DESIGN AND IMPLEMENTATION OF MULTIBAND RFID SYSTEM FOR HYPERMARKET e-PAYMENT SYSTEM

by

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Renuka Nalinggam

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LIST OF ABBREVIATIONS

ACK	Acknowledge
ASCII	American Standard Code for Information Interchange
AGP	Antenna Gain Penalty
AT	Transparent
COM	Communication
DI	Data Input
DO	Data Output
DOE	Design of Experiment
DH	Destination Address High
DL	Destination Address Low
EBG	Electromagnetic Band Gap
EEPROM	Erasable Programmable Read Only Memory
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EPARFID	Embedded Passive Active Radio Frequency Identification
EPC	Electronic Product Code
FEM	Finite Element Method
FF	Far Field
FTDI	Future Technology Device International
GEN 2	Generation 2
GUI	Graphical User Interface
HF	High Frequency

ID	Identification
ILT	Item Level Tagging
IOT	Internet of Things
LF	Low Frequency
LOS	Line-of Sight
LSB	Least Significant Bit
MAC	Media Access Control
MBS	Modulated Backscattering
MTC	Machine Type Communication
M2M	Machine to machine
NF	Near Field
NLOS	Non-Line-of-Sight
PAN	Personal Area Network
PC	Personal Computer
PHY	Physical Layer
PR	Passive Reader
RF	Radio Frequency
RL	Return Loss
RFID	Radio Frequency Identification
RO	Packetization Timeout
RMS	Root Mean Square
RSN	RFID Sensor Network
RSSI	Received Signal Strength Indication
RTF	Reader Transmit First
R_X	Receive Mode

RXD	Receive Data
SA	Spectrum Analyzer
SM	Sleep Mode
SPM	Standard Packaging Materials
STD	Standard Deviation
TTF	Tag Transmit First
TTL	Transistor – Transistor Logic
Tx	Transmit Mode
TXD	Transmit Data
UART	Universal Asynchronous Receiver Transmitter
UHF	Ultra-High Frequency
UPC	Universal Product Code
USB	Universal Serial Bus
UWB	Ultra-Wideband
WSN	Wireless Sensor Network
ZC	ZigBee Coordinator
ZED	ZigBee End Device
ZR	ZigBee Router

REKABENTUK DAN IMPLEMENTASI SISTEM RFID PELBAGAI JALUR UNTUK SISTEM e-BAYARAN DI PASAR RAYA BESAR

ABSTRAK

Kaedah penciptaan bil yang sedang digunakan di pasar raya besar adalah memakan masa dan pelanggan perlu menunggu masa yang lebih lama untuk mendapatkan bil mereka. Kajian ini memberi tumpuan kepada mencari penyelesaian untuk mengurangkan masa menunggu di kaunter bil menggunakan teknologi RFID. Melalui kajian ini, kombinasi RFID berasaskan pasif dan aktif ZigBee (EPARFID – embedded passive and active RFID) telah dicadangkan untuk digunakan sebagai alat pengeluaran bil di pasar raya besar. Sistem EPARFID telah dibangunkan bagi mendapatkan data eksperimen untuk menganalisis ciri-ciri RFID. Sistem EPARFID telah tertanam dengan dua mekanisme iaitu 915 MHz modul RFID dan 2.54 GHz ZigBee modul tanpa wayar. Prestasi sistem EPARFID telah diuji dan dibandingkan dengan sistem mandiri dari segi rangkaian komunikasi, penilaian kendalian, kependaman, pemulihan diri dan perlanggaran data di pelantar rangkaian tanpa wayar. Ia dapat diperhatikan bahawa dari segi konsisten EPARFID adalah lebih baik daripada sistem mandiri. Beberapa set eksperimen telah dijalankan dalam kajian ini dan beberapa ciri-ciri penting teknologi RFID berjaya diperolehi. Ia adalah jarak optimum antara tag pasif dan antena tampalan didapati sebagai 0.7 m antra tag dan pembaca di LOS dan 0.3 m antara tag dan pembaca di NLOS. Berdasarkan siasatan, ia berjaya mengesahkan bahawa teknologi RFID tidak perlu LOS dalam mengesan tag pasif. Ia juga mendapati bahawa ketelusan dielektrik relatif bahan-bahan yang digunakan dalam eksperimen itu memberi kesan yang besar ke atas prestasi

EPARFID. Bahan-bahan dengan ketelusan relatif lebih rendah bersaing prestasi yang konsisten membandingkan bahan-bahan dengan ketelusan relatif lebih tinggi. Gabungan data eksperimen dengan analisis model EM meningkatkan kadar bacaan ekstrapolasi RFID dalam persekitaran tertentu. Pendekatan model adalah satu langkah ke arah membangunkan metodologi yang mantap untuk meramalkan kadar bacaan EPARFID ke atas set kompleks bahan-bahan. Keputusan yang diperolehi daripada kadar bacaan model ramalan yang dicadangkan berdasarkan Friis persamaan ruang bebas melalui kuantifikasi ketidaktentuan memberikan pandangan baru kepada sifat pada jenis tag. Tambahan pula, pengesahan keakraban pendekatan model yang dicadangkan dengan data eksperimen sistem EPARFID menetapkan kesahihan pendekatan model yang dicadangkan.

DESIGN AND IMPLEMENTATION OF MULTIBAND RFID SYSTEM FOR HYPERMARKET e-PAYMENT SYSTEM

ABSTRACT

The bill creation method that applied in hypermarkets is time-consuming and customers have to wait for a long time to get their bill. This research focuses on finding a solution to reduce the waiting time at bill counter using embedded multiband RFID technology. Passive RFID technology and ZigBee wireless module characteristics were studied and multiband RFID system (EPARFID) system was developed to be used to obtain experimental data to analyze WSN performance and RFID characteristics. The EPARFID system was embedded with two mechanisms which are the 915 MHz RFID passive system and 2.45 GHz ZigBee based active RFID. The EPARFID system performance was tested and compared with the standalone ZigBee module by focusing on common performance indicators such as Communication range, Throughput Evaluation, Latency, Self-Healing and Data Collision. Set of RFID characteristics experiments have been performed in this research and some essential characteristics of RFID technology are successfully found. It was found that the optimum distance between tag and reader is 0.7 m for LOS and 0.3 m for NLOS. Based on the investigation, it is successfully validated that RFID technology does not need LOS in detecting the passive tags. It also found that the relative dielectric permittivity of the materials that being used in the experiment is giving significant effects on EPARFID performance. Materials with lower relative permittivity show consistence performances compared to materials with higher relative permittivity. A combination of experimental data with analytical EM models improves the extrapolation of RFID read-rates in a given environment. The model approach is a step towards developing a robust methodology to predict

RFID read-rates on complex set of materials or standard packaging materials (SPM). The results obtained from the proposed prediction modeling of read rate based on the Friis free space equation through a quantification of uncertainties provides new insights on the nature of tag read rates. Furthermore, the confirmation of the closeness of the proposed model approach with the EPARFID system experimental data establishes the validity of the proposed modeling approach.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Internet of Thing (IoT) can be called as data exchange or interaction between two networked physical devices. IoT will increase the presence of the Internet by integrating every object for interaction via embedded systems, which leads to a highly distributed network of devices communicating with human beings or other devices. IoT is opening tremendous opportunities for a large number of novel applications that promise to improve the quality of lifestyle. In recent years, IoT has gained much attention from researchers and practitioners from around the world (Xia, 2012). IoT research has its roots in several domains, where different IoT aspects and challenges were being addressed. These research domains include the Radio Frequency Identification (RFID), Machine-to-Machine (M2M) communication, Machine-Type Communication (MTC) and Wireless Sensor Network (WSN). These technologies have been applied in many vertical application domains, varying from automotive and machinery to home automation and consumer electronics. All these elements together help a networked device to interpret data on its own in order to be able to come to the right decisions.

The demand or need of IoT in near future are well understood, thus as a supporting based on the huge requirement for address spaces that are needed in the IoT inspired future has encouraged and trigged an idea to come out with a research which is related to these field. Therefore, this research is intensively focusing on developing wireless embedded system by merging RFID and WSN technologies on a single platform to show the eligibility for hypermarket application.

RFID technology has come a long way in the last few years. Standards have been established. Prices for systems and tags have dropped. RFID technology has become much more reliable read rates and ranges are much higher than they were, and technologies and techniques to deal with metals and liquids have been developed. Software applications that can be integrated into retailers' systems and that are user-friendly at the store level are now available. Solution providers and systems integrators have much more experience with retail RFID and integrating to operational systems. There are many more experienced implementers who understand the difficulties and how to avoid them. RFID providers have progressed to more of a complete solution approach, rather than requiring such heavy-lifting component-by-component integration, engineering, and customization (McBeath, 2013). The original wave of adoption in the early 2000s focused on tracking pallets and cases. But the real growth in adoption occurred as retailers realized value from item-level tagging, especially by improving on-shelf availability at the store. This has driven the implementation of RFID on billions of items by retailers like Macy's, Walmart, Marks & Spencer, American Apparel, and others. As a result, they are realizing a sizeable operational, financial, and customer satisfaction advantage over competing retailers who are not using RFID (McBeath, 2013).

Most of the researches are focused on system development for item level tagging and checkout system by using RFID technology (Kannan & Asthana, 2013). In order to develop an item level tagging system, RFID characteristics towards different materials surface is crucial information that needs to be collected as RF signal will get affected due to the reactions from materials. There are very limited researches that have been carried out to find out those characteristics (Chiara, 2011), (Baker-Jarvis, Janezic, & DeGroot, 2010), (Kosuru, 2011), (Mei, 2014) and some of the materials are not related to hypermarket applications. On top of that, the RFID characteristics can also be predictable by using RFID power prediction models which can help to predict the tag read rate (Nikitin, 2007). Both methods would be fundamentals platforms in order to gather materials reaction and tag read rate predictions. By applying these information's will make the developed system more reliable and as the proof with full analysis to show the eligibility of applying RFID technology in hypermarket application.

Thus, the proposed system designed and implemented in this research is based on passive and active RFID system that incorporates several ZigBee functionalities into a coherent whole to provide real-time identification and location data. The entire system consists of passive and active tags (front end) & active RFID long-range portable reader (back end), wireless transceivers in a self-healing mesh network, and a work station system. The integrated node consists of an RFID reader and wireless module.

This research intends to upscale 915 MHz RFID passive reader operate at 2.4 GHz embedded with an active tag be applied in hypermarkets replace the current payment system. To discover the RFID Technology eligibility by focus on developing standard guidelines for DOE specification requirement for hypermarket application. On top of that, based on real experiment data RFID read rate model will be modified and proposed. The proposed model can able to predict RFID read-rates for standard packaging materials (SPM) in hypermarkets and provide guidelines for system developers on the possibility of what going to happen in real environment.

1.2 Problem Statement

To purchase essential groceries, people who stay in cities tend to go to hypermarkets, which have high quality branded items. The time spent by the people waiting for their turn to get the bill and pay the money may be more than the actual time they spent in selecting their goods. For the past 35 years, barcode technology has been chosen by retailers to keep track of products in the store until leaving the checkout counter. Barcode system scans the grocery individually and requires line-of-sight in order to detect the object. Once the grocery is scanned individually, then the customer’s bill is prepared. The bill creation method applied in hypermarkets is time-consuming and customers have to wait for a long time to get their bill (Kannan, 2013; Finkenzeller, 2010).

RFID (Radio Frequency Identification) is progressing as a major technology enabler for identifying and tracking goods and assets around the world. Thus, an attempt has been taken to discover RFID technology ability for bill creation and product labelling purpose in hypermarkets. RFID technology is grouped under the more generic Automatic Identification (Auto-ID) technologies. RFID is positioned as next generation bar coding because of its obvious advantages over barcodes. The existing barcode technology is required human intervention to scan item manually and it required line-of-sight (LOS) to scan items. Whereas, RFID Technology scans items automatically without human intervention and does not need (LOS) to scan items.

The range that can be achieved by an RFID system is determined by the power emitted by the reader antenna, the power available within the tag, passive tag types, antenna and tag orientation and tag surface material which tag is placed. Tag surface materials also play a vital role as RFID performance may be affected in terms of distance and read rate due to the effect of parameters such as dielectric constant, radiation efficiency, radiation impedance caused by the diversity material properties (Gao et al., 2014). Typical material reactions towards RF signal are reflection, absorption, and attenuation, which will reduce the reliability and performance of RFID system in terms of tag detection (Kerry & Butler, 2008). This phenomenon will limit RFID system implementation on materials related application. To overcome this problem, tag types, tag orientation and tag surface materials characteristics have to be investigated to predict read rate reliability of the RFID system in different types of materials.

Different materials will give different read rates in the RFID system. Making real experiment towards materials reaction at the preferred materials is a very effective way to obtain every material read rate. But it is not economically feasible and time consuming to measure read rate of all the available materials in hypermarkets. The lack of measured read rate data on the material of interest has resulted in the development of RFID power prediction models. Many RFID power prediction models are available for the use of researchers to predict tag read rate (Griffin et al., 2006; Piche et al., 2016; Zhang et al., 2015; Pavel V.Nikitin et al., 2007; Chiara, 2011).

Most of the models were developed by focusing on the available power in tag, reader transmitted power, antenna gain and estimated distance alone. In order to demonstrate RFID technology's eligibility for hypermarkets application, tag surface material parameters would be the main consideration to be used in the prediction model. Even though many researchers have developed prediction models (Griffin et al., 2006; Piche et al., 2016; Zhang et al.,2015; Nikitin et al., 2007; Chiara, 2011) that can be used to predict tag read rate, there is still some hesitation in picking the right model to be suitable for research. Thus, some real time measurement results are necessary to compare with suitable prediction model to validate its accuracy.

Each prediction model will have its potentials and limitations. Based on the limitations in the existing models, the power prediction model need to be modified. Therefore, it is very important need to determine the measured experimental data in order to choose the optimum read rate prediction model. On top of that, current payment systems use a wired connection to display the data. Total sales of the day or week data only can be obtained from a server. To obtain the data, the user must have an Internet connection. A slow Internet connection may cause some delay in getting data for a speedy process. Therefore, WSN technology is being merged with RFID technology so that the system will perform in wireless platform.

By integrating RFID and WSN, a significant improvement can be seen in monitoring. This will provide a chance for RFID technology to work in a longer range, wider area and in multi-hop communication (Jain & Vijaygopalan, 2010). WSN generally consists of a base station; communicate through radio links with wireless sensors. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection. In the proposed system, a wireless ZigBee mesh network has been used. This research is intended to become fundamental research work focusing on Design of Experiments (DOE) with full analysis related to materials available in hypermarkets and proposing read rate power prediction model to predict read rate of materials based on their dielectric permittivity value using RFID technology. Furthermore, it also focuses towards the system design methods for development, improvement, implementation, mixtures of great technologies and testing to achieve maximum objectives from different perspectives.

1.3 Objectives of the Research

The main objectives of the research are:

1. To develop multi band RFID by embedding the passive and active RFID as a single system platform for hypermarket application and for RFID to work in wireless platform.
2. To discover RFID eligibility and develop the standard guidelines for DOE specification requirements for hypermarket applications.
3. To propose a suitable modified RFID read rate Prediction model to predict tag read rate reliability based on materials' relative permittivity.

1.4 Research Motivation

RFID technology is well known for tracking system application. Most of the research which have been carried out related to RFID technology are asset tracking, vehicle tracking, retail and inventory tracking, supply chain management and health care platforms. Only few researches have been came out with an idea about applying RFID technology for automatic payment system by replacing existing barcode technology (Kannan, 2013). The idea of replacing existing barcode technology with RFID has been explained well. The limitations which have been found from existing research is that there are no complete experiments were done on RFID performance on different materials surfaces which is suitable to be applied in hypermarkets environment (Kannan, 2013). On top of that, power rate detection modelling for RFID would be very useful portion in order to identify the passive tag read rate performance without performing real time experiment. The existing RFID modelling research has been performed by focusing on the success of detecting the passive tag alone without considering tag surface type which is being used to place the passive tag.

Limitation of research related to applying RFID technology in hypermarket environment, effect of tag surface materials on RFID reading performance and RFID read rate prediction model on variety type of surfaces are the three main reasons which motivated to carry out this research. Thus, this research would be a fundamental platform to prove the potential of multiband RFID technology for payment system in hypermarkets.

1.5 Research Scope & Limitation

The scope of this research are to develop multi band RFID by embedding the passive RFID and active RFID as a single system platform (EPARFID), investigate the eligibility of the developed EPARFID system in hypermarkets checkout payment system and to propose a suitable modified RFID read rate Prediction model to predict tag read rate reliability based on materials' relative permittivity. For the first part, the main reason of integrating RFID (passive system) and WSN to become active RFID (EPARFID) system is to observe a significant improvement in monitoring. This will provide a chance for RFID technology to work in a wireless platform, longer range, wider area and in multi-hop communication. It emphasizes on the design and development of the hardware architecture of an active RFID to be embedded with the sensory part; the passive RFID. At this stage of process, it includes the components selections, designing and developing the embedded system, hardware principle design, schematic design, Printed Circuit Board (PCB) layout design and fabrication

The passive and active portion in the proposed EPARFID system is a not separable part which involved three main segments namely passive tag (Tag on materials), active tag (payment counter) and active reader (Display). The system has to do two types of communications in order to display the data; first part communication is between passive tag and active tag. Second part communication is between active tag and active reader. Then, the data can be displayed. Therefore in second part, the software development which focuses on the virtual basic at the active RFID tag to receive the data from the Passive RFID reader and send the data wirelessly to the RFID reader with the wireless transmission to the host computer.

In the third part, test was done in a real environment of hypermarket and the experimental measurements for hardware prototype are conducted for verification, evaluation and comparison of all results. The real experiments were conducted to identify RFID characteristics and also to provide standard guidelines for EPARFID system. Based on the characteristics the power prediction model was modified and compared the result with the real experiment data to find the efficiency. Furthermore, the Design of Experiment (DOE) are designed and conducted specifically to suit the hypermarket requirements through statistical data analysis based on the resulted system performance and robustness and fulfil the standard requirements for the hypermarkets references.

1.6 Research Contributions

There are three main contributions that can be claimed from the research. They are in term of system design, system methods and RFID read rate prediction model.

1. System Design
    a) Embedment of dual band RFID into single not separable platform.
    b) A 915 MHz RFID passive reader up scaled to operate at 2.4 GHz wirelessly by embedding the dual RFID and WSN technologies.
2. System Methods
    a) Introduced new methods into the system by performing DOE an experimental method to find WSN and RFID Characteristics.
    b) Based on the outcomes standard guidelines for WSN and RFID are proposed.
    c) The visual basic terminal designs (software method) carefully designed to give smooth communication between from one segment to another segment until display without any failure.
    d) Designed a complete RFID system with proper DOE specifications and guidelines to fulfil requirement for hypermarket application.

3. RFID Read Rate Prediction Model

   a) By proposing a suitable RFID read rate prediction model items read rate in hypermarket can be predictable.

   b) Special emphasis has been given on the permittivity value of surface (metal, glass, plastic and cardboard) and subsurface (water, powder and paste) of packaging materials and found a method of mixing the permittivity values.

   c) A very unique technique RFID read rate prediction model was proposed to add uniqueness to the research. The proposed model will predict tags read rate performance based on distance and tag surface and subsurface relative permittivity values.

1.7 Thesis Organization

The structure of the thesis divided into seven chapters as shown below. The main focus of the thesis can be grouped into three main parts. Firstly are fundamental studies and improved results from foundational research work. Secondly, the new design of prototype development could be applied at short and long ranges. Lastly is the improved experimental analysis and proposed modified power prediction model.

Chapter one is about introduction on the background and problem statement which motivated the research to be conducted.

Chapter two emphases on the description about background of RFID system, review of previous works undertaken related to RFID system for item level tagging in retail and the purpose of embedment with WSN. WSN characteristics are also investigated in terms of data communication and types of communication that can be performed. Furthermore, reviews about the existing RFID prediction models being implemented are also included. Basically, this chapter is mainly focusing on reviews about entire research works which have been carried out that motivates the research with the proposed prototype.

Chapter three is about the methodology of the EPARFID system was compared with existing payment system in terms of hardware platform and software platform. Hardware and software communication and design requirements. On top of that the chapter also explained about hardware testing development, experimental set up methodology in details. Lastly, RFID rad rate prediction model modification methods are also described.

Chapter four present the results that obtained from hardware testing in term of calibration, WSN experiment and RFID characteristics experiment. Moreover, this chapter also discussed about the results obtained from RFID read rate prediction model with standard packaging materials. Real time test results also presented.

Chapter five is the conclusion to conclude the work and suggestions for future work improvement. The conclusions section is a summary of the objectives of the project and the restatement of its main results.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter emphasizes on the description about the background of RFID system, review of previous works undertaken related to RFID system for item level tagging in retail and the purpose of embedment with WSN. WSN characteristics are also investigated in terms of data communication and types of communication that can be performed. A study of available wireless protocols in market and their limitations and advantages are explained. The significant part of RFID for the research which is discovering the behaviours of RF signal towards materials and the dielectric characteristics on complex set of materials like metal, glass, plastic and cardboard were performed. Comparisons were performed and presented related to the previous works which consist of similar platform to show the RFID behaviour towards materials and current research gaps. Furthermore, reviews about the existing RFID prediction models being implemented are also included. Basically, this chapter is mainly focusing on reviews on similar research works which have been carried out that motivated the research with the proposed prototype.

2.2 RFID Technology

Radio Frequency Identification (RFID) technology has been available for decades, but has only recently matured and enhanced to prominence. Over the past decade, UHF RFID has progressed significantly. Passive UHF RFID tags are emerging in use for many applications, such as tracking apparel and vehicles. Increasing competitiveness between tag manufacturers has led to significant reductions in the cost of the technology, which in turn means that there is an increasing number of industry sectors interested in utilizing RFID for applications ranging from asset tracking to security (Nikitin et al., 2012)**.** RFID is a technology where the data is stored in the microchip and transmitted through antenna to a reader. The reader captures data from tags and passes the data to a base station (usually a Personal Computer (PC)) through its interfaces, with or without a cable for data processing.

Due to the nature of RFID technology, which is applied in locating and tracking objects, RFIDs are used in a wide range of industrial fields, such as factory automation, distributed and process control, traceability management, supply chain management, real-time monitoring of health, and radiation check (Wang et al., 2014). RFID has been recently applied to many location identification systems to detect the presence of tagged objects and/or people. Localization using an RFID reader is important for providing better and more efficient context-aware services (Wang et al., 2014). Such interactive handheld technology is currently used in real time location system devices. Many opportunities have emerged for further improvement in attaining operational efficiency and accuracy. The interest in handheld technology is growing. RFID has also attracted interest in locating applications, as its features, such as an extremely low-cost, able to send information when powered by electromagnetic fields generated by an RFID reader without line-of-sight are put to good use (Petracca et al., 2013).

Most research works related to RFID are concentrated on applying RFID technology to provide tag identification and tracking purposes only. Table 2.1 shows the comparison of existing RFIDs research works. The comparison was done in terms of frequency, range of the system, data rate, compatibility of RFID tags, and type of application.

Table 2.1: Characteristics Comparison of Existing RFIDs system

Reference	Carrier Frequency	Range	Data Rate kb/s	Compatible Tag	Application
(Moeinfar et al., 2012)	2405 - 2485 MHz	Long	250	Customized active tag	Container Tracking
(Lee & Jin, 2011)	915MHz	Short	250	EPC Class-0/Gen1, Class-1/Gen1 and 2 and ISO18000-6B	Remote inventory management
(Huang et al.,2011)	2.45GHz	Long	250	Customized active tag	Container Transportation
(Nikitin, 2012)	915 MHz	Short	250	EPC Gen 2	Tag to tag communication
(Petracca,2013)	2.45GHz	Long	250	EPC Passive Tag	Smart Factory safety system
(Donno,2014)	865-868 MHz	Long	512	EPC Class-Class-1/Gen 2	RFID based sensor network

2.2.1 RFID vs. Barcode

RFID technologies are grouped under the more generic Automatic Identification (Auto-ID) technologies. RFID is positioned as the next generation bar coding because of its obvious advantages over barcodes which is automatic scanning. With more and more applications, RFID technology will become one of the most popular technologies to improve economy and social lives in the near future (Gao et al., 2014).

For the past 35 years, barcodes technology has been chosen by retailers to keep track of products in the store until leaving the checkout counter. Barcode systems scan each grocery individually and require Line of Sight (LOS) in order to detect the object. Once the groceries are scanned individually, then customer’s bill can be made ready.

Rather than using light to collect or read a number from a bar code, radio waves are used to read a number from the RFID tag. RFID therefore does not need LOS to operate. Using radio means that the tag no longer has to be visible on the object to which it is attached. This minimizes or eliminates the need for a person to have to present the reader to the tag (Finkenzeller, 2010). A comparison of Bar codes and RFID standards can be seen in Figure. 2.1.

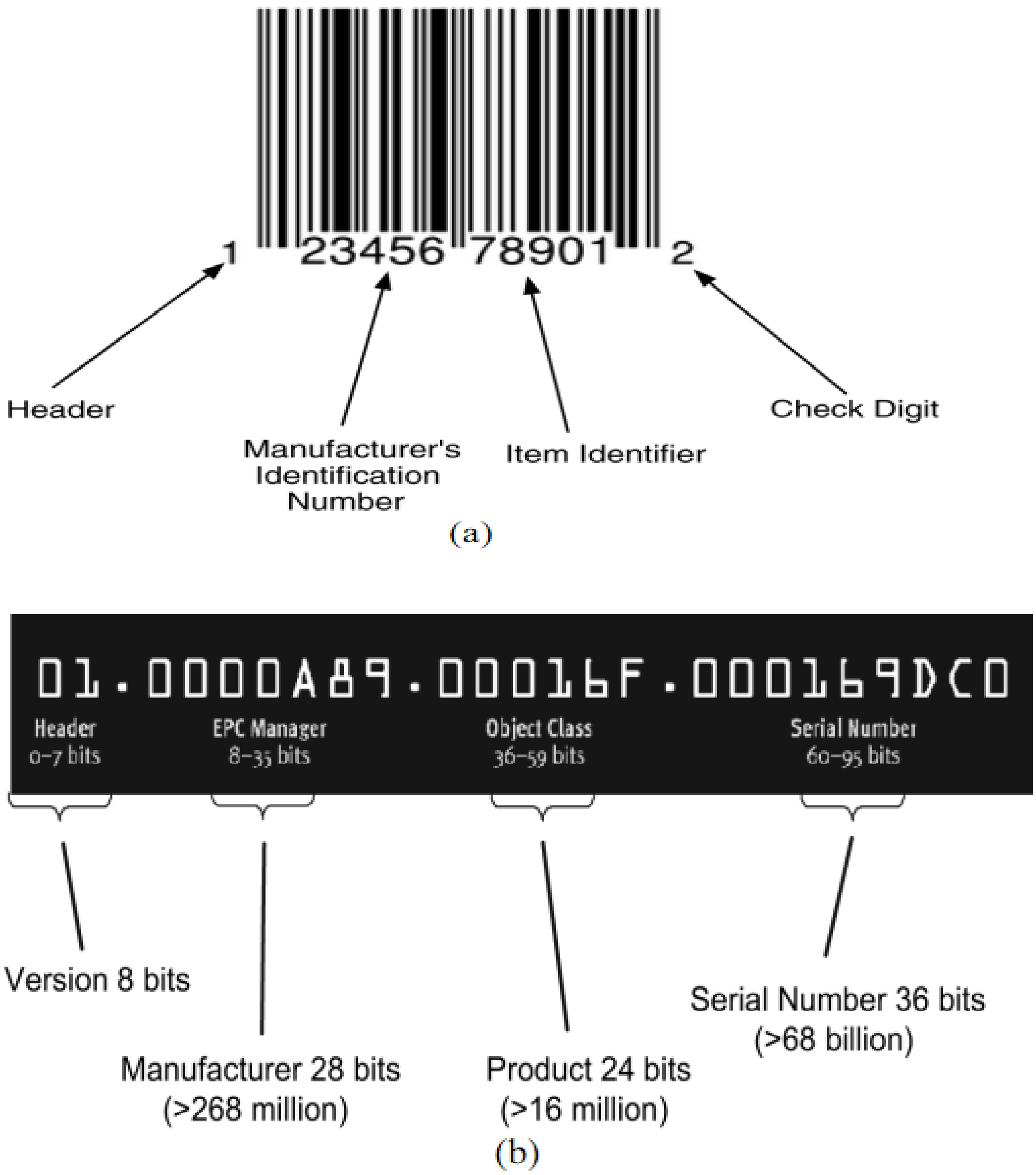


Figure 2.1: Barcode and RFID Technology; (a) Barcode standard; (b) RFID standard (Finkenzeller, 2010)

Barcode Technology, using Universal Product Code (UPC) for the 12-digit barcode, has a header digit, 6 digits for manufacturer information and 4 digits for type of item identification, with one checking digit. The advantages and disadvantages of Barcode technology over RFID technology are described in Table 2.2 below:

Table 2.2: Advantages and Disadvantages of Barcode Technology

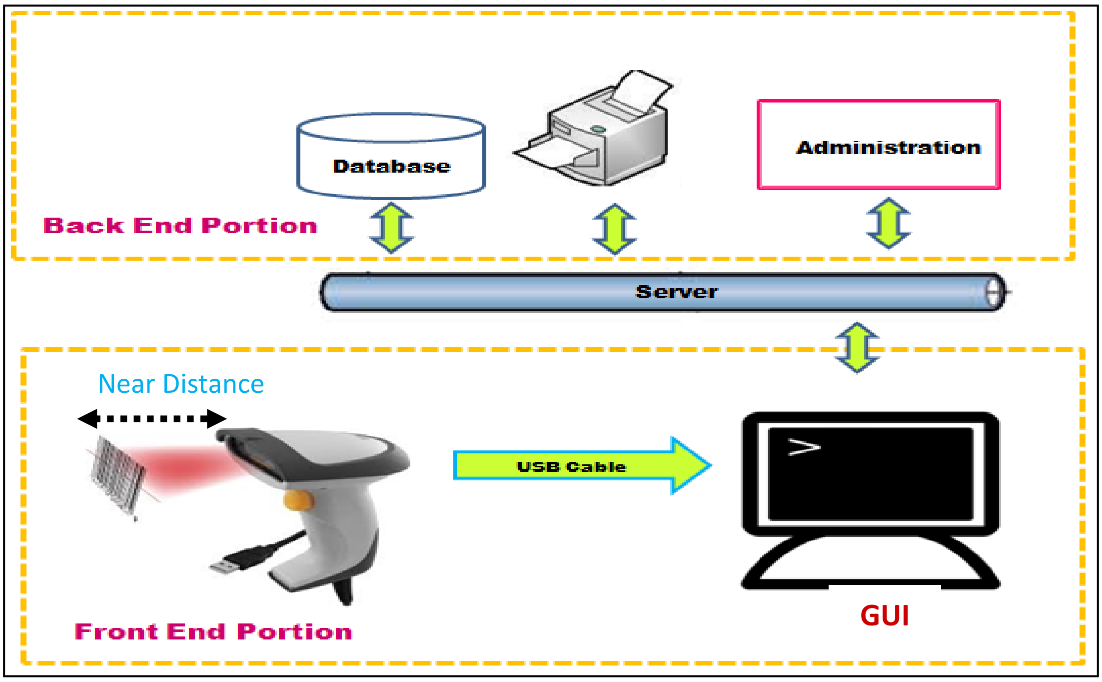
Barcode Technology	
Advantages	**Disadvantages**
A barcode is smaller in size	Scanner need LOS to scan the items
The accuracy of identification is same for all types of materials	Human intervention is required to scan the items
UPC code is universal technology	Items must be scanned individually
Less expensive compared to RFID tags	Does not have read/write function

RFID has 2-digit version number, digits for manufactures information and 24 digits for types of items identification. The advantages and disadvantages of RFID Technology over Barcode Technology are shown in Table 2.3.

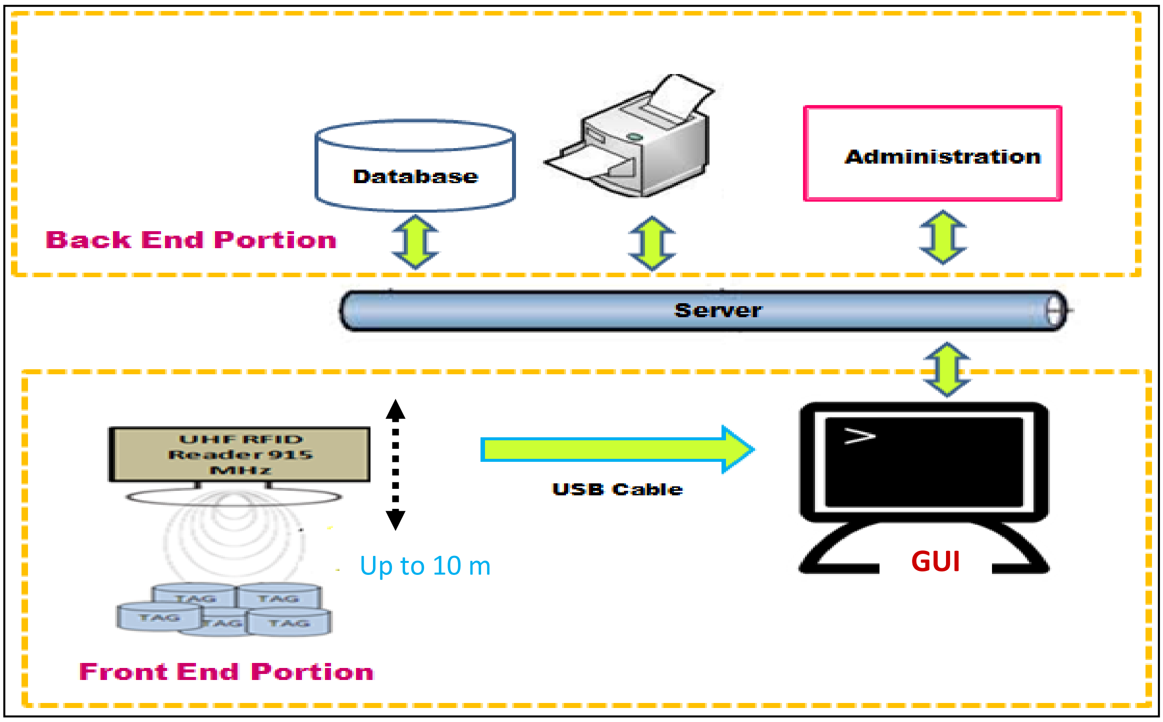
Barcode system can send item in near field as it requires LOS between barcode and scanner. RFID system distance between tag and reader can be determined by antenna gain, the distance achievement could be up to 30 m. The above mentioned characteristics comparison diagram between Barcode and RFID system is shown in Figure 2.2 (a) and (b) respectively.

Table 2.3: Advantages and Disadvantages of RFID Technology

RFID Technology	
Advantages	**Disadvantages**
Does not need LOS to read the tag	The accuracy of identification is not same in all types of materials
Can read tag information up to 3 m.	Reader collision could happen when two readers' RF signals overlap
Fully automated	Tag collision could happen when two tags respond to the same reader at the same time
Can read multiple tags at one time.	
Has read/write function	
Able to carry large data and all can be programmed in the tag	



(a)



(b)

Figure 2.2: System Comparisons (a) Barcode System and (b) RFID System

2.2.2 RFID System

RFID is a system in which data is stored on an electronic data carrying device called a tag. The power supply to data carrier device and data exchange use magnetic or electromagnetic fields (Finkenzeller, 2010).

An RFID system is usually made up of two elements, namely a tag and a reader. The tag represents the actual data carrying device of a RFID system. The device normally consists of a coupling element and an electronic microchip. Inductively coupled transponders are always operated passively, meaning that it does not possess its own power supply and all the energy needed for the operation of the microchip has to be provided by the reader. The tag will be activated when it is within the interrogation zone of a reader. Usually, the tag is located on the object to be identified (Finkenzeller, 2010).

A reader also can be called the data capture device. A reader typically contains a radio frequency module (transmitter and receiver), a control unit and a coupling element to the tag. In addition, many readers are fitted with an additional interface (e.g.RS 232) to enable them to forward the data received to another system such as a PC. Usually, the reader's antenna coil generates a strong and very high frequency electro-magnetic field, which penetrates the cross-section of the coil area and the area around the coil of the transponder antenna (Finkenzeller, 2010).

RFID technology uses several frequency ranges, including low frequency (LF, 30 ~ 300 KHz), high frequency (HF, 3~30 MHz, typically 13.56 MHz), ultra-high frequency (UHF, 0.3 ~ 3 GHz), and microwave (>3 GHz) and is classified accordingly as Low Frequency(LF) RFID, High Frequency(HF) RFID, Ultra High Frequency (UHF) RFID, and microwave RFID, respectively. UHF RFID systems have several advantages compared to LF or HF systems, UHF band offers longer reading distances (3.5 m ~ 10 m) than other RFID frequency bands because of a relatively compact high-gain antenna. A relatively high transmitter power is also permitted at an ultra-high frequency. The major technical weakness of UHF is its performance in the presence of dielectrics materials on tag surfaces (Nikitin *et al.*, 2007). To make the UHF RFID technology economically feasible, it is essential that a tag be used while attached to a variety of objects. There has been moderately very little related research work investigated on how UHF tags perform on dielectric surface (Kosuru, 2011). Now, near field UHF RFID gets more attention as a potential solution for Item Level Tagging (ILT) in retail application (Nikitin *et al.*, 2007). The UHF RFID systems are potentially suitable for Item Level Tagging applications due to the cost of the tag is cheaper and convenient as the antennas have simple planar structures, they can be manufactured using the inexpensive printed conductor compared to the LF tag as the size of the antenna and the manufacturing cost of the coil antennas is relatively high (Lee, 2011).

2.2.3 Type of Tags

Tags and readers are two crucial components in the RFID system. Tags store the identification and information of the tracking object and reader will transmit signal and retrieve it from tag. For different types of tags, readers are designed differently and implemented with different standards. A typical RFID reader contains transmitter (signal modulation), baseband processor, circulator and receiver (signal demodulation) as well as the reader antenna. RFID tags are usually categorized as passive, semi-passive, and active tags. The categories will be segregated according to power source of the tags.

Table 2.4 compares the tags characteristics in terms of internal power source, read range distance, weight, cost and life cycle. Compared to the other two tags, passive tags have longer life cycle as it does not contain internal power source. In terms of price, active and semi-passive tags will be more expensive due to complex design within and increased weight of the tags. Thus, passive tags will be the best candidates for the item level tagging and an active tag will be the best choice for wireless communication portion for the research.

Table 2.4: Summary Table for RFID Tag Types

Attribute	**Passive Tag**	**Active Tag**	**Semi-passive/active Tag**
Internal Power Source	No	Yes	Yes
Response Distance	Short	Very long	Long
Weight	Light	Less light	Less light
Cost	Cheap	Expensive	Less expensive
Life Cycle	Long	Short	Long

2.3 Wireless Sensor Network (WSN)

WSN is a network build by the sensor itself to transmit information data collected from group of sensors and assists them to reach the control centre. WSN is one of the most speedily growing research and development field. They are expanding day by day in terms of their market potential and applications. The crucial part of WSN is involved in sensing, computing, and communication. Sink node is responsible in aggregates some or all the information. Usually a sink node will be at a remote node and placed far from the coordinator, since sensor energy may not reach and support long range communication. It will use a router in between to do multi-hop wireless connectivity with nodes to forward information data to the Sink node (Jain & Vijaygopalan, 2010).

Usually, WSN contains thousands of sensor nodes and able to communicate among each other and also able to make a direct connection with base station. The greater number of sensors allows for sensing over a larger region with great accuracy. The great part of WSN is each sensor has the capability to sense data, process it and route it to the sink node (Al-Karaki & Kamal, 2004). The basic communication architecture of WSN is shown in Figure 2.3 below.

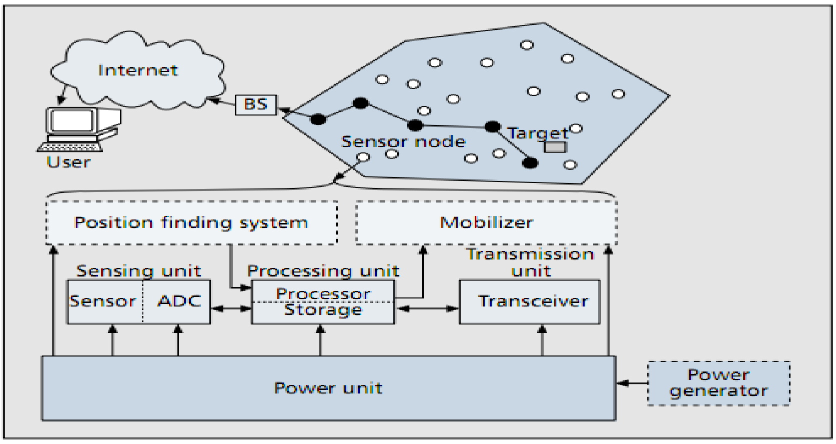


Figure 2.3: WSN Communication Architecture (Al-Karaki & Kamal, 2004)

2.4 Wireless Standard

Evaluation was done between existing wireless standard to choose the optimum wireless protocol to apply for this research. A comparison was made between Bluetooth, Wi-Fi, WiMAX, wireless USB, Infrared and ZigBee wireless standards. They were compared in terms of distance, data rate, connections, LOS, relative power consumption, typical application and security as shown in Table 2.5.

Table 2.5: Comparison between Wireless Standard

Characteristics	Bluetooth	Wi-Fi	ZigBee
Standard	IEEE 802.15.1	IEEE 802.11 B-G and others	IEEE 802.15.4
Distance (max)	100 m (Class 1)	100 m	100 m nominal
Data Rate (max)	3 Mbps	54 Mbps	250kbps (2.4GHz)
Connections	Ad Hoc, max 8 devices	Point-to-hub	Ad hoc, Peer-to-peer, star
LOS	No	No	No
Relative Power Consumption	Medium	High	Very low
Typical Application	Voice and data applications for consumer electronics and personal computing devices	Data and voice applications, wireless LAN, broadband internet access	Sensing and controlling applications in home automation

2.4.1 Wi-Fi

The Wi-Fi protocol was developed as replacement for a wired LAN and actively being utilized for PC based communication system (IEEE, 2000). The communication range is approximately 100 m. Applicable data rate from 1 Mbps up to 144 Mbps. Its indoor range can reach up to 300 ft. The features indicate that the protocol can be suitable to merge with RFID in higher data rate requirement applications (Abdulla & Ismail, 2012).

2.4.2 Bluetooth

The Bluetooth uses a master/slave based Medium Access Control (MAC) protocol, with user friendly interface and the sending data is secured and reliable (Abdulla & Ismail, 2012). The Bluetooth operate at the 2.4 GHz, for short range communication, with low cost and low power. The protocol supports ad-hoc wireless networking, which allows formation of a network without base stations. Wi-Fi and Bluetooth have the same indoor range around 300 ft. at the limitation part, Bluetooth protocol is time consuming device as it will take few seconds to find the device to be connected (Raed, 2012).

2.4.3 ZigBee Protocol

ZigBee is a well-known wireless protocol for low-cost, low power consumption and transmitting and receiving data capability. Given the IEEE 802.15.4 specifications on PHY and MAC layer, the ZigBee Alliance defines the network layer and the framework for the application layer. The responsibilities of the ZigBee network layer include: mechanism to join and leave a network, frame security, routing, path discovery, one-hop neighbours discovery and neighbour information storage. The ZigBee application layer consists of the application support sublayer, the application framework, the ZigBee device objects and the manufacturer application objects. The responsibilities of the application support sublayer include: maintaining tables for binding (defined as the ability to match two devices together based on their services and their needs) and forwarding messages between devices. The responsibilities of the ZigBee device objects include: defining the role of the device within the network (e.g., PAN coordinator or end device), initiating and responding to binding requests, establishing secure relationships between network devices, discovering devices in the network and determining which application services they provide.

ZigBee is capable of doing data packet transmission with the range from 10 to 75 m by depending on output power and environmental characteristics. Raw data throughput rates of 250 Kbps can be achieved at 2.4 GHz (16 channels), 40 Kbps at 915 MHz (10 channels) and 20 Kbps at 868 MHz (1 channel). For any given quantity of data, transmitting at a higher data rate allows the system to shut down the transmitter and receiver more quickly, saving significant power. Higher data rates at a given power level mean there is less energy per transmitted bit, which generally implies reduced range (Misal, 2007).

2.5 Type of ZigBee Modules

XBEE PRO Series 2 is the latest type of wireless module. This module requires supply voltage in the range of 2.8 V to 3.4 V, with 40 mA operating current for each receive and transmit at 3.3V. This module responds at operating frequency band of ISM 2.4GHz. In (Hyncica,2006), he was describing that Xbee-Pro modules with built-in low noise amplifier and a power amplifier provide superior range, but at the cost of increased power consumption. The power amplifier allows 60 mw of output power that enables us to reach across the whole floor, which is about 44 meters and 15 walls with 83.2 % successfully received packets with average received signal strength of -96.5 dBm.The modules were preloaded with software that is able to communicate via serial interface. The interface enables changing modes of operation and parameters using AT commands. The available modes of operation are “Sleep Mode”, “Command Mode”, “Receive Mode”, “Transmit Mode” and “Idle Mode”. The module parameters can be modified after entering the “Command Mode”.

2.6 ZigBee Network Topology

ZigBee has the capability to form an own network, send and receive data packet in the formed network over communication links. The communication between nodes is usually wireless and every single node has a certain amount of power to send and receive data