7.5 µm thick RFID IC chip, Feb 2006).

2.2.2.2.2 Semi-passive

Semi-passive RFID tags are very similar to passive tags except addition of small battery. This battery allows the tag to be constantly powered, which removes the need for the aerial to be designed to collect power from the incoming signal. Aerials can therefore be optimized for the backscattering signal. Semi-passive RFID tags are thus faster in response, though less reliable and less powerful than active tags. (RFID Technology, RedPrairie.)

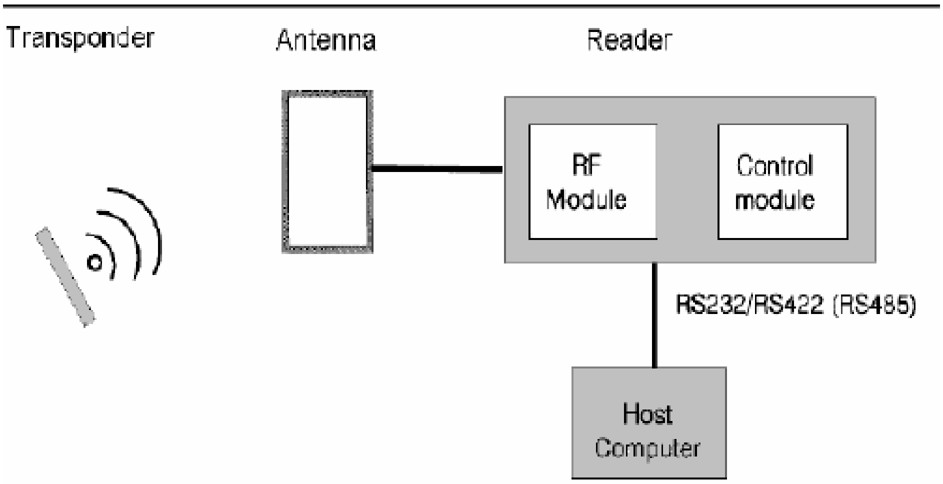
2.2.2.2.3 Active

Active tags functions the same way as their passive, except that they have their own power source and thus longer ranges (dozens of meters) and more memory. Because of this power source, active tags today are bigger and more expensive. Becoming smaller and cheaper, they might be the choice of the future. For example, a new generation of active tags called "Dice" was presented by YRP Ubiquitous Networking Labs in April 2005. They are about 15mm x15mm x 15mm and according to the manufacturer, the battery will last for 2 years and 3 months if the tag communicates every 5 minutes. If manufactured in volume, the price of a "Dice" tag will might be at the "lower end of several dollars".

2.2.2.3 The RFID System

An RFID system may consist of several components: tags, tag readers, edge servers, middleware, and application software *(*Jeff Kabachinski. Biomedical, 2007).

RFID tags are usually viewed as a wireless link to uniquely identify objects or people. The basic RFID system consists of two basic components – a transponder (i.e., the tag itself) and a transceiver (i.e., the reader). The tag consists of an antenna and an integrated circuit which requires a small quantity of electrical energy to function. The power source, in this case is not a battery, but a low-level radio frequency magnetic field which is emitted by a tiny antenna on the reader. When the tag is brought into the vicinity of the reader, at a range of typical three to four feet for passive tags, the transponder gathers energy from magnetic field, processes the information, and emits a radio frequency signal back to the reader for processing (HiPoint, 2002).



Components of the reader/transponder system

Figure 9: RFID Components (d'Hont, 2002)

2.2.2.4 RFID Carrier Frequencies

The carrier frequency is an important consideration in both inductive/passive and propagation/active RFID systems. It distinguishes the vehicle for carrying data across the air interface. It also provides a convenient classifier for distinguishing the inductive/passive and propagation-based/active divisions of RFID technology and the spectral regulatory constraints that govern their use in different countries of the world.

(Shepard, 2005) divides transponders frequencies into 3 major carrier frequencies regions distinguished for RFID for which there is a degree of international harmonization as show Table 2.

Frequency Bands and Applications

FREQUENCY BAND	CHARACTERISTIC	TYPICAL APPLICATIONS
Low 100-500 Khz	Short to medium read range Inexpensive Low reading speed	Access control Animal identification Inventory control Car immobilizer
Intermediate 10-15 Mhz	Short to medium read range Potentially inexpensive Medium reading speed	Access control Smart cards
High 850-950 Mhz 2.4-5.8 Ghz	Long read range High reading speed Line of sight required Expensive	Railroad car monitoring Toll collection systems

Table 2: RFID Frequency and Applications (Aimglobal, 2003)

The choice of carrier frequency and associated bandwidth of RFID systems and tag design is influence by a number of factors, including:

- Data transfer rate (higher the frequency the higher the data rate)
- Propagation capability and associated range (higher the frequency the further the range and higher the power needed)
- Size and cost of transponder construction (lower the frequency the higher the cost of antenna for inductive/passive systems)

2.2.2.4.1 Low frequency inductive/passive RFID tags (100-500 kHz) have a long-standing, well establish application base. Most common in this carrier frequency range is 125 kHz. (Shepard, 2005). Heavy-duty, ruggedised tags and associated interrogators (readers/programmers) are available for a wide range of industrial applications where low capacity and low data transfer rate are specified. A wide range of manufacturer and supplier literature is also available to support these systems. However, this first generation RFID technology is being slowly replaced by higher frequency RFID technology

2.2.2.4.2 Intermediate frequency inductive/passive RFID tags (10-15 Mhz) represent the latest and most innovative products in terms of RFID technology. An expanding range of chip-based tags are appearing in the 13.56 Mhz carrier frequency range (Shepard, 2005). The realization of low-cost integrated chip plus antenna structure is favoring devices for a variety of applications. The popularity of 13.56 Mhz is mainly due to the lower cost of tag, higher data transfer rate and higher data storage. Development in both products and standardization are now favoring this frequency range.

2.2.2.4.3 High frequency (850-950 MHz and 2.4-5.8 GHz) RFID tags operate in both passive backscatter and propagation/active modes. This frequency carrier range has been gaining increasing attention, primarily as a consequence of the higher range capability achievable with passive backscatter technology compared to inductive coupled systems.

RFID systems can process as many as 50 tags per second – 40 times faster than bar-code scanning (Bylinsky, 2000). A high level of data integrity is provided as error rate are lowered and labels are unlikely to be damaged.

RFID systems have been around since the late 60's. Recent technology advancements (specifically advances in automated integrated circuit assembly) have brought prices down to a level that is reasonable to enhance the application base. The industry is currently moving in the direction of conductive inks for printable antennae and tags. With advances in these types of technologies, RFID tags may soon reach the once-unachievable 5-10 cent price range.

2.2.2.5 RFID Standard

Presently there are many companies finding various applications for RFID. However, there are two major organizations creating standards for RFID use, International Organization for Standards (ISO) and Electronic Product Code (EPC)

2.3 COST / BENEFIT ANALYSIS

Many factors contribute to calculating RFID costs and benefits. In terms of costs, they can be either fixed, such as investment in new tools or processes, or recurring, such as the cost of the tags and costs associated with applying them and establishing the benefits of data harvesting. As for the benefits, they can be direct, such as reduction in labor cost and shrinkage, or indirect, such as improved customer service. For example: Wal-Mart Retail Giant, cost and benefit analysis as the attached.

2.3.1 COSTS

Total Costs**:** $3 Billion

Cost Breakdown for the First Stage of Implementation

Tags to be installed in first implementation	~ 1 Billion tags
Costs of Passive Tag:	
Walmart Estimate (@ $0.05 per tag)	~ $50M
Industry Actual (@ $0.50-$0.70 per tag)	~ $500-$700M
Cost of Reader	$30-$2,000
There will also be additional costs associated with conversion/upgradation of existing hardware and software systems to fully exploit the potential benefits of implementing RFID.	

Table 3: WalMart Cost Breakdown Implementation
(Bar Code & RFID, Vienna University of Technology)

2.3.2 BENEFIT

Estimated benefits for Wal-Mart when RFID technology is deployed throughout its operations:

- $6.7 Billion: Eliminating the need to have people scan bar codes on pallets and cases in the supply chain and on items in the store **reduces labor** costs by 15 percent.
- $600 Million: Even with the most **efficient supply chain** on earth, Wal-Mart suffers out-of-stocks. The company boosts its bottom line by using smart shelves to monitor on-shelf availability.
- $575 Million: Knowing where products are at all times makes it **harder for employees to steal goods** from warehouses. Scanning products automatically reduces administrative error and vendor fraud.
- $300 Million: **Better tracking** of the more than 1 billion pallets and cases that move through its distribution centers each year produces significant savings.
- $180 Million: **Improved visibility** of what products are in the supply chain-in its own distribution centers and its suppliers' warehouses-lets Wal-Mart reduce its inventory and the annual cost of carrying that inventory.

Total Savings: $8.35

2.3.3 SUMMARY Wal-Mart's' Operations

The cost analysis is based on the first implementation of RFID. The first implementation will be conducted with the top 100 suppliers and will only be applicable to big ticket items.

The estimated costs of implementing the tags along is around $50 M though it is not clear at this point as to what would the price that Wal-Mart would be able to get out of vendors, given it's large size and clout with vendors.

The costs involved would include the cost of readers/scanners but this will be a one time cost (at least till the next upgrade) as opposed to the tags which are recurring cost.

In order to take advantage of the RFID tags, the current software to manage inventory, supply chain etc, will have to be upgraded. While the major ERP vendors are introducing middleware components to handle RFID tags and the copious amount of data generated from the tags, the costs associated with the implementation of the software (as well as hardware upgrades, if any) will have to be taken into account. This amount will not be insignificant given the size of Wal-Mart operations.

The benefits are based on RFID being implemented throughout Wal-Marts' operations. The actual benefits in the first stages of implementation are not known precisely since the first implementation will essentially be a replacement for bar codes. The benefits of implementing RFID will surely go up over the years because the cost of the tags will decline as the technology matures (see Figure 10). Moreover, when the costs of the tags do go down, Wal-Mart will have the infrastructure to take advantage of the reduction in the yearly recurring costs.

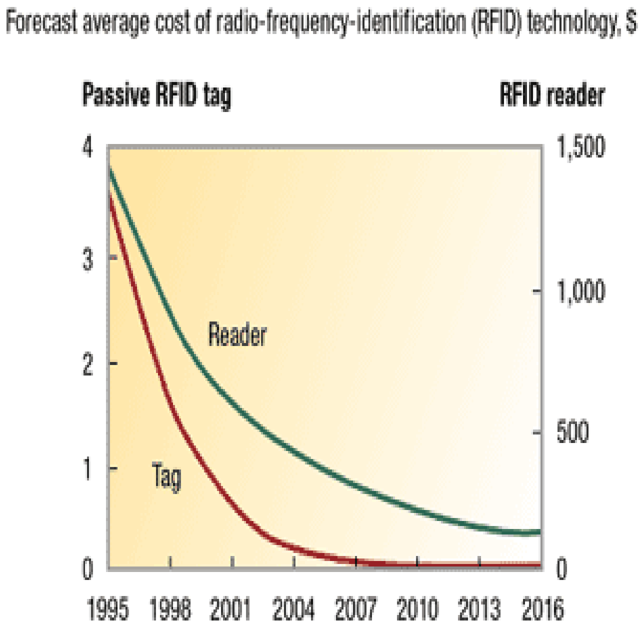


Figure 10: Forecast RFID Average Cost (Auto-ID Center, McKinsey Analysis, 2003)

To meet the growing demand for RFID, over 140 suppliers already exist nationwide. A comprehensive list of supplier, their websites, and the applications served by each company (RFID-Handbook, 2003)

Potential Areas of Benefit from RFID versus Bar Coding

Area	Activity	Benefits of RFID over Barcode	Cost Reduction %
Warehouse	Storage	Automated, accurate inventory management	28%
Warehouse	Dispatch	Automated checking process	26%
Supplier	Claims Management	Automated, accurate data records decrease claims generated	18.5%
Hub	Cross-Docking	Automated checking, reduced paperwork decrease admin	18%
RDC	Receipt	Automated checking process	9.4%
RDC	Claims Management	Automated, accurate data records decrease claims generated	20.8
RDC	Dispatch	Automated checking process	5%
RDC	Storage	Automated accurate inventory	21.7%
All	Inventory Cost	Reduced inventory due to visibility through supply chain	55%
All	Asset Utilization	Improvement in asset utilization	30%
Retail	Receipt	Reduced paperwork	2.8%
Retail	Storage	Automated inventory management	16.3%
Retail	Replenishment	Improved efficiency	4.5%
Retail	Losses	Reduced loss (out of code, overstocking) from inventory visibility	11%

Source: FKI Logistex, 2005

Table 4 : Benefit from RFID versus Bar Coding

As illustrated in Table above, Potential Areas of benefits of RFID Versus Bar Coding, there can be tremendous returns in isolated areas of an operation along with opportunities for significant cost saving. These include automated and accurate inventory management, reduced paperwork, and reduced inventory and automated processes.

2.4 Summary

Many aspects of this newly found technology plus its usage in different sectors of the world economy have been provided in this chapter. Different functionalities plus its usage as discussed. Definitions of Bar Codes, components of RFID were provided. Wal-Mart Retail Giant, which is using the RFID Technology, was introduced in this chapter.

CHAPTER 3: METHODOLOGY

Action research is "learning by doing" - a group of people identify a problem, do something to resolve it, see how successful their efforts were, and if not satisfied, try again. While this is the essence of the approach, there are other key attributes of action research that differentiate it from common problem-solving activities that we all engage in every day.

This project will adopt the General Methodology of Action Research Model (adapted from Gerald Susman 1983), which is basically summarized as the attached.

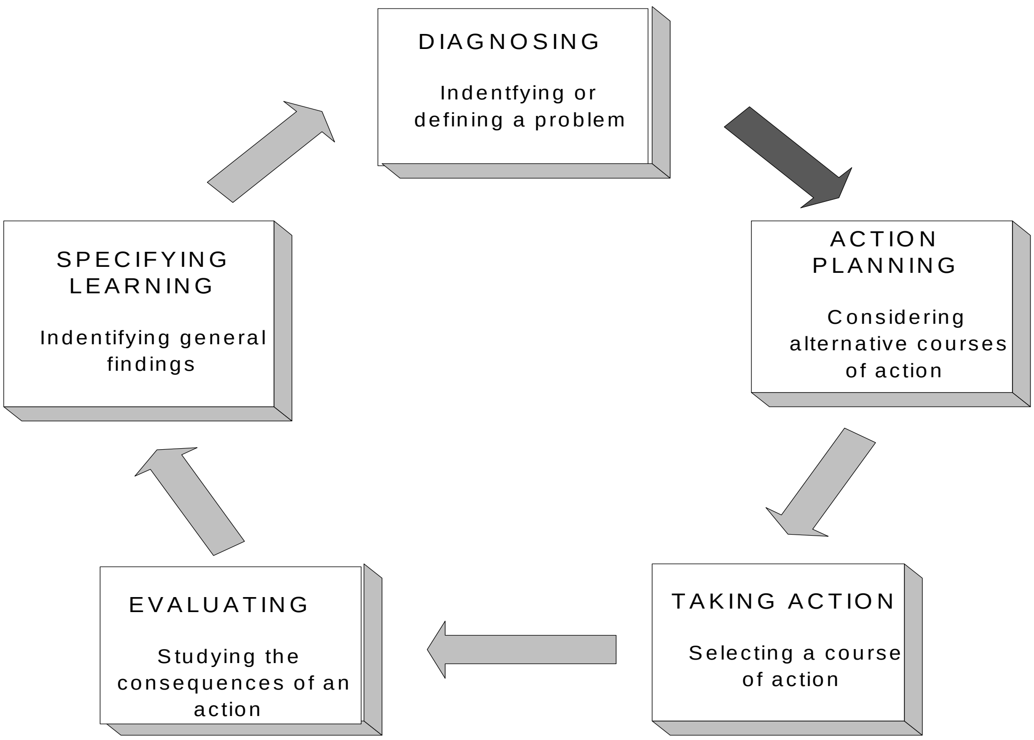


Figure 11: Action Research Methodology

There are five Phases; Diagnosing, Action Planning, Taking Action, Evaluating, Specifying Planning.

3.1 Phase 1: Diagnosing

For this project, there is a problem associated with the process in barcode reader at Turnstile and this is even more critical if the occurs during peak season like public holiday. More specifically there is a delay in the manual barcode process to identity visitors in entering parks with the barcode tag that they purchased.

Since the barcode data is recorded manually, an automated procedure would virtually eliminate the problems. The Objective of this process is to verify and validate the RFID enable software module, Turnstile, Hardware according to the Theme Park Management requirement as the attached.

Software Module	
RFID Theme Park Management System	Include Ticketing System, Retail and F&B POS, Event Order Management System, CRM, Tube Rental, Business Intelligent Reporting Module and Administration Module
Inventory Management System	This Module integrated with POS system
Turnstile	
Turnstile Entrance and Exists at Wildlife Park, Dry Park, Water Park and Main Entrance	Integrated RFID Reader with 13.56 MHz
Hardware	
RFID Readers for POS Terminal at Main Entrance, Hotel Entrance, Surfbeach and Animal Park	13.56 MHz RFID Reader enable for all POS Terminal.
RFID Hand Wristband designed with water and weather resistant for Visitors wearing	Built in 13.56 MHz RFID enabled hand wristband

Table 5: RFID Enable to Hardware, Turnstile and Software Modules

3.2 Phase 2: Action Planning –System or Application Design

System Design specifies how the RFID TPMS system will accomplish the objective of the project. It consists of designing activities that produce system specification. There are five activities include Graphical User Interface (GUI) Design, RFID Chip Control Design, Data Design, Peer to Peer Connectivity Design and Modeling Flows Design that adapted from O'Brien, 2006.

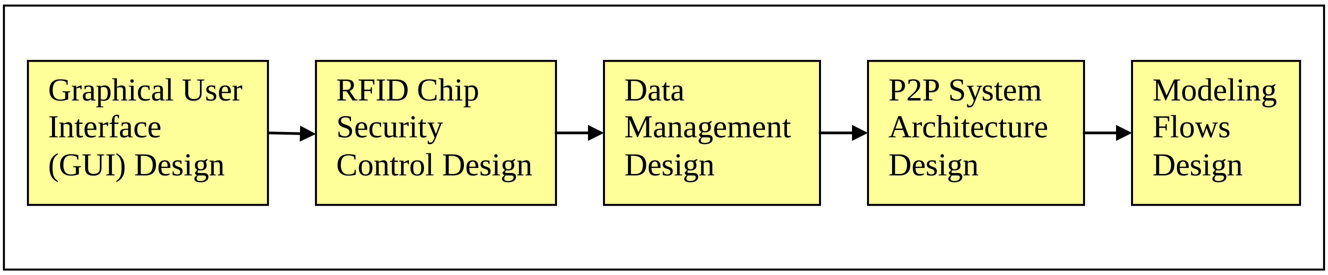


Figure 12: System Design Framework (O'Brien, 2006)

3.2.1 Graphical User Interface (GUI) Design

User interface design basically is focusing on the interaction of two parties, the end user and the computer-based application (system). An attractive environment or interface is a way to attract user to use the system. Besides that, a system should be in more user friendly manner. By applying this method, it can encourage the fast learning activities because designer should assume that the end users are novice

3.2.2 RFID Chip Security Control Design

This design stage focusing on the RFID transponder or tags specification base on Mifare MF1 IC S50 to be used in RFID Theme Park Management System (TPSM). It's designed for optimal visitors convenience. The high data transmission rate for example allows complete ticketing transactions to be handled in less that 100ms (Philips Semiconductor, 1999)

3.2.3 Data Management Design

The TPMS database layers can be divided into three layers: logic, data and presentation. Not only are these layers used to architect and manage applications, also enable applications to communicate with each others and other applications. Each layer has its own purpose and relation to accessing enterprise information. Therefore it is important of the functionality of each layer and how it can be used in Peer to Peer (P2P) Network.

3.2.4 Peer to Peer (P2P) Architecture Design

The peer to peer system design is to allow all terminals to work independently ensuring continuous operations even in the event of a network or host computer failure or both. RFID TPMS's advanced data synchronization capability and transactional consistency is maintained on all terminals at all times. This wills maximum system availability.

3.2.5 Modeling Flow Design

The above assists to visualize and specify parts of the TPMS systems using RFID technology and the way those parts relate to one another

3.3 Phase 3: Taking Action

Attached is the "***flowchart representing Guest Admission with the New System***" when RFID enabler fully in place.

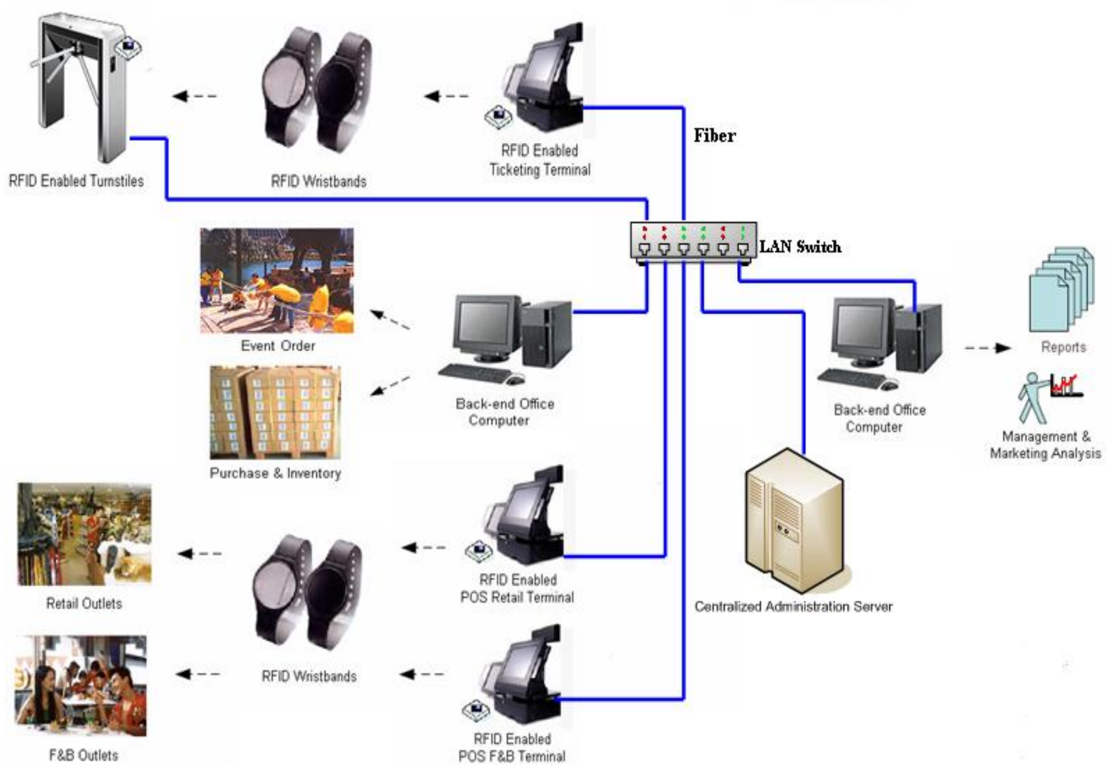


Figure 13: RFID Architecture

The above is designed based on a centralized database mechanism. In such architecture, all data and systems can be controlled within the office or remotely through a dedicated channel with different authentication level. Supporting, maintenance and collecting data for research or marketing can be done easily.

For example:

a) Inventory or Consumables product able to be traced by centralized system that can be provided:
   - Better Resources Planning
   - Better Utilization of Resources
   - Full Reports for ALL Resources

b) Centralized Administration to ALL System that can be provided:
   - View status online in real time
   - Saves Time and Labor

3.4 Phase 4: Evaluation

The above activity is to validate the software module design application and produce solution design specification based on requirements

- Conduct joint sessions to review the Technical Solution Details and to achieve mutual understanding of the scope of each item.
- Review the out-of-scope requirements with customer and handle them in accordance with the Sunway Lagoon Change Management Procedure.
- Conduct unit Test to validate the software module design.
- Develop fixes the problems encountered during the testing

3.5 Phase 5: Specifying Learning

This step would involve the drawing of a conclusions based on the results, finding, experience and encounters that had occurred during the course of the project.

3.6 Summary

In this chapter, the methodology and approaches of the project management is described. The basic approach in conducting this project was used as guideline. The methodology used on each stage is reviewed. The hardware and software requirement is being monitored. This is done is to ensure the result generated will meet the expectation.

CHAPTER 4: THEME PARK RFID SYSTEM

4.1 Discussion

In this Chapter, the process solution will be discussed, that include the algorithm used in each stage of the system design framework. As mentioned in previous chapter, system design framework consists of five components which adapted from O' Brien, 2006, namely: RFID Chip Security Control Design, Data management Design, P2P System Architecture design, Modeling Flow Design and the user interface. It will draw a focus towards the used of algorithm designed and the result or solution produced

4.2 System Requirements

The System requirements on Memory, storage of Server, POS Terminal and RFID Reader and RFID Tag for this TMPS as the attached:

Memory requirements:

Machine Type	Software	Memory Usage
Enterprise Central-Synchronization point	Win2000 OS	78MB
	Synchronization Server	10MB
	Sybase ASA	70MB
	Estimated Total Memory	158+ MB
	Total Entry level Memory on Machine	512 MB
POS Terminal (Windows)	Win2000 OS	78MB
	POS Front Office JVM	30MB
	Sybase ASA	30MB
	Estimated Total Memory	138MB
	Total Entry Level Memory on Machine	256 MB

Table 6 : Memory requirements for Server and POS Terminal

For Storage space requirements:

Machine Type	Software	Hard disk space Usage
Enterprise Central-Synchronization point	Win2000 OS	3GB
	System Logs Server	2 GB
	Sybase ASA	20GB
	Estimated Total Storage	25GB
	Total Entry Storage on Machine	36GB
POS Terminal (Windows)	Win2000 OS and POS	3GB
	POS System Logs	2GB
	Sybase ASA	10GB
	Estimated Total Storage	15GB
	Total Entry Storage on Machine	20GB

Table 7: Storage Space requirements for Server and POS Terminal

RFID requirements:

RFID Hand-Tags	Built in 13.56 MHz RFID enabled hand wristband
RFID Readers for Turnstiles	Integrated RFID Reader with 13.56 MHz
RFID Readers for POS Terminal	13.56 MHz RFID Reader enable for all POS Terminal.

Table 8: RFID Enable to Hand-Tags, Turnstile and POS Terminal

4.3 RFID Chip Security Control Design

As describe earlier, the design stage more focusing on the RFID transponder or tags specification base on Mifare MF1 IC S50 chips that according to ISO/IEC 14443A under the EEPROM (electrically erasable programmable read-only memory) as figure 14 attached.

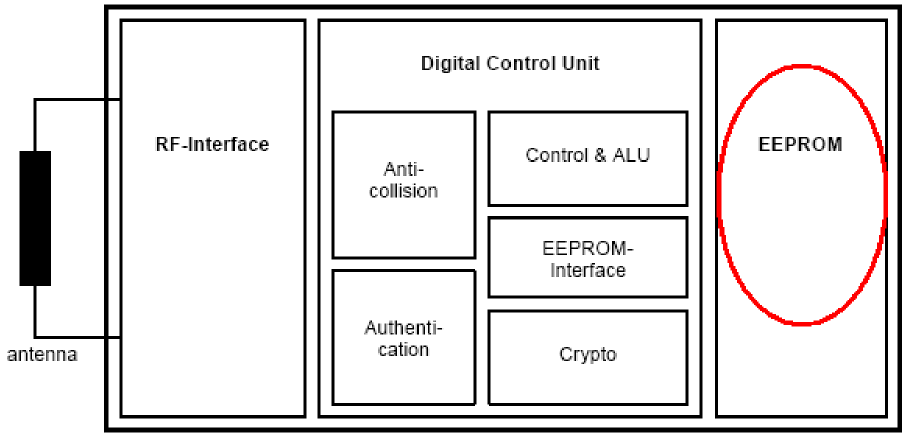
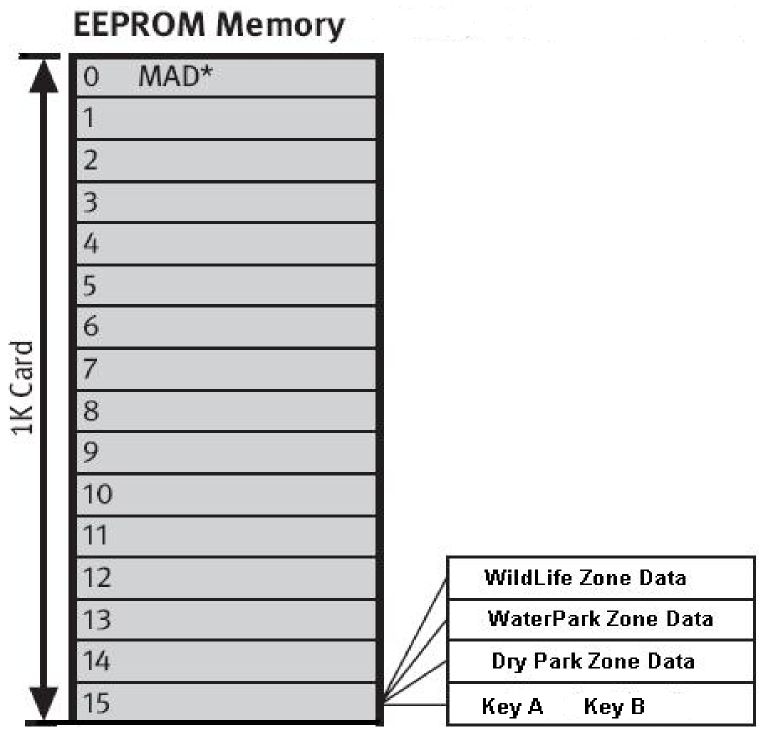


Figure 14 : RFID Chip (NXP B.V. 2007)

For TPMS all the applications data or according to Zone section that consists of Wildlife Zone, Water and Dry Park Zone is stored in an EEPROM memory chip. The EEPROM memory at RFID standard chip is 1 Kbytes is made up of 16 sectors. Each sector can be used as purses or for general data storage for a different application. Sector 0 is normally used as a directory for the rest of the card. The directory name is MAD (Mifare Application Directory), leaving 15 sectors available for data or purses. In the erased state EEPROM cells are read as a logical "0", in the written state as a logical "1".



*MAD –Mifare Application Directory

Figure 15: Memory organization (Cardax Prox(Mifare Series), 2006)

Each of the 16 Sectors consists of four 16 byte blocks numbering 0 to 3 that containing the above: Block 0 is Wildlife Zone Data, Block 1 is Water Park Zone data and Block 2 is Dry Park Zone Data

Each Sector has two keys, called the A and B keys, allowing different access privileges to that sector. These key pairs are designed as read and read/write, or decrement and increment/decrement. With this move, these would allow:

For Example: If Customer would like have Wildlife Zone, The Ticketing Counter would scan and validate the RFID Wildlife zone with value stored. In the scanning process, one of Wildlife block at memory chip in RFID tag will write ‘1’ from defaulted ‘0’. Other blocks defaulted ‘0’ unchanged. With this code in place, this customer only valid enters into Wildlife Zone via Wildlife Turnstile Reader scanning process with validation wildlife block with ‘1’ status code. For others zone is invalid due to RFID memory block is ‘0’ code.

4.3.1 Summary

- With this design in place, all the Turnstile reader able to identify each visitor RFID hand-tag enter into differentiate zone; wildlife, wet or dry park automatically without human interference.
- Visitor can make any purchase from retail shops, F&B, Tube rental outlet easily via their passive RFID hand-tag on the RFID Reader attached to POS terminal with auto decremented or incremental store value on the passive tag.

4.4 Data Management Design

In this stage is the solution represents data management design that segregated into 3 main parts: The presentation layer, the business logic layer and data layer as shown in figure 16.

The presentation layer: This layer is pure GUI that written in Java Swing. It makes called to the Business layer using TPMS's API. The TMPS libraries are embedded into the system at each terminal.

The Business Layer: This layer consists of two parts. The first part is handles the movement of the transactional data and is built suing the TTPS POS engine. The TPMS POS engine is designed to ensure that distributed data is accessible in real-time on demand.

The TPMS POS engine is decentralizes host services, distributing the responsibilities with the terminal that allowing the terminals to operate with full feathers with sharing transaction among terminal, even host computer is not available.

This increase fault tolerance and up time. The system is fully distributed and peer to peer that eliminating any single point of failure.

The second part of the **business layer** contains the business logic. This part publisher the API's for the presentation layer to call. ie: creating a new order, add item to menu, set price level, etc.

The Data layer: This layer is used by the business layer to store and retrieved stored information in the database.

TPMS allows access to all three layers with reliable, scalable and simple to maintain solution for full automation as describe to peer to peer System Design.

4.5 Peer to Peer (P2P)System Architecture Design

Overview of Peer to Peer Application

Each Terminal is equipped with a local Database. Having a local Database on each terminal allows the system to run independently when no network or server is available. This allows for a Fault tolerant system. Terminals can remain operational when failure of server or network.

However in this environment, it is required that transactional information to be shared among terminals. This task is usually done through a server. However, if server is single point of failure and drastically reduces the ability for terminal to function independently with maximum fault tolerance. POS eliminated the need for a server by creating distributed transaction services, which is a communication layer using RMI technology allowing the terminals to share their transactional information peer to peer, thus eliminating the need for a server to operate but allowing sharing of transactional information from terminal to terminal as shown figure 17.

Location Configuration

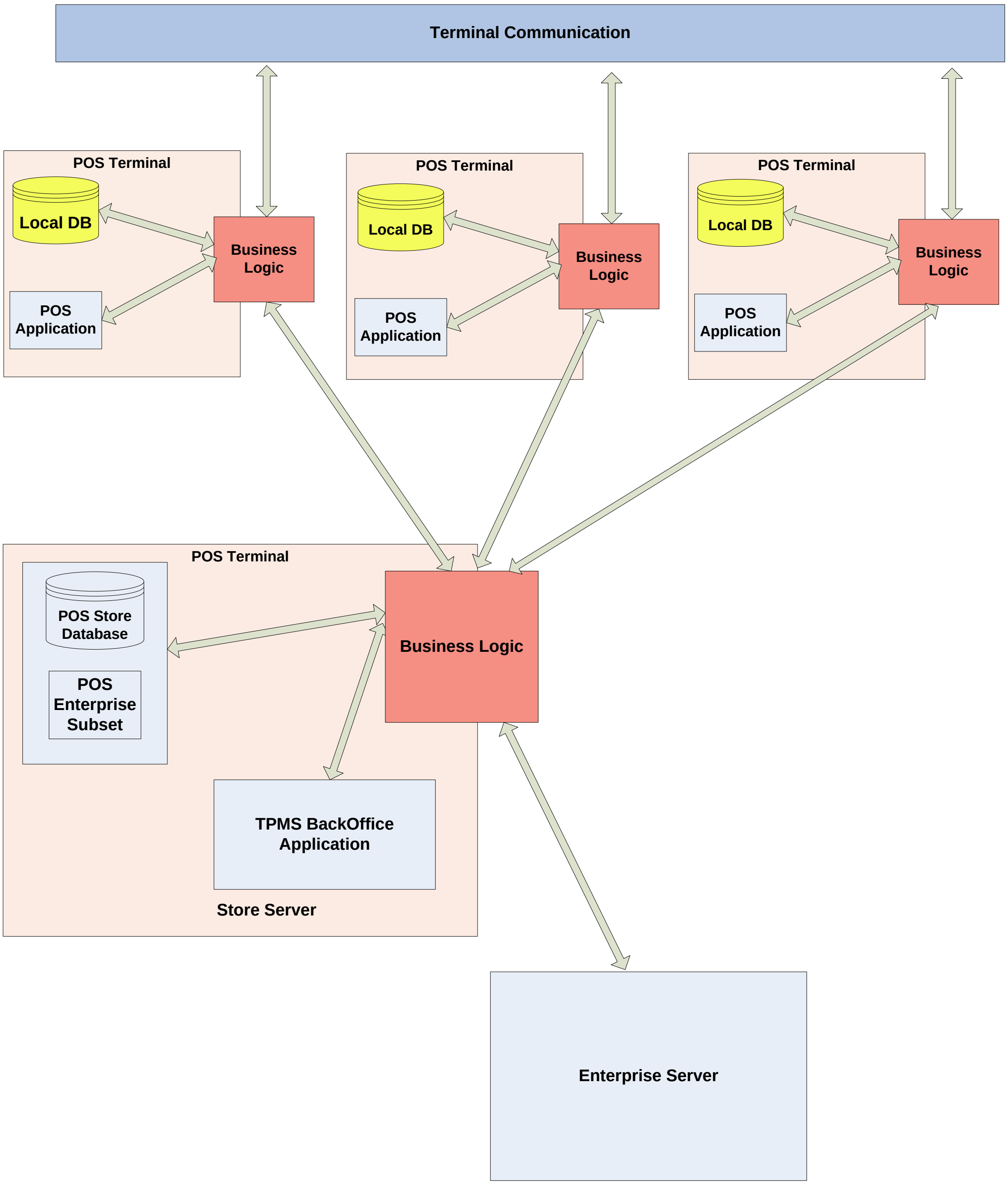


Figure 16: Overview Peer to Peer Design

Transaction movement is move from terminals to server in real-time when network connection active. All servers and terminals are fully operational with transaction update locally and synchronized to the host as shown at figure 17.

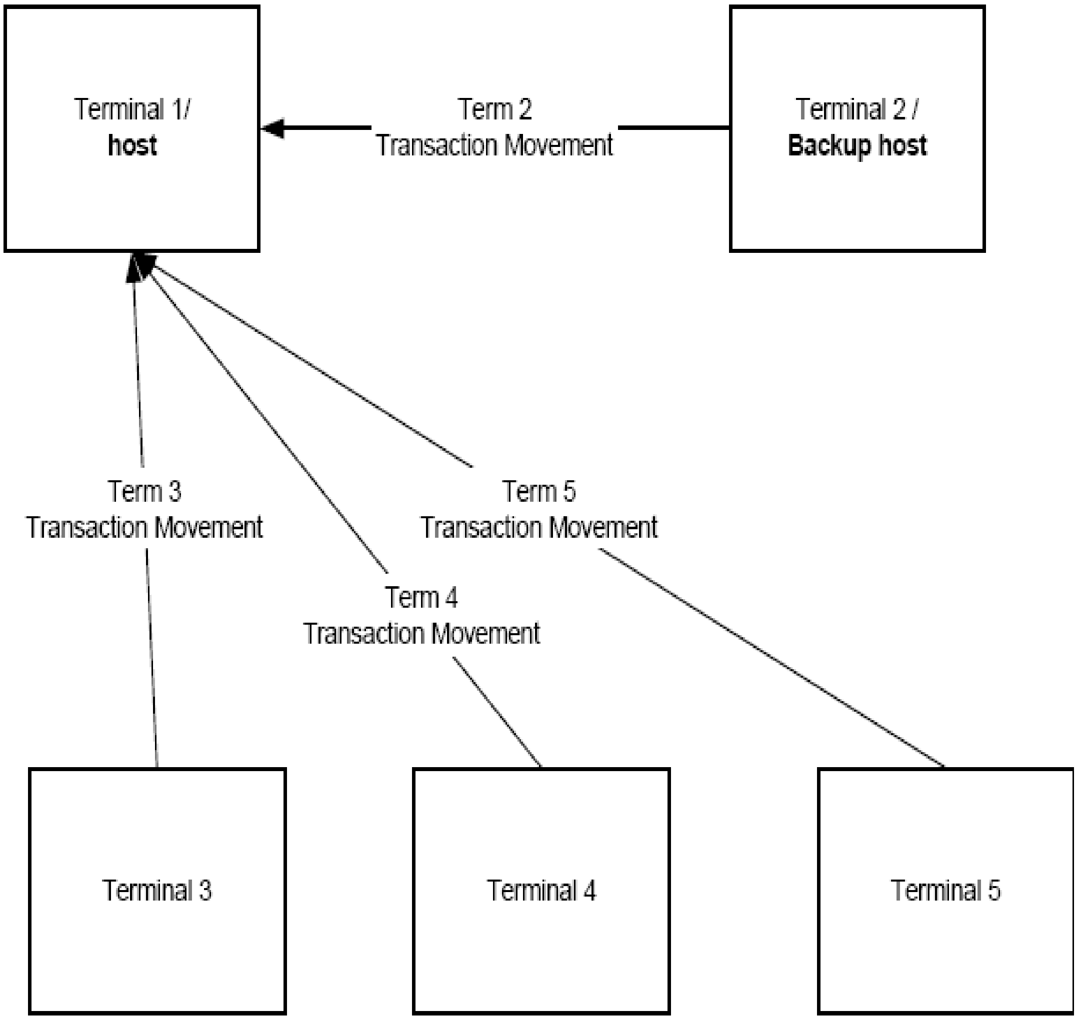


Figure 17: Transaction Movement in Real Time

At periodic rate, depending of network traffic, all the transaction information also filtered to the designated Backup Host, shown at figure 18.

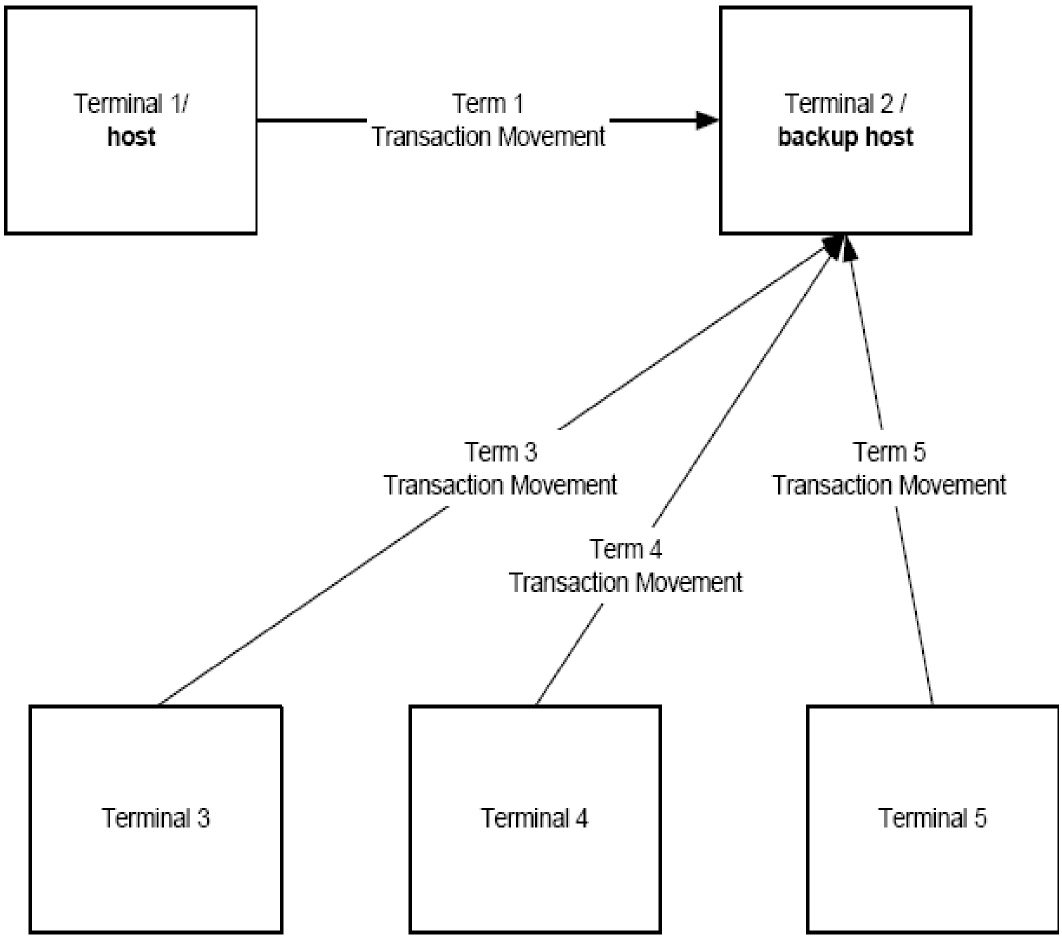


Figure 18: Transaction Movement Update into Backup Host

For figure 19, when terminal 3 initial the transaction, the information will generated and stored at the local database itself. Also, able to synchronized with the host.

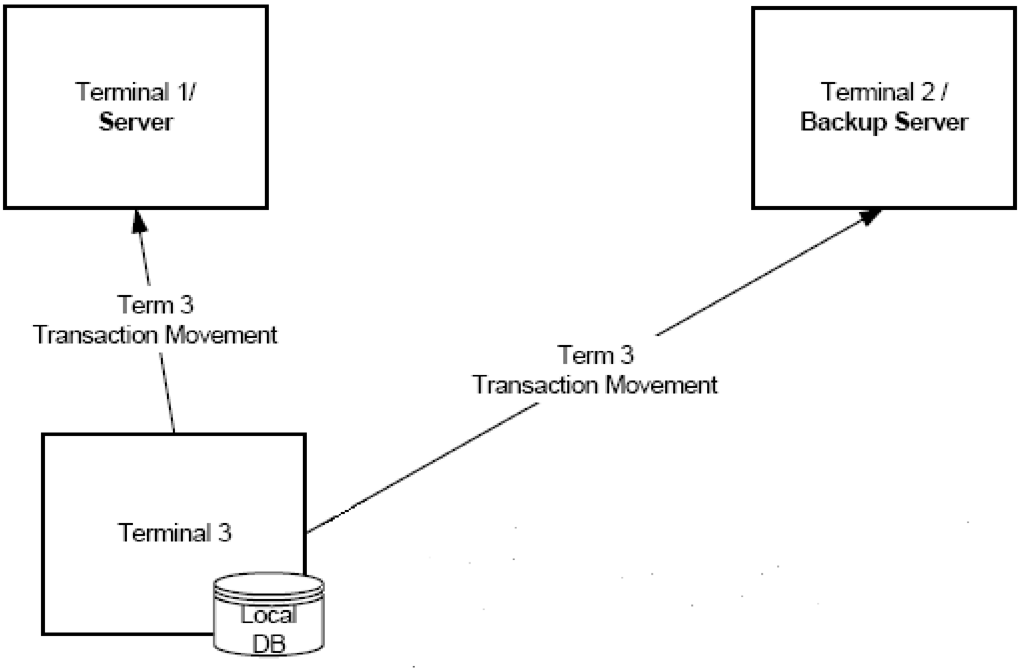


Figure 19: Terminal 3 Update to Server and Backup Server

When Terminal 5 wants to retrieve the transaction from Terminal 3, a RMI call is invoked to Terminal 3 to access the transaction stored on Terminal 3. No Host or Backup Host is needed for this transaction as shown figure 20.

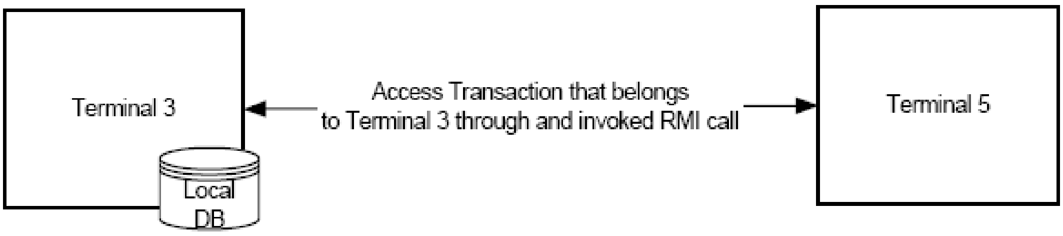


Figure 20: No Host or Backup Host needed

If Terminal 3 is down, there are 3 options to recover the table. If the RMI object is still cached on Terminal 5, it will be able to recover from cached terminal. The other 2 options, it may look for transaction recovery from the Host or Backup Host.

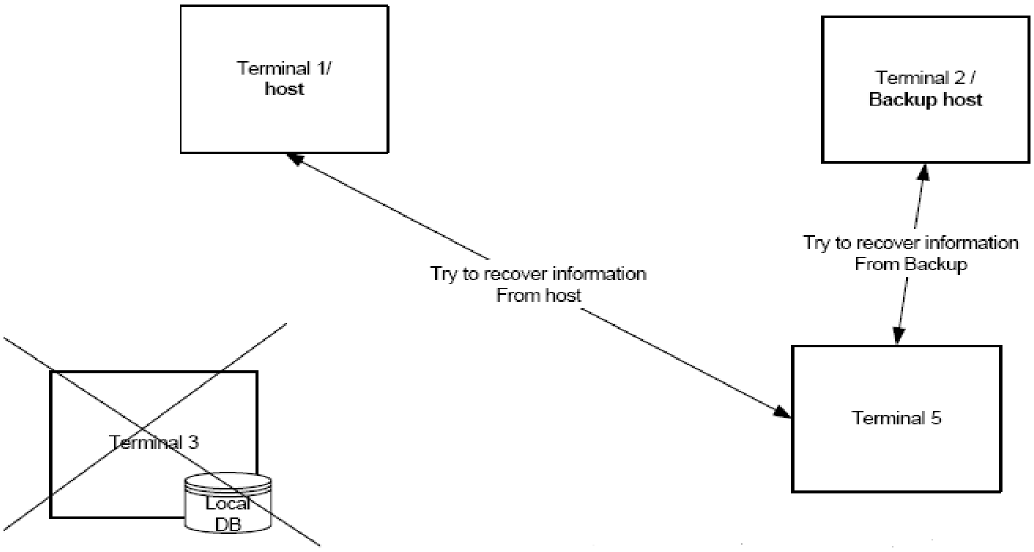


Figure 21: Terminal 3 is Down

If Terminal 3 and Terminal 2 are down as shown figure 22, Backup Host or cached information still available on Terminal 5.

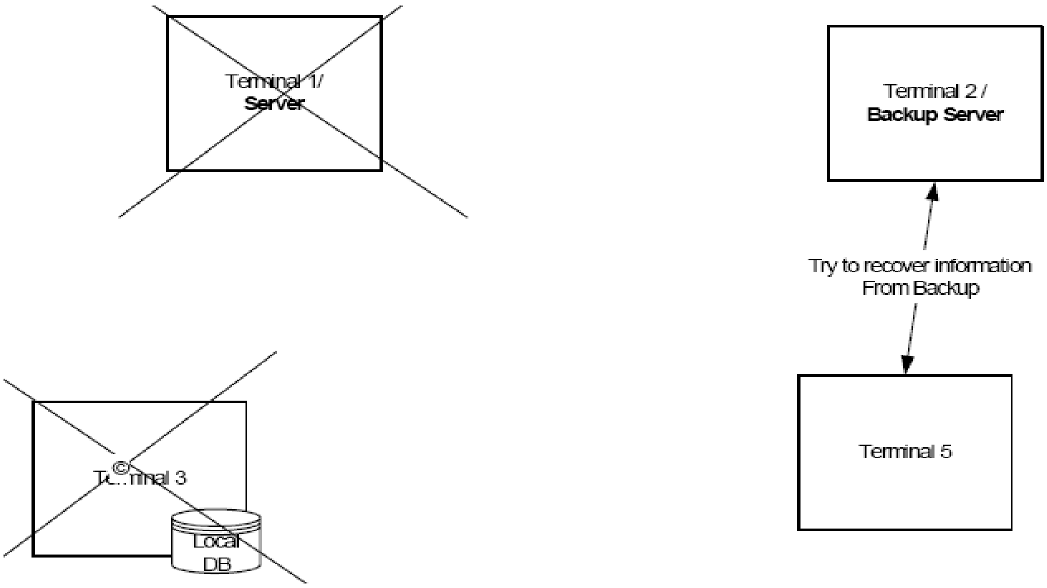


Figure 22: Terminal 5 is Active

If cached information is available on Terminal 5, the transaction still can recover.

Other terminals may also be tried to search if they have a cached copy of the transaction to be recover as shown figure 23.

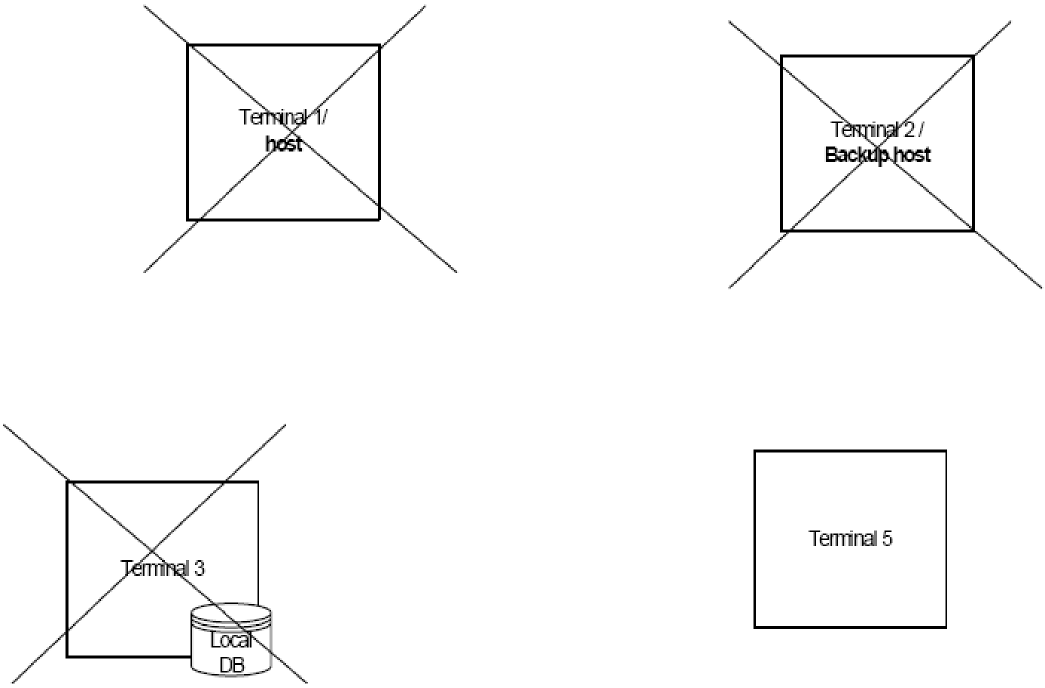


Figure 23: Other Terminal Searching

All recovered information will marked as RECOVERED TRANSACTION that to avoid any transaction conflict.

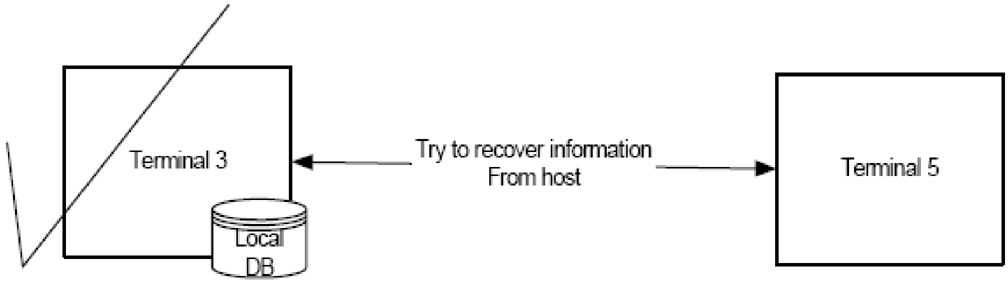


Figure 24: Recovered information is Marked

In a Scenario where the Hub is down that means no connection available.

All terminals will be access to their local transactions and able to recover locally cached transactions.

Terminal 1: is the host will able to recover transactions synchronized previously

Terminal 2: is Backup Host will also be recover transactions that synchronized previously.

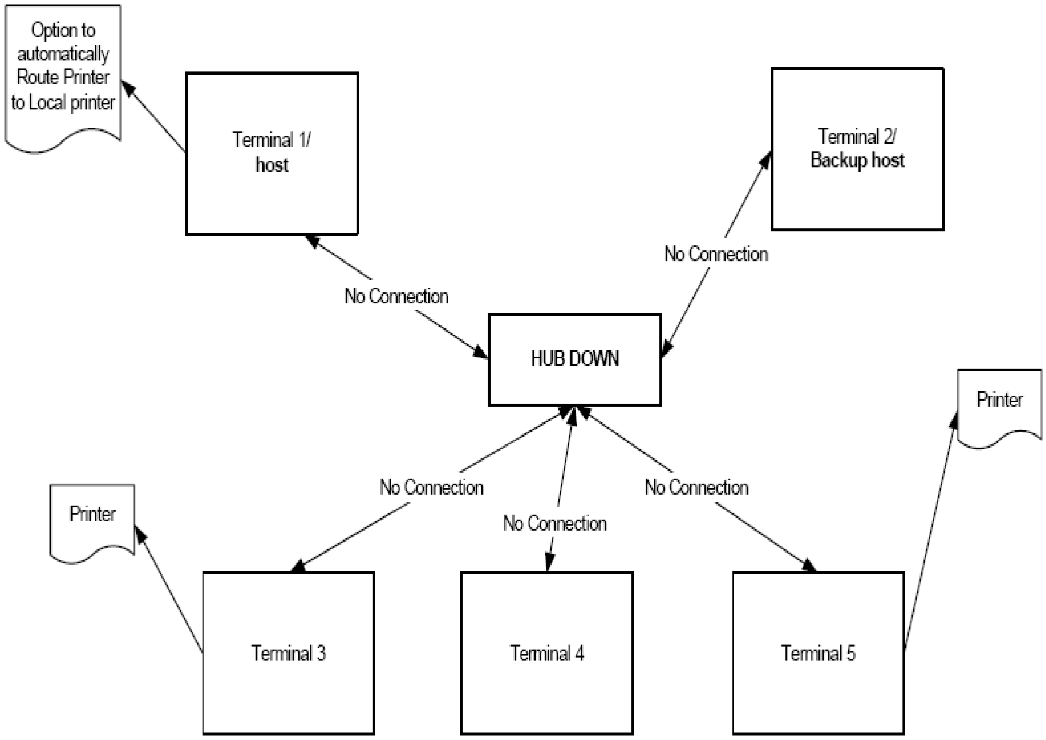


Figure 25: Hub Down

POS and TPMS do not require any special hardware, software or network components to operate. It supports all standard TCP/IP network infrastructures, run in any current commercially supported environment using ODBC compliant to database.

4.5.1 Summary

With peer to peer technology in place, all the databases are link all together. Technically, databases are centralized that ease of the data analysis system for Customer relationship Management and Marketing Analysis.

4.6 Modeling flows Design

In order to make the design of the overall Theme Park Management System more efficiency, it is break down two separate components for the system, one to support the customer interaction and one to support the functionality of the RFID Turnstile. In this stage, only focus on the former of the two components.

The support provided to the visitors or customers has two aspects: (a) support for purchasing RFID Tags and (b) support for RFID Turnstile Entrance. Regarding the user interface aspect would be supported by a separate user interface, namely issue RFID Tag and Scanning RFID Tag respectively.

4.6.1 Purchase RFID Tag Interface design (Case Diagram)

Use Case Description. Provide an extended real use description of the purchase RFID Tag use case. The use case starts with the customer specifying his/her preferences park zone, which is followed by the system presenting a number of multiple park zones for the customer to choose from. After a particular Park Zone has been specified, the customer can continue to request RFID Tag and payment options as shown as figure 26

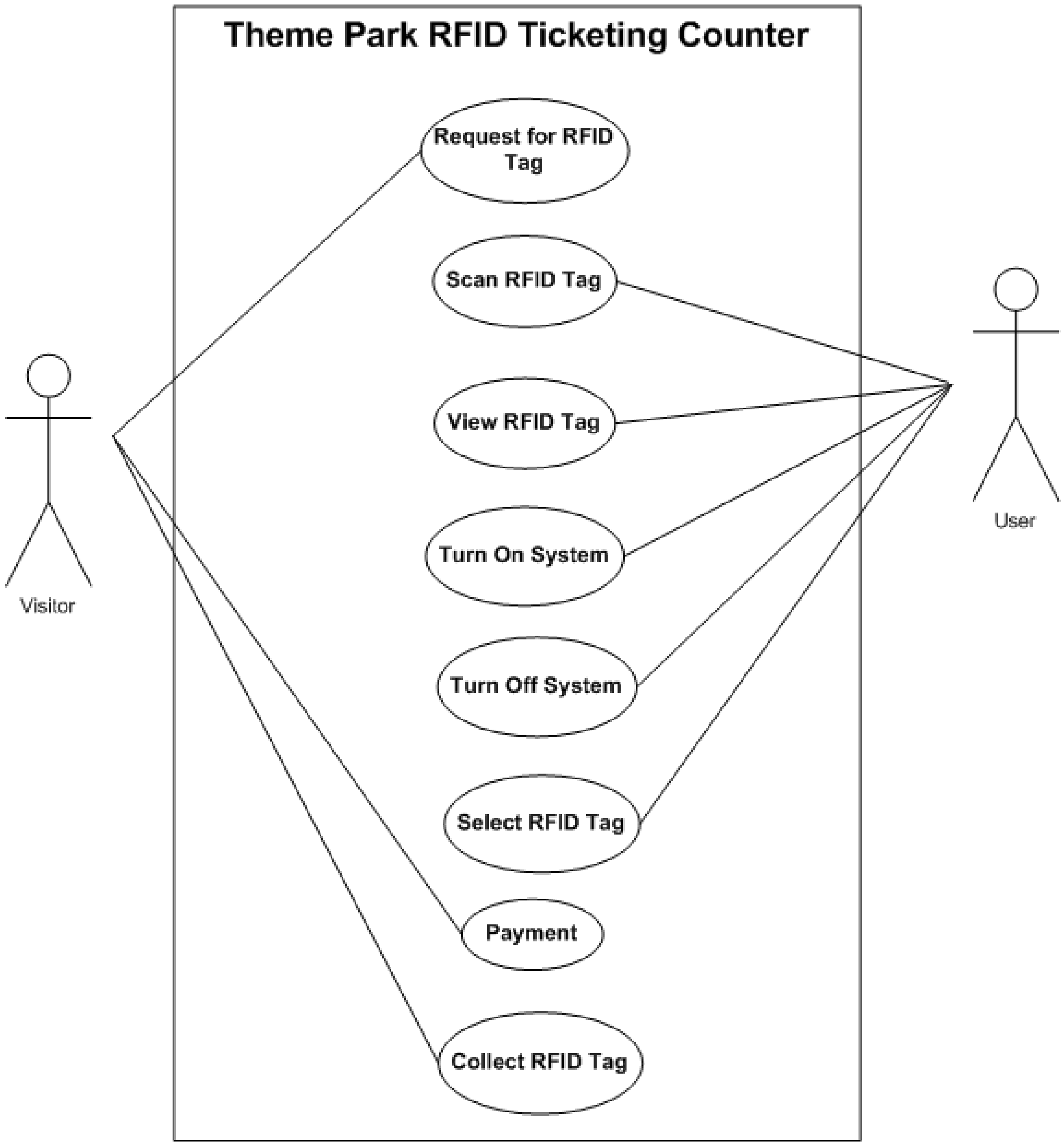


Figure 26: RFID Ticketing Counter Casa Diagram

4.6.2 Sequence Diagram.

Provide a sequence diagram for the purchase RFID Tag use case. This diagram includes both boundary (user interface) and entity classes and also provides describe the interaction between visitors during the execution of the use case (see also the class figure 27 and figure 28 provided below respectively).

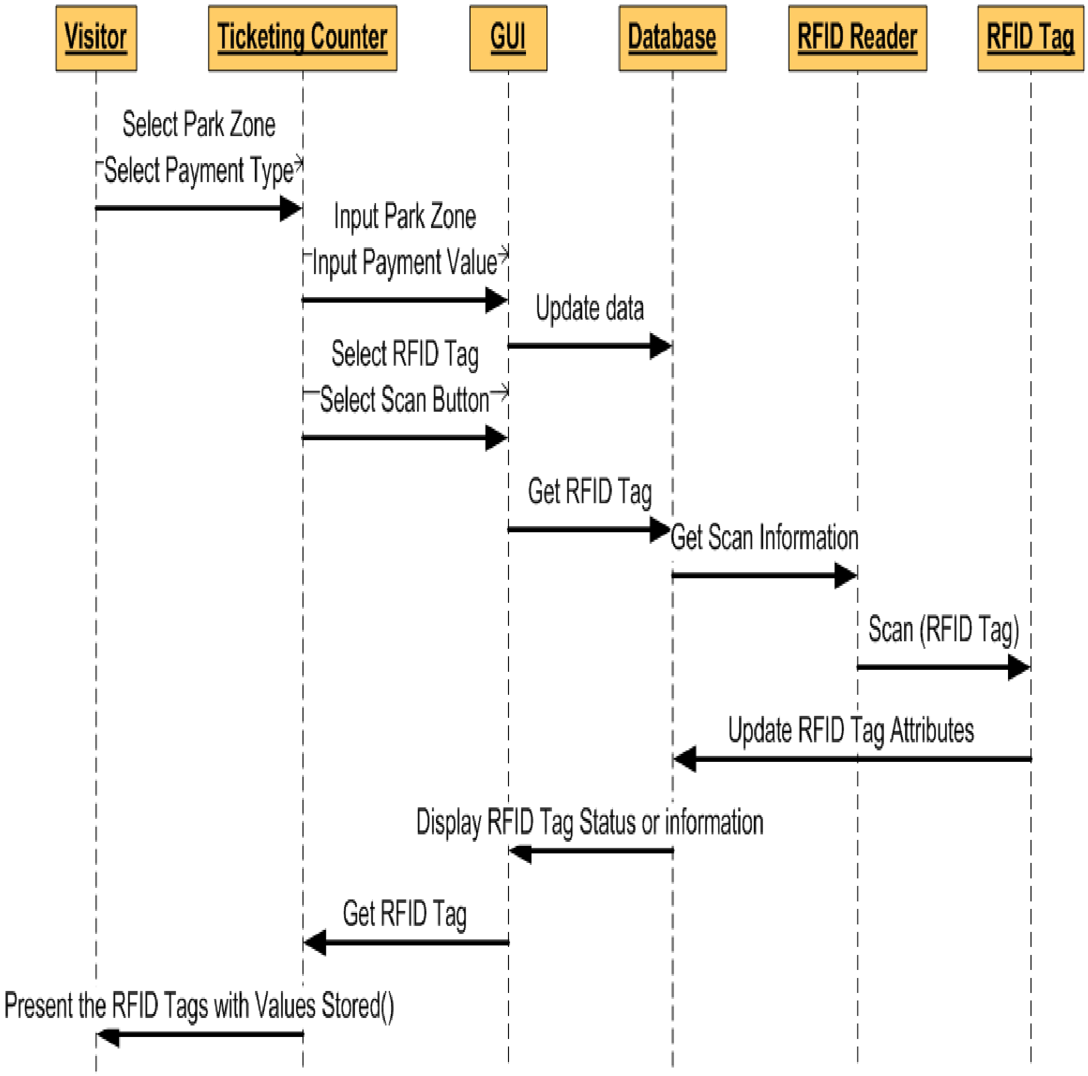


Figure 27: RFD Ticketing Counter Sequence Diagram

4.6.3 RFID Ticketing Class Diagram

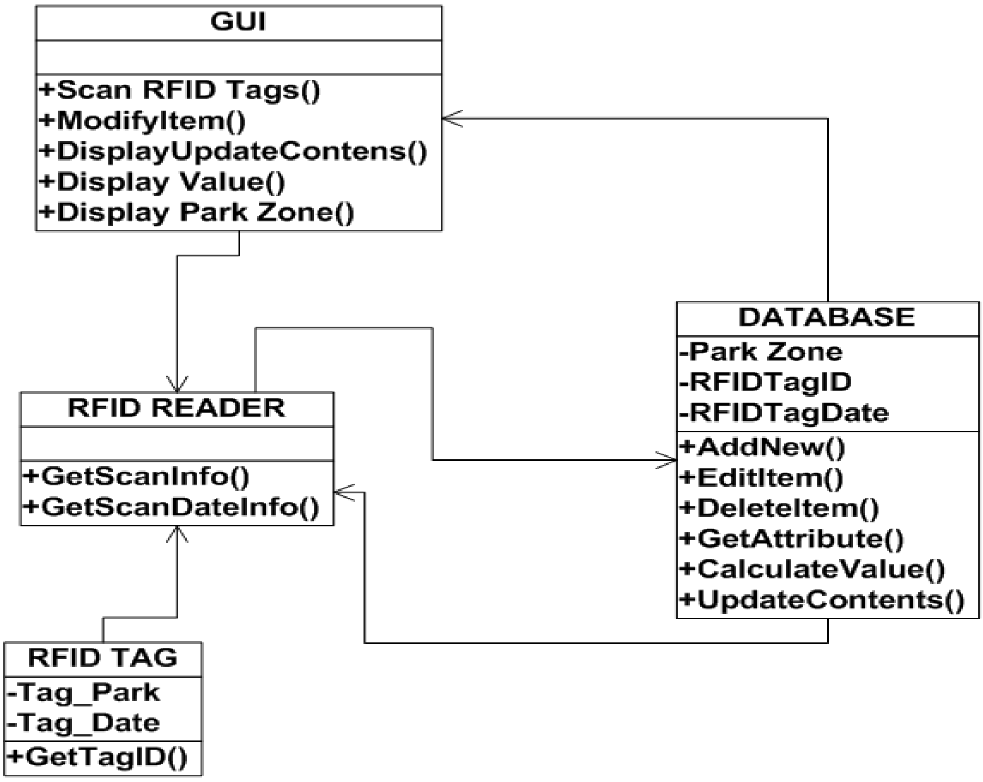


Figure 28: RFID Ticketing Class Diagram

4.6.4 Use Activity Diagram: RFID Process At POS

The visitors select the preferable park and present the payment type to the cashier at the RFID POS terminal. The cashier scans the RFID wristband tag into POS system. The RFID reader at POS system validates captured the Park Zone and value into the RFID tags before present to visitor. An activity diagram is drawn to represent to the above in figure 29.

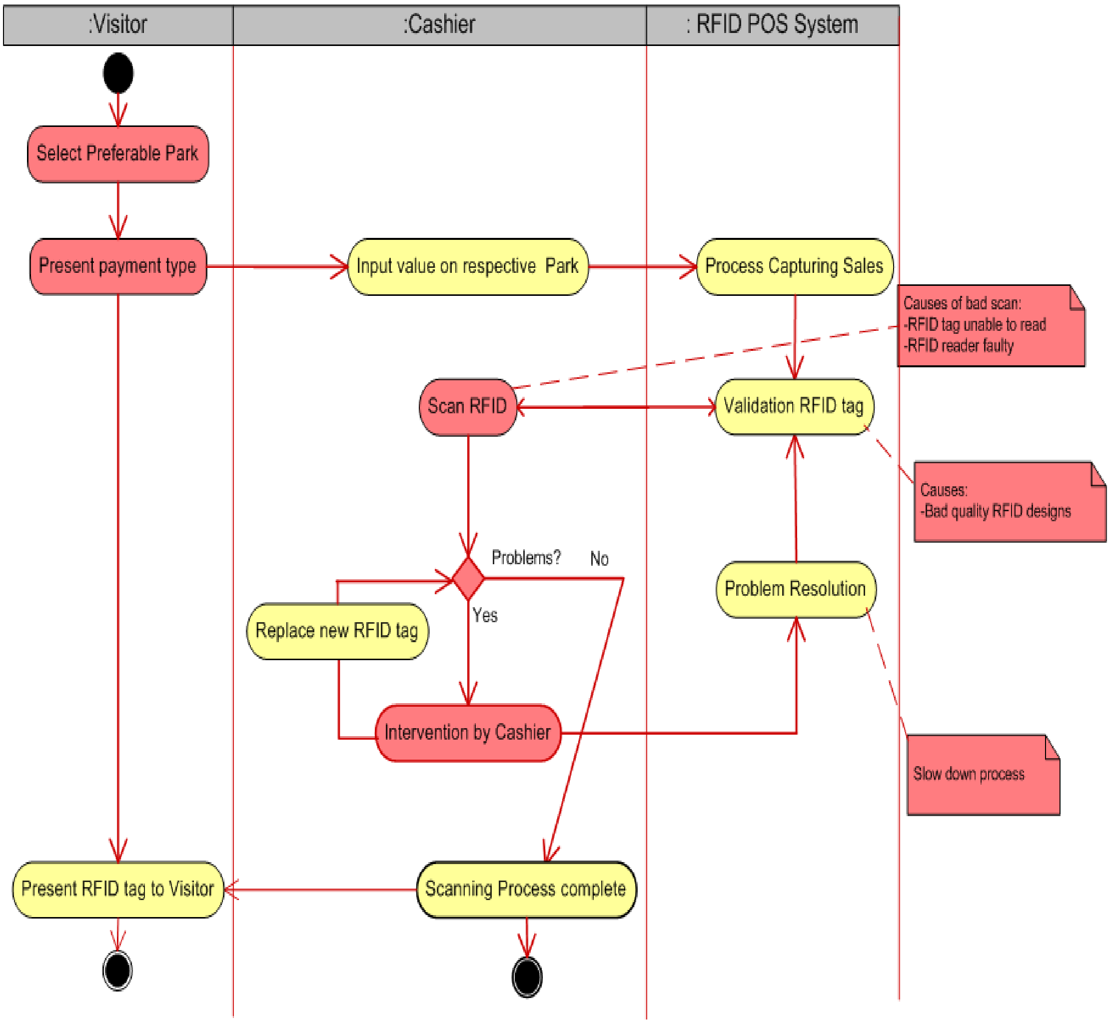


Figure 29: Activity Diagram: Process Payment Type at RFID POS System

4.7 RFID Turnstile Entrance Interface design.

4.7.1 Use Case Description

Provide an extended real use description of the RFID Turnstile Entrance use case. The use case starts with the customer attempt to enter restricted Park Zone area through RFID Turnstile via their RFID Tag with valid Park Zone stored after the operators or users has turn n the RFID Turnstile System as shown figure 30.

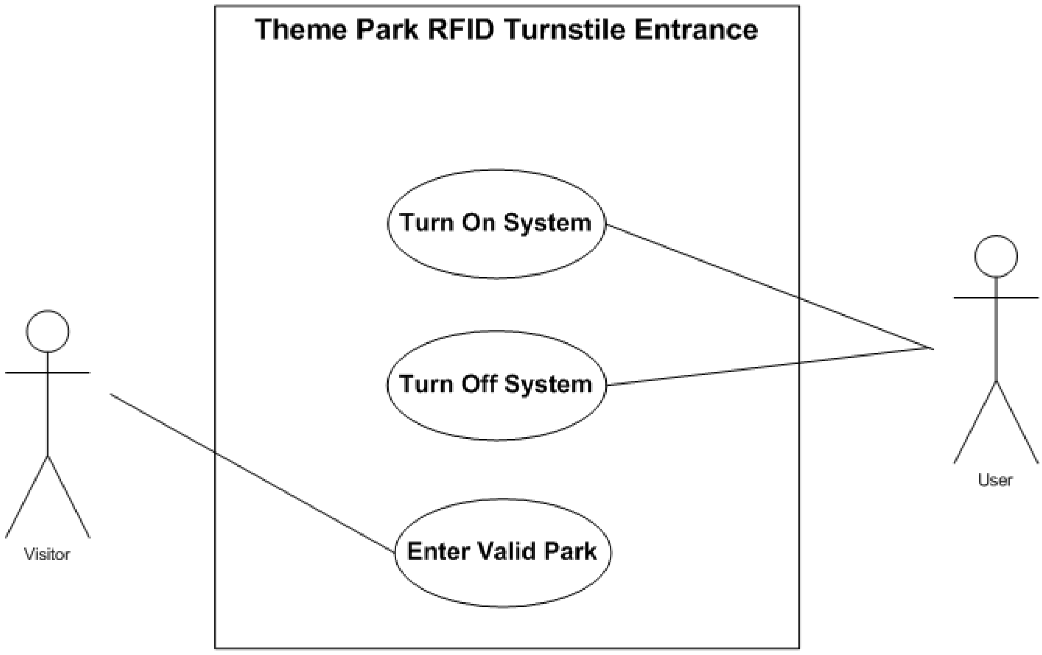


Figure 30: RFID Turnstile Entrance

4.7.3 Sequence Diagram.

This sequence diagram shows how the RFID Turnstile' barrier auto unlock after the visitor scan their RFID Tag via RFID reader attached the Turnstile and will auto turned off and locked to prevent others RFID visitors from entering.

RFID Turnstile Sequence Diagram and class as shown figure 31 and figure 32 respectively.

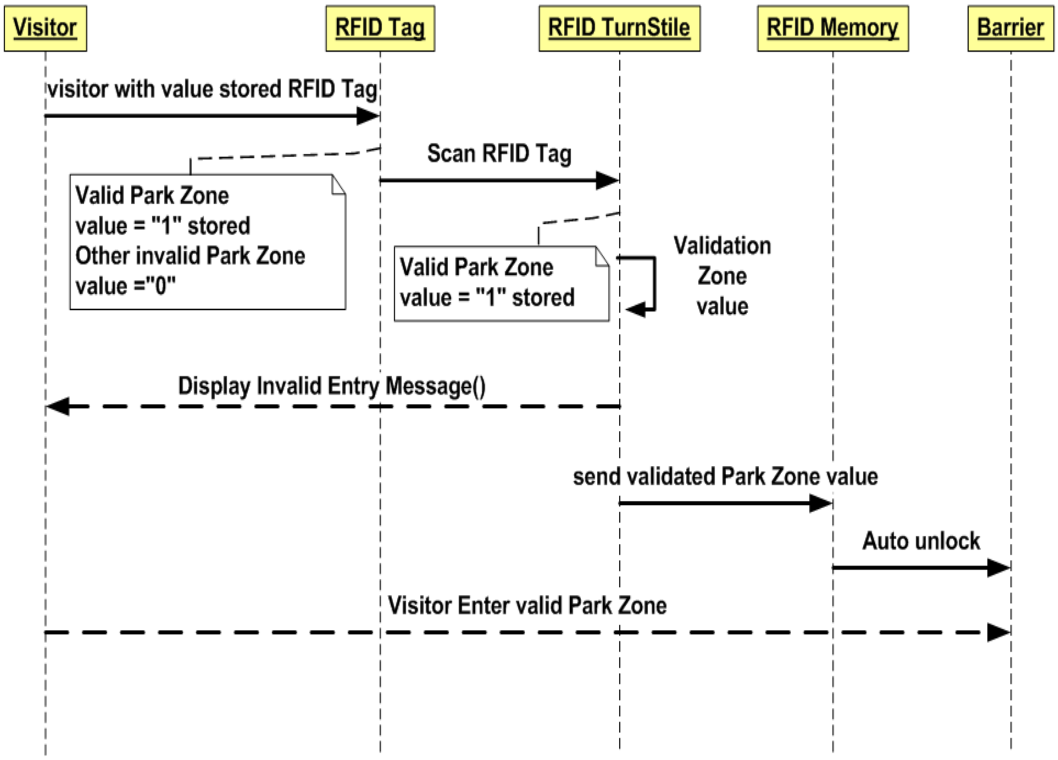


Figure 31: RFID Turnstile Sequence Diagram

4.7.4 Class Diagram.

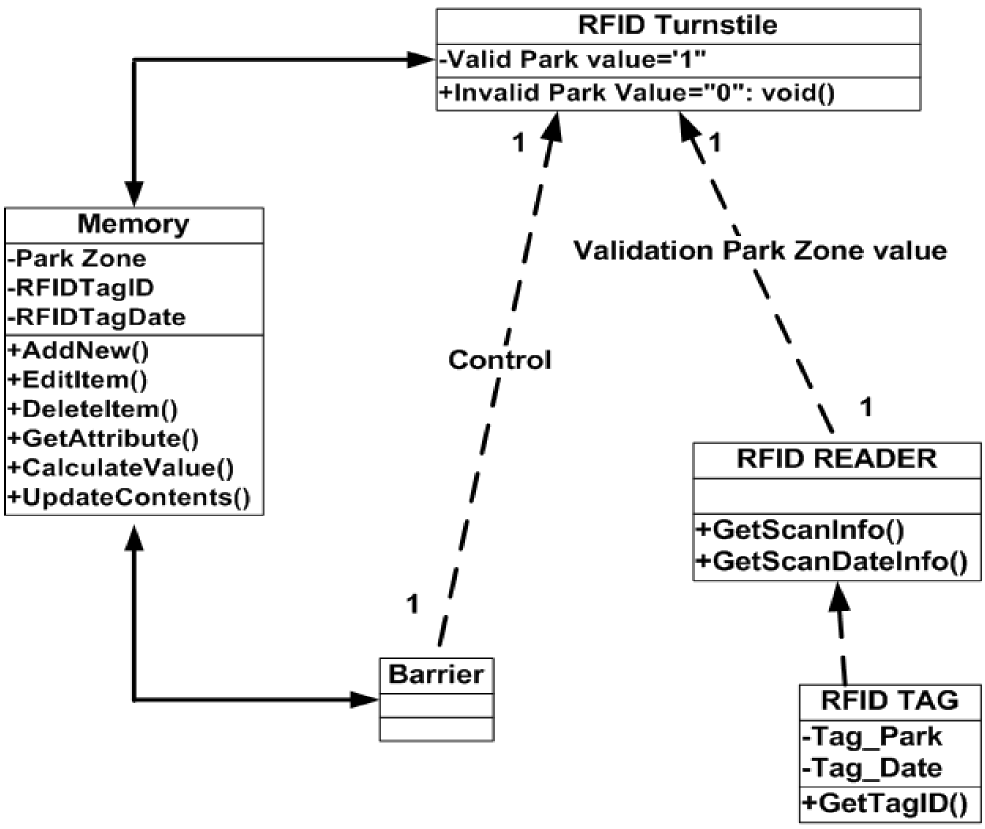


Figure 32: RFID Turnstile Class Diagram

4.7.5 Use Activity Diagram: RFID Turnstile Process

Visitor presents the RFID tag to the RFID enable Turnstile (self scan) for entering to the Park Zone. First the visitor scans the RFID tag at the RFID reader enable in Turnstile performs the validation check. The RFID reader credit the visitors RFID tag automatically.

An activity diagram is drawn to represent the general behaviors of the RFID enable Turnstiles shown in figure 33.

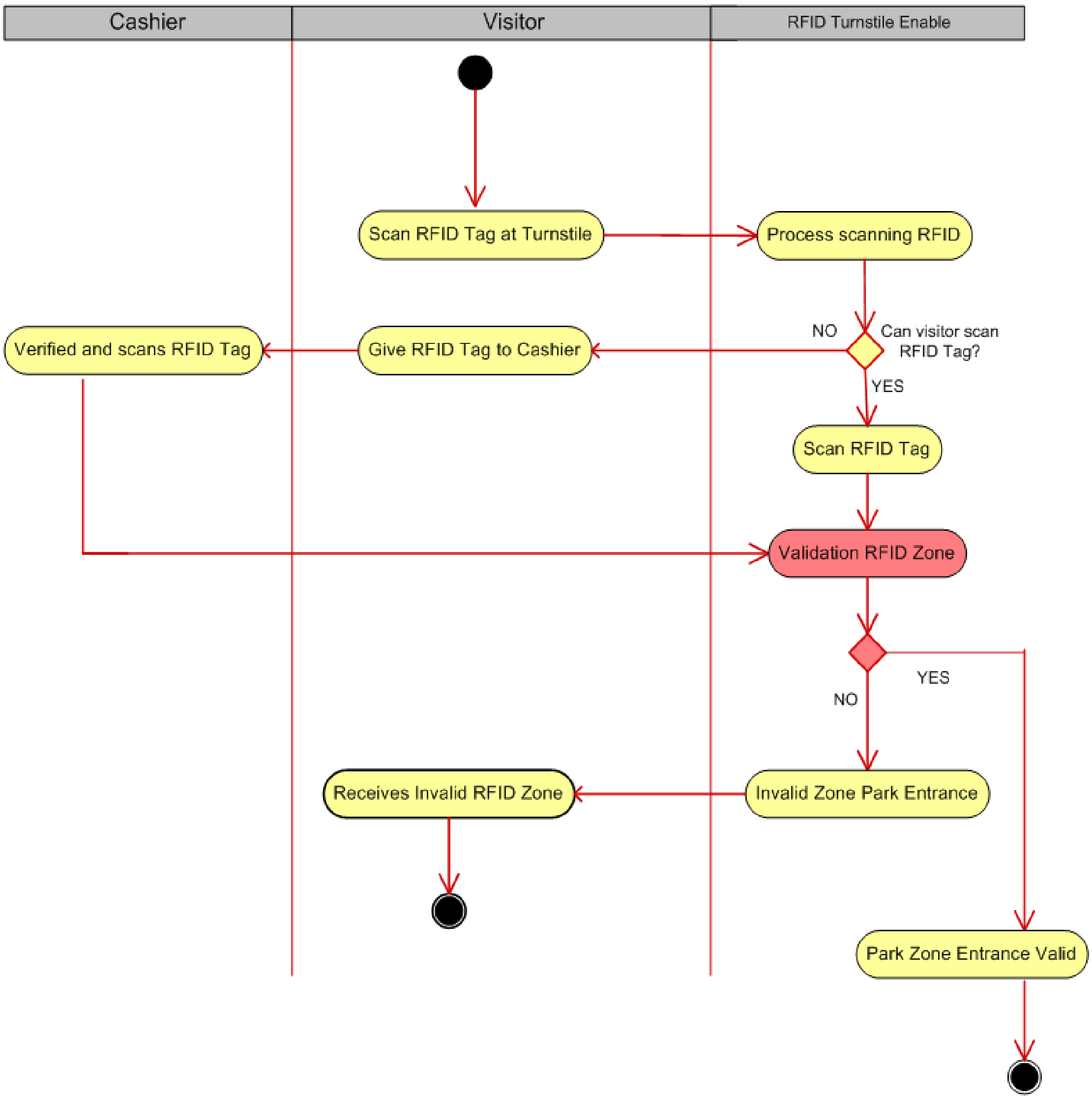


Figure 33: Activity Diagram: Scanning RFID Process at RFID Enable Turnstile

4.8 Graphical User Interface (GUI)

Graphical User Interface (GUI) Design is used to provide more user-friendly interface. Selecting a proper screen-based control makes the system much easier to use. Input and Selection plays a significant role in the input design. There is some sample of the TMPS POS system interface has been designed in a simple way as shown the attached.

Figure 34: Enter cashier mode and key in password

The first screen is known as Authorization and authentication login that only allow those users have the access rights in place.

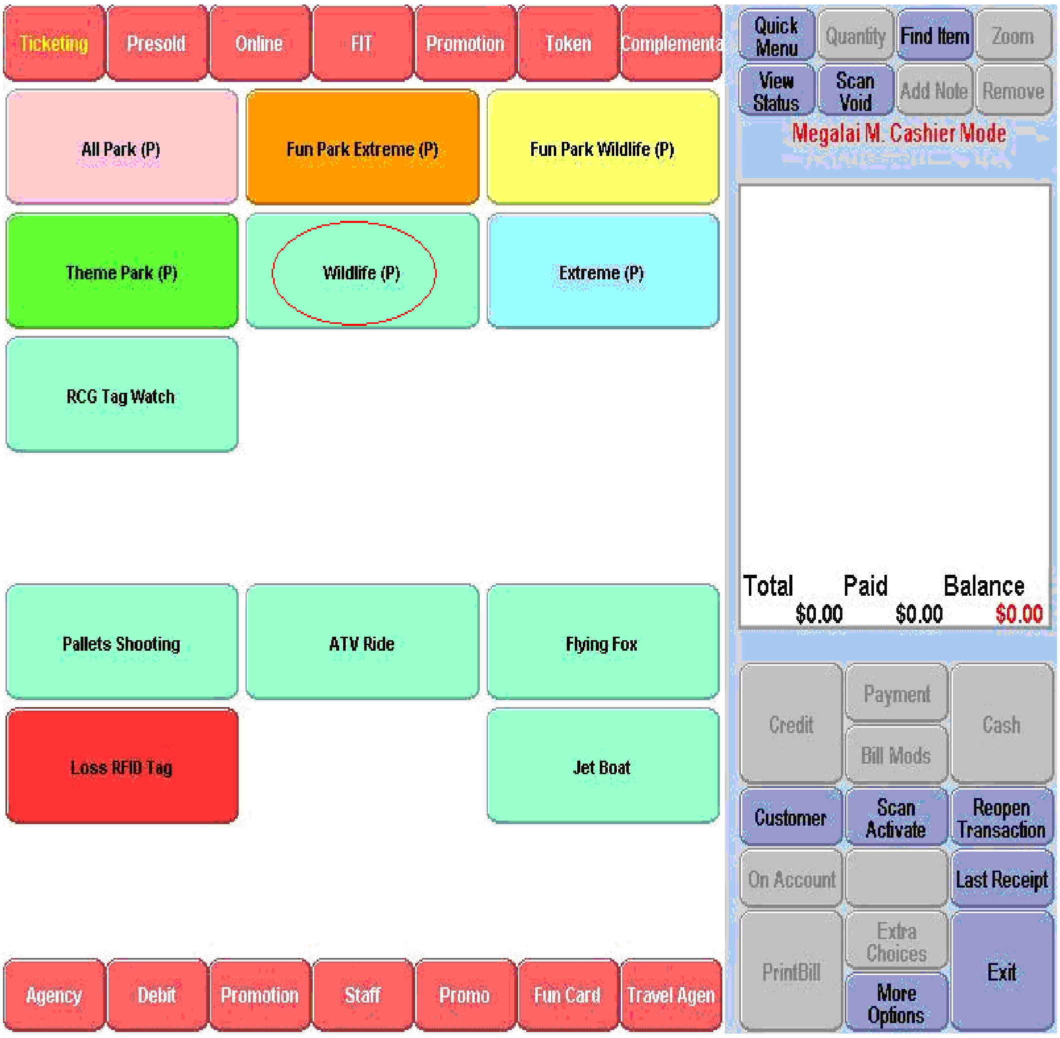


Figure 35: Select Wildlife button

The above screen is display selection of park preferable by visitor before enter value by cashier.

Select category whether is Adult, Child or Senior Citizen. For this example is Child category preferable.

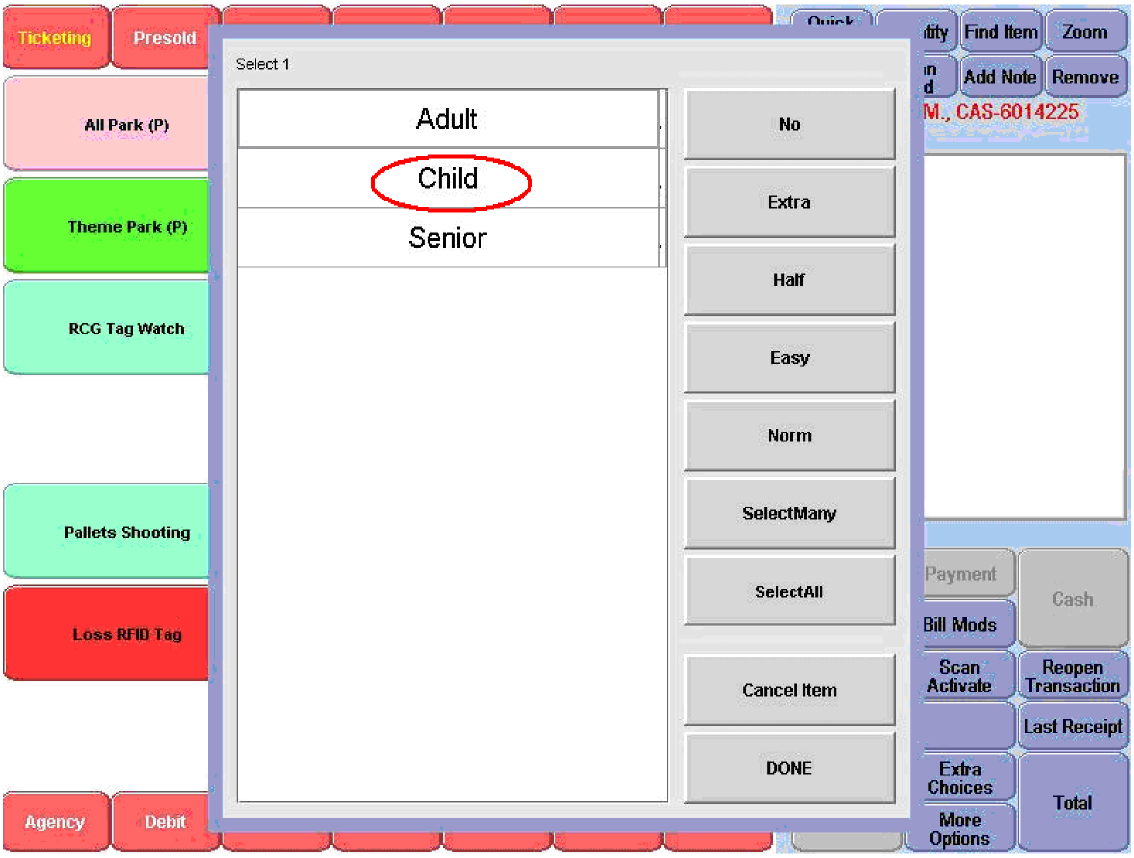


Figure 36: Category Selection

Select the payment type either Cash or Credit type payment as shown figure 37

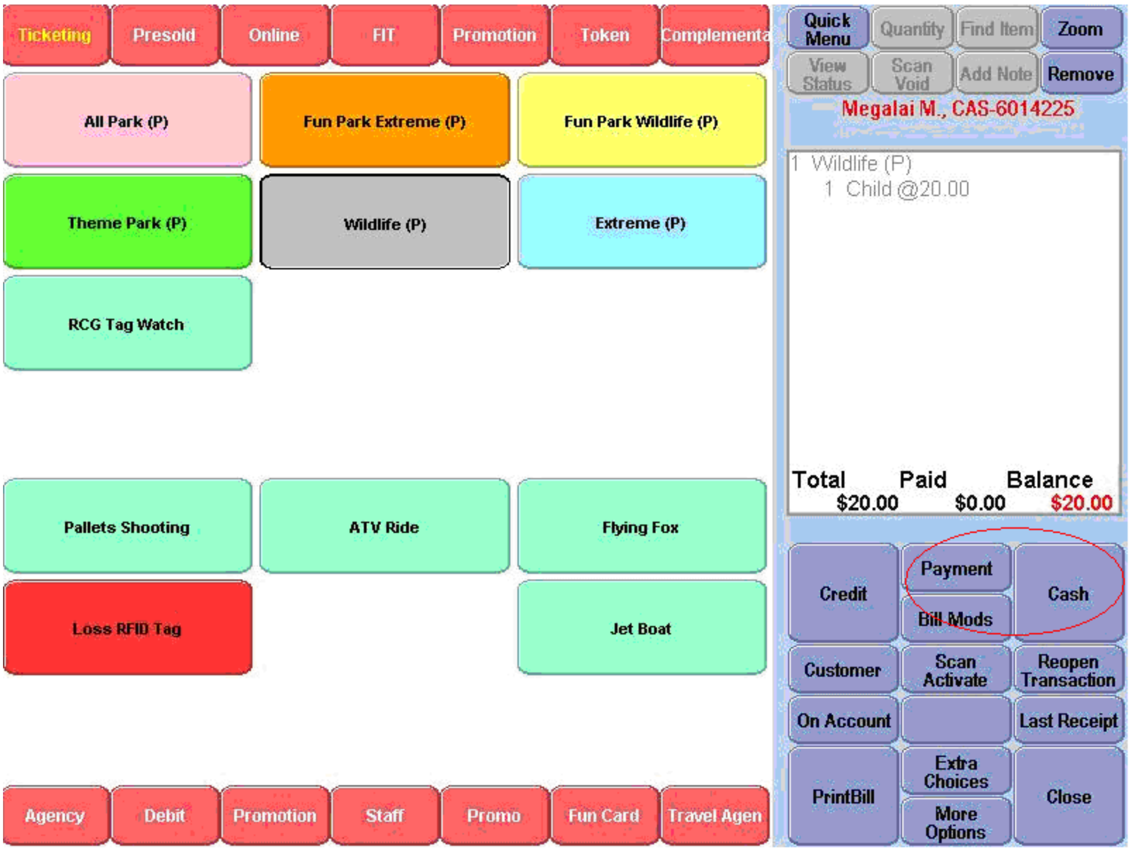


Figure 37: Selection of Payment Type

Then Cashier is total up the first transaction of the value of RFID tag visitor purchased

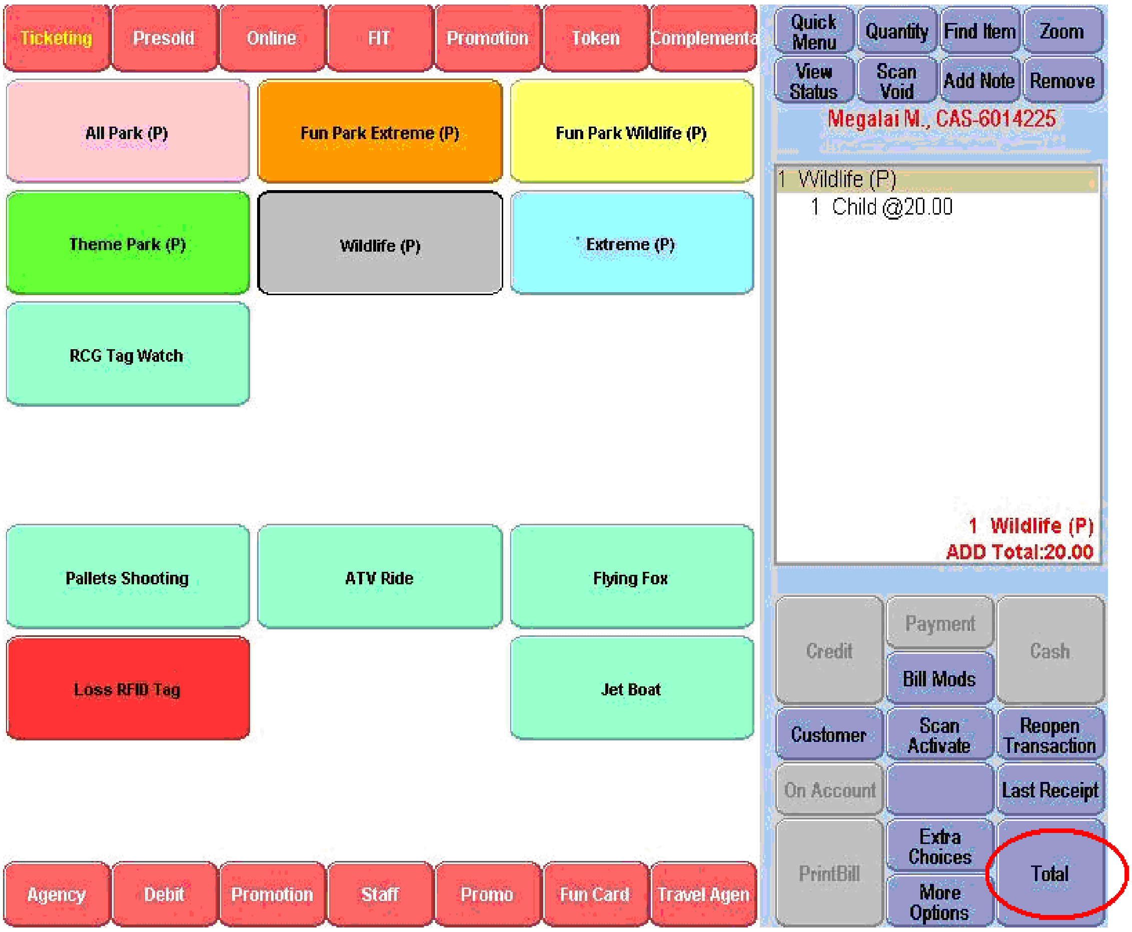


Figure 38: Total of first transaction

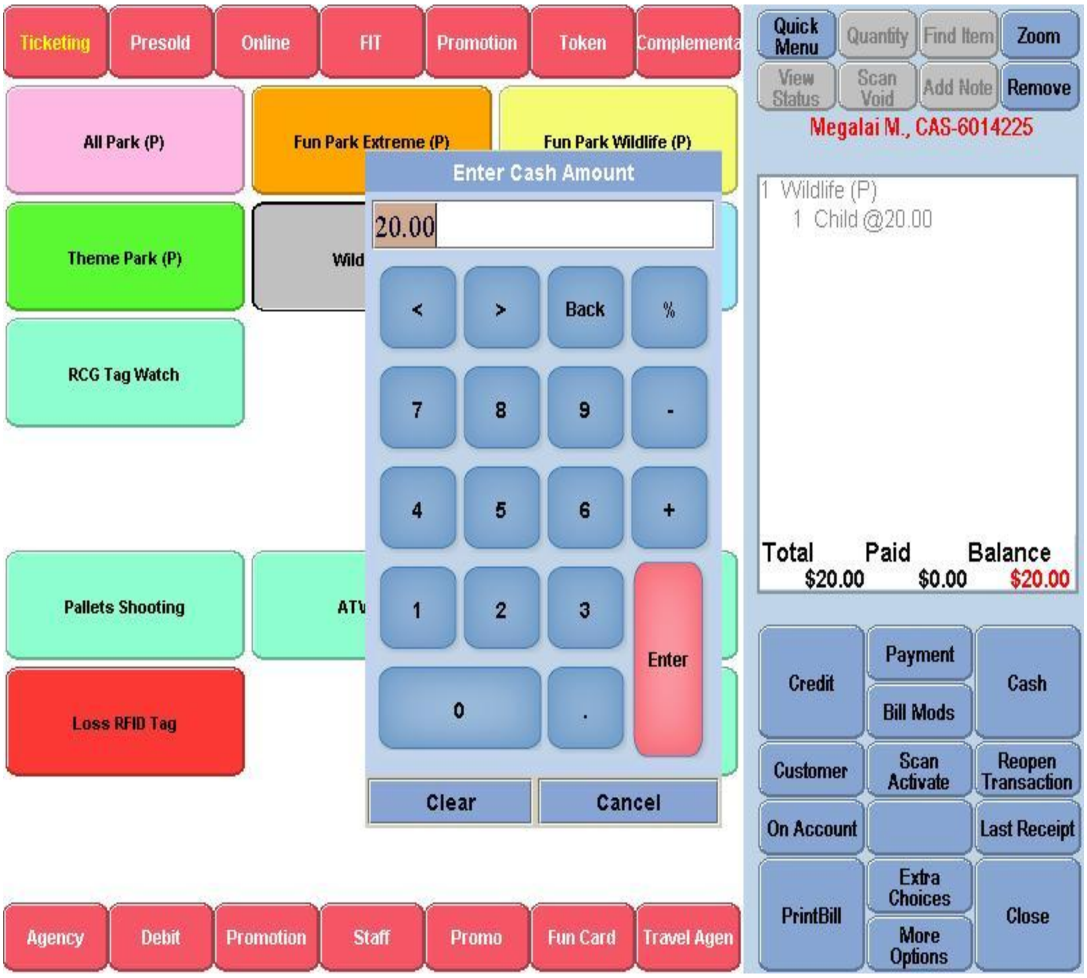


Figure 39: Input Value Screen

This screen basically describes to the input of value of the Wildlife Park under Child category at total cost RM20.00.

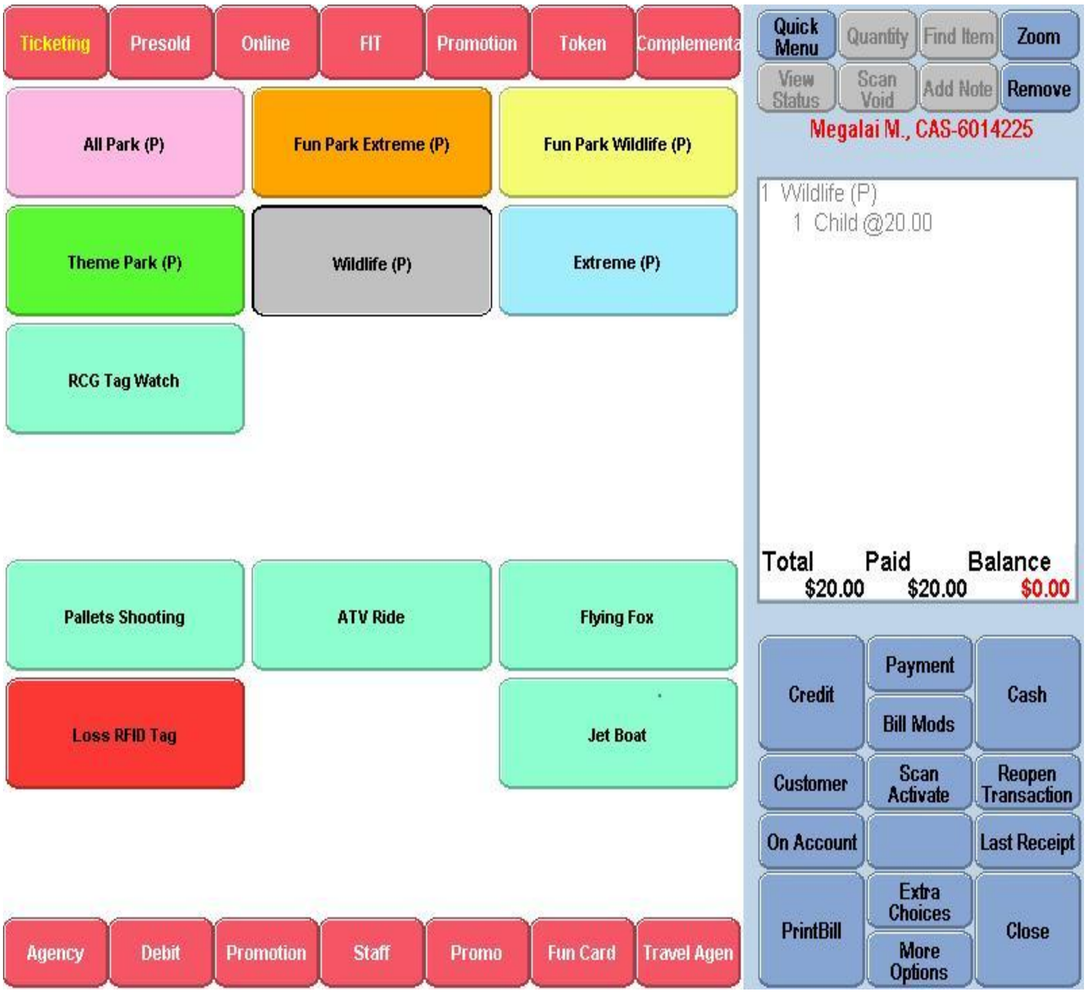


Figure 40: Selection closed the transaction before next process

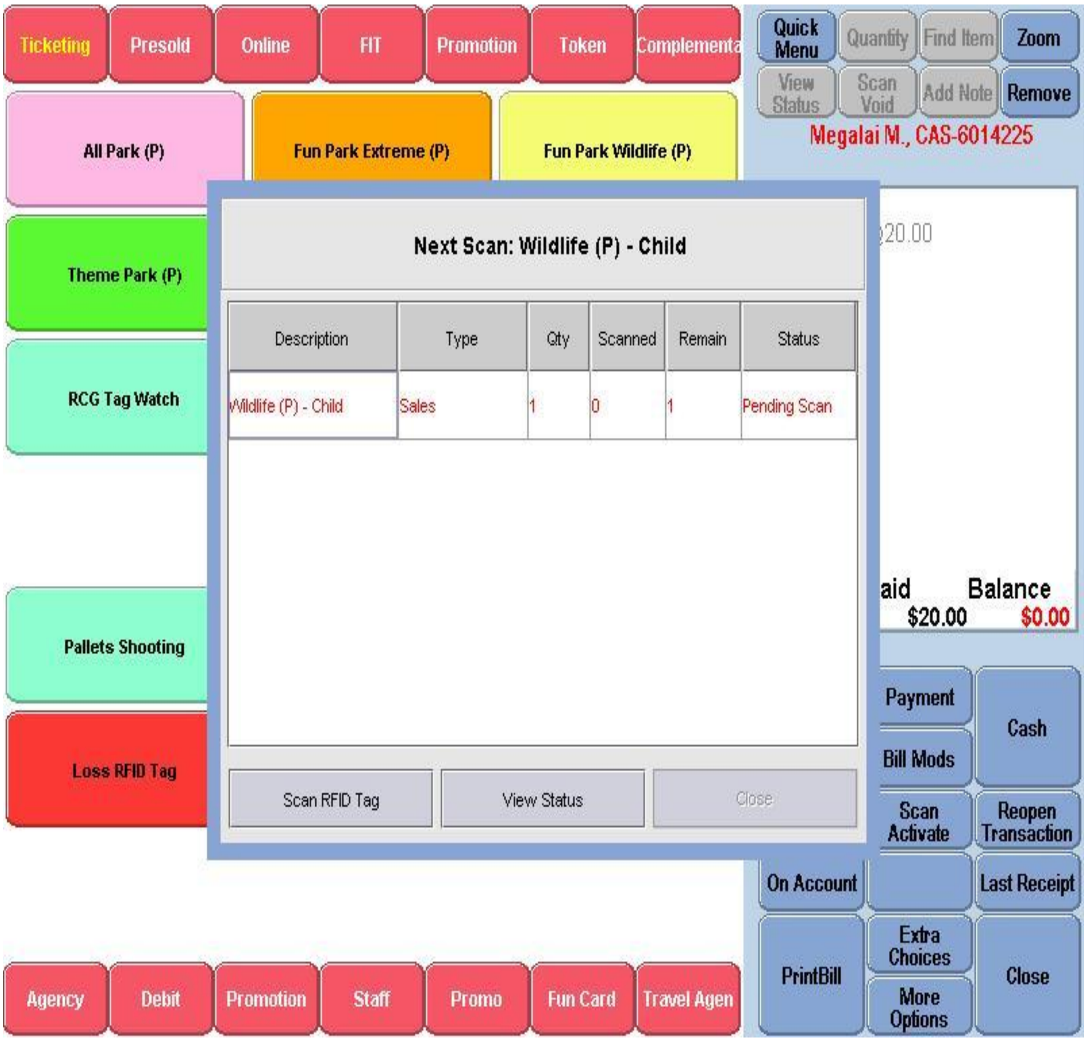


Figure 41: Initial RFID Scanning Process

The last two screens are the explanation of the RFID scanning process of the TPMS POS System. The figures 41 shown that the RFID scanning process is pending scan that cashier require placing the RFID wristband tag on top of the RFID reader at POS terminal .This shown as for a clear understanding from user.

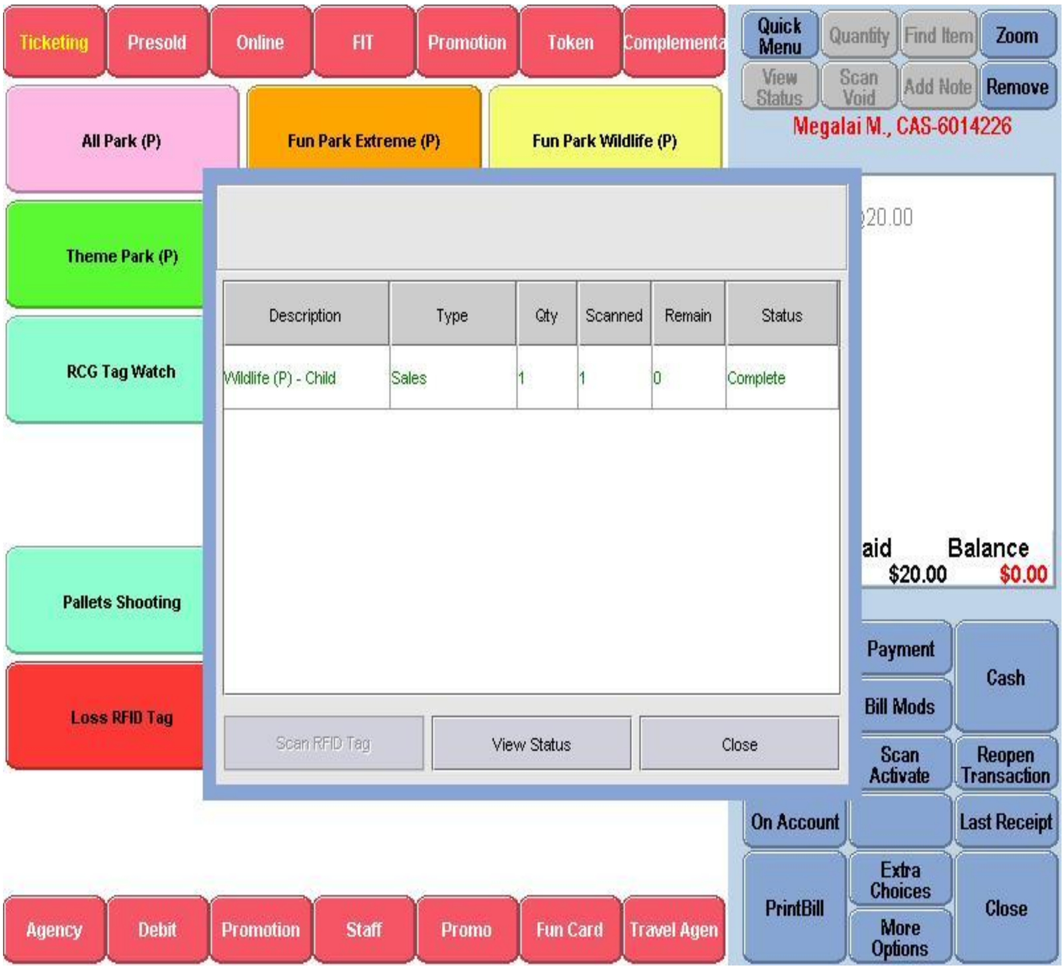


Figure 42: RFID Scanning Process Completed

This screen is last process of the POS RFID. It's shown that the RFID tag scanning process completed whereby the RFID tag has captured the value and the Wildlife Zone code into RFID Chip itself. Thereafter, the RFID tag is present to visitor for the entering park.

4.9 Summary

All front-end POS Terminal, including Ticketing POS, F&B POS, Retail POS as well as Tube Rental POS will be installed with RFID Reader. When Visitor purchases a ticket for park access at any ticketing office, he/she will be issued with a passive RFID enabled hand-tag. By the time, visitor can prepaid an amount of cash for spending throughout the park. The prepaid value will be stored immediately in the system according to the passive RFID hand-tag.

Next the visitor can enter the park simply by beeping their hand-tag on the RFID reader installed in the entrance turnstile as shown figure 43.

Figure 43: Visitor Scanning RFID Wristband at Turnstile

When visitor needs to make purchase in any retail shops, food and beverage stalls or required to rent equipment thought the tube rental outlet, customers can beep their passive RFID hand-tag on the RFID Reader attached with the POS terminal as shown figure 44.

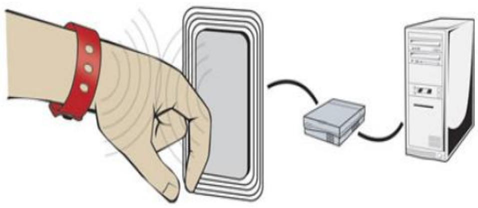


Figure 44: Visitor scanning at outlets

Visitors also add value to their prepaid account anytime through these terminals.

On the backend site, all the POS terminals will be linked via LAN to backend server. Data will be synchronized in the centralized database in real time. Systems administrators, marketing colleagues or managements can always access to the system for maintenance, data analysis or freely generate customize reports when necessary.

The system will also handle the backend inventory. The inventory system will be linked with POS terminals, handling the whole flow from ordering materials, to consuming including selling within shops.

With the inventory system, Event Management can also be done with better planning simply by clicking for what is required on the screen, and enters quantity required to make up budgeting planning.

In this chapter, the details design implementation and result of the RFID system has been discussed properly. Discussion also had includes the concept and theories that were used throughout the research process. The next chapter will discuss the conclusion of this project and future enhancement recommendation.

CHAPTER 5: CONCLUSION

This is the final chapter of this project paper. The chapter will conclude everything that has been explained from the beginning of the chapter 1 until chapter 4. Furthermore, in this chapter will also include weaknesses and future expansion also be summarized.

5.1 Conclusion

Employing of RFID design concepts to the Theme Park industry in order to boost the efficiency and thus the amount of manual processes is outlined using idea of RFID technology in the processing of the identify Park Zone Entrance as well as store prepaid value. By using RFID technology, the process of the above becomes streamlined and automated, thus able to provide a larger profit margin in the Theme Park industry. Increased profitability means increase market, creating a larger economic as well as social demand.

It is clear that there are many opportunities to improve customer benefit through the use of RFID tag technology. The key driver for the adoption of such technologies is the customer, and the desire to provide value-adding features that provide real consumer benefit. In situations where Theme Park can improve the product and services to produce clear visitor benefit, also will proactively engage in development activity by collaborating with appropriate technology providers, whether it is RFID or other technologies.

5.2 System's Weaknesses

Even how great and potential of a system was developed, but weaknesses still can be found. TMPS also owns its weaknesses. All data of the system is stored in the internal database instead of external database. Due to the reason, the quantities of data can be stored limited.

5.3 Future Expansion

Besides software enhancements, as part of the future development of the Theme Park Management System, its can integrate with online ordering platform for visitors. In addition, an intranet of Sunway Group can also be incorporated into it that here can be name as **Complete Leisure Solution.**

5.4 Summary

Theme Park Management System (TPMS) is being used to provide a system that provides an ease of use and enhance business processes more efficiency. Even-though TPMS manage to meet the setting objectives, there are still limitation that can be found affect the system. The limitation of the system has been explained early on. Besides that, ability of the system also has been clarified as to show the strength of the system. Some useful future expansion recommended as the ideas to make the system more integrate and produce more effective solution.

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APPENDIX – RFID APPLICATIONS

Applications of RFID - 47

- Access Control
- AFC
- AGV positioning
- airline ticketing
- Animal ID
- anti-theft
- assembly line id
- asset tracking
- automotive
- baggage tags
- Car Immobilizer
- car manufacturing
- configuration management
- Container
- conveyor belt clothes hangers
- electronic Keys
- e-purse
- factory automation
- fleet management
- Forklift positioning
- gambling
- gas cylinder
- healthcare
- Industrial ID
- logistics
- loyalty schemes
- maintenance logs
- medical device
- Membership Cards
- mining
- paint shop
- pallet tagging
- park and ride metering
- payphones
- people locating
- pigeon races
- process control
- road toll
- security areas
- Ski tickets
- T&A
- toll collection
- traffic management
- truck fleet tracking
- university cards
- vehicle access control
- vehicle movement

(AIM 1998)