DESIGN AND IMPLEMENTATION OF A 2.4GHZ PORTABLE ACTIVE RFID READER SYSTEM IN MULTI-HOP WIRELESS SENSOR NETWORK FOR INDOOR TRACKING

HANIS MAISARAH BINTI HASHIM

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Particularly for

Beloved parents

(Hashim Bin A. Bakar & Musalmah Binti Omar),
sister (Maria Fatinah Binti Hashim), brother (Muhammad Syahmi Bin Hashim),
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ABSTRACT

Warehouse's workers are found to have consumed more time in order to configure the location of the stored products. A quality control for each stock product which has a limited shelf life is lacking as well as present in over-stocking a product. Due to these issues, a portable 2.4GHz active RFID reader system is implemented to overcome the problem. This would be achieved by fulfilling the objectives of the purposed project: To develop a portable 2.4GHz active RFID reader for warehouse management system, to implement it in a real environment and to analyze the performance of the develop system in terms of distance, latency, RSSI and tag collection time. There will be three parts: Monitoring station, RFID reader and RFID tag. Monitoring zone is where the RFID connects to a computer that will display the received data. RFID reader acts as a transceiver which receives and transmits data from RFID tag to the monitoring zone and also may be placed in different positions within the warehouse for providing a continuous inventory control. RFID tag is where the RFID attaches to the product that will transmit its data of the assigned product's information to the RFID reader. The key equipment to receive and send radio signals from RFID tag to the monitoring zone of the purpose work is by using XCTU and Arduino IDE softwares, XBee modules, Arduino boards and power supply. RF module that works on XBee standard (IEEE 802.15.4) will require a development of connection and programming according to its platform. The communication between XBee modules uses an AT command. From the performance analyzation of range test, local RSSI value at Coor-Tx (-68dBm) has better signal strength than Rx-Tag (-72dBm). Meanwhile for latency test, Tx-Coor (3.65Kbps) has a faster average transfer ratio than Tag-Rx (4.28Kbps). Both analyzation show packet lost, thus sending non-reasonable amount of packets by the RFID tag may result in lost of packet.

ABSTRAK

Pekerja gudang didapati mengambil banyak masa untuk ke sesuatu lokasi bagi produk penyimpanan. Kawalan kualiti kurang bagi setiap stok produk yang mempunyai jangka hayat yang terhad. Oleh itu, sistem mudah alih 2.4 GHz pembaca aktif RFID dibangunkan untuk mengatasi masalah tersebut. Dengan itu setiap projeck objektif telah pun tercapai: membangunkan sistem mudah alih 2.4GHz pembaca aktif RFID bagi sistem pengurusan gudang, untuk melaksanakan ia dalam persekitaran yang sebenar dan menganalisis prestasi sistem dari segi jarak, laten, RSSI dan tag koleksi masa. Terdapat tiga bahagian: zon pemantauan, pembaca RFID dan tag RFID. Zon pemantauan adalah di mana RFID disambungkan pada komputer yang akan memaparkan data yang diterima. Pembaca RFID bertindak sebagai penghantar-terima: menerima dan menghantar data dari tag RFID kepada zon pemantauan dan juga boleh diletakkan dalam kedudukan yang berbeza dalam gudang untuk menyediakan kawalan inventori yang berterusan. Tag RFID adalah di mana RFID dilekatkan pada produk untuk menghantar maklumat produk kepada pembaca RFID. Peralatan utama untuk menerima dan menghantar isyarat radio dari tag RFID kepada zon pemantauan adalah dengan menggunakan perisian XCTU dan Arduino IDE, modul XBee, papan Arduino dan bekalan kuasa. Modul RF menggunakan standard XBee (IEEE 802.15.4) akan memerlukan pembangunan sambungan dan pengaturcaraan berdasarkan platfomnya. Komunikasi antara modul-modul XBee menggunakan perintah AT. Analisis menunjukkan nilai RSSI tempatan pada Coor-Tx (-68dBm) mempunyai isyarat yang kuat berbanding Rx-Tag (-72dBm). Sementara itu, bagi ujian latency, Tx-Coor (3.65 Kbps) mempunyai purata nisbah pemindahan yang lebih cepat daripada Tag-Rx (4.28 Kbps). Kedua-dua analisis menunjukkan paket yang hilang yang disebabkan oleh tag RFID menghantar kuantiti paket yang tidak munasabah.

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LIST OF SYMBOLS AND ABBREVIATIONS

RF	-	Radio Frequency
RFID	-	Radio Frequency Identification
Coor	-	Coordinator
Tx	-	Transmitter
Rx	-	Receiver
AT	-	Abbreviation Of Attention
API	-	Application Programming Interface
ATND	-	Abbreviation Of Attention Node Discovery
TTF	-	Tags Talk First
DH	-	Destination High
DL	-	Destination Low
RSSI	-	Receive Signal Strength Indicator
TDoA	-	Time Difference of Arrival
ToA	-	Time of Arrival
WSN	-	Wireless Sensor Network
GPS	-	Global Positioning System

LCD	-	Liquid Crystal Display
SoC	-	System on Chip
ID	-	Recognition
PC	-	Personal Computer
GSM	-	Global System for Mobile Communication
PIR	-	Passive Infrared
SNF	-	Social Network Forensics
WiFi	-	Wireless fidelity
CCR	-	Clear Channel Rate
UWB	-	Ultra-wide Band
CDF	-	Cumulative Distribution Function
LOS	-	Line of Sight
IC	-	Integrated Circuit
RF-PCB	-	Frequency-Printed Circuit Board
CSSDA	-	Cascaded Single-Stage Distributed Amplifier
SMA	-	SubMiniature version A
PHY	-	Physical
MAC	-	Medium Access Control
FFD	-	Full Function Devices
RFD	-	Reduced Function Devices
PAN	-	Personal Area Network

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Generally, warehouse is large for it to store manufactured materials. It is found that to configure the location of the stored materials is harder for the worker to find and consuming more time due to its extremely large in size. From this issue, placing the tags with the using of Radio Frequency Identification (RFID) on each manufactured goods helps the workers' working system in the warehouse. The existence of the device reduces time-consuming, uses less human energy and needs no worries when locating the materials' area because they are easier to find.

RFID is one of automatic technology to identify and collect object data quickly through RF signals. It is known to be the automatic identification system that stores and recovers information from its tags or named as transponders by using a reader or interrogator and computer network [1]. RFID technology may be an extensive way to data collection, improve the supply-chain operation, provide many automated and informative alternative to a barcode.

Previously, the advantages of RFID system over a system that uses barcodes have formed a preference in the retail industry. Due to this, it allows improvement in automation that capable the tags to be read without a visual line-of-sight and their capability to compile more data than barcodes. RFID also is suitable to locate and

track objects. So, the applications of RFID have been applied to location identification systems for the detection of the presence of tagged objects and human. RFID is used in diversified applications, such as preventing theft of automobiles and merchandise; collecting tolls without stopping; gaining entrance to buildings [2].

The system is monitored by an RFID reader is necessary to give efficient context-awareness services [3]. RFID tags believe to be a reliable, sufficiently small and low cost. This affects its reputation to have increment lately. Unfortunately, the RFID development is slow due to the anticipated implementation difficulties in terms of monitoring and tracking items in a wide warehouse: signal quality, mobility, and energy efficiency. Figure 1.1 shows an architecture of networks smart nodes.

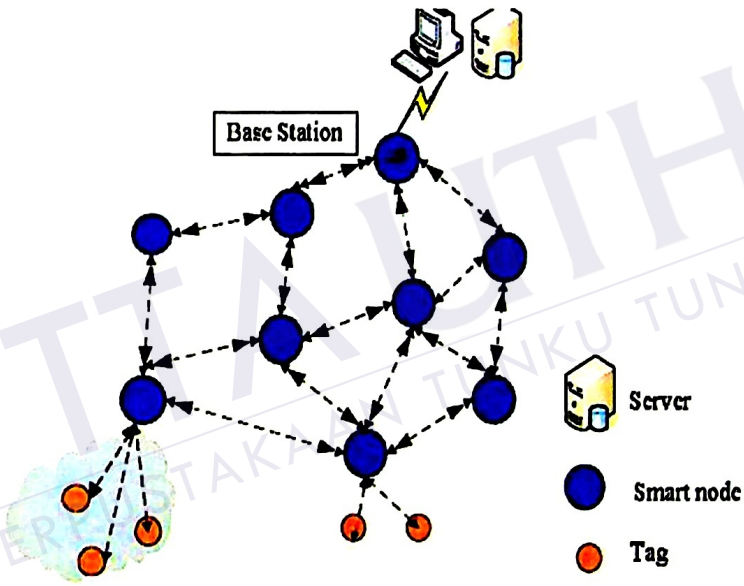

Figure 1.1 An architecture of networked smart nodes [2]

RFID has no provided information about detected objects condition. Meanwhile, Wireless Sensor Network (WSN) has provision information about objects' condition and multi-hop wireless communication [4]. Wireless sensors have made a meaningful effect on human daily life that is also the key to enabling the technology in emerging cyber-physical systems and improving the life quality [5].

1.2 Problem Statements

Many challenges to overcome when it comes to developing a system, such as in the case of Wireless Sensor Network (WSN), power consumption, data reporting, per-hop latency and reliable communication on the performance of the network. This matter happens is when RFID tags are set up in the multi-hop conditions in warehousing facilities. This research highlights problems that give disturbance in RFID system, which is usually used in a large building due to the quantity of signal loss or attenuation experienced by the transmitted signals from RFID tag to RFID reader and the other way around.

For a multi-hop RFID system, it is compulsory to obtain an efficient collection of data from all the tags in the reader communication range. Moreover, data sent to and from the RFID reader and the multiple of RFID tags are useful if the data is relayed to a workstation that is pre-installed with proprietary software to integrate the collected data. Usually, RFID systems send collected data from the RFID reader to the workstation over a wired connection, which increases the cost of implementation of RFID.

Active RFID devices based on WSN are self-powered and containing a battery within the tag to power the transceiver, which then broadcasts the stored data continuously. This circuit limits the lifetime of the tags and is the main disadvantage of the active system. Tags also will remain inactive for a long time period but become suddenly active when a signal is detected.

RFID technology is limited by the difficulties of system implementation. Therefore, to achieve more reliable communication, energy efficiency, and low data volume, there is a need to overcome the problems related to active RFID reader signal attenuation and tag energy consumption, in order to extend the RFID system network's operational lifetime.

1.3 Project Objectives

The aim of this project is to establish a portable 2.4GHz active RFID system prototype using a standards-based WSN, preferably ZigBee, for a large indoor

building, and apply it to a reliable asset identification system. This would be achieved by fulfilling the specific objectives of the project:

i. To develop a portable 2.4GHz active RFID reader for warehouse management system.
ii. To implement the developed portable active RFID reader in a real environment.
iii. To analyze the performance of the developed system in terms of distance, latency, RSSI and tag collection time.

1.4 Scopes of Study

To achieve the objectives, scopes have been identified in this project and there are:

i. The developed RFID reader will communicate with only one RFID tag and a host (computer).
ii. The range communication available between a tag and transceiver or a tag and a host is limited to the specifications of ZigBee model. So, XBee Series2 model has an indoor range up to 40m.
iii. This study will be conducted using a low power usage by sleeping mode.
iv. Indoor usage has been chosen to conduct this study.

1.5 Overall Thesis Organization

This thesis is consisting of five chapters: Chapter 1, Chapter 2, Chapter 3, Chapter 4, and Chapter 5. The first chapter introduces the study background, problem statements, objectives and scopes of the project.

The second chapter discusses studies and researchers that have been conducted in terms of the definition of Radio Frequency Identification technology, Wireless Sensor Network, division between active RFID and passive RFID.

Next, the third chapter describes the flowcharts of Master Project 1 and 2, flowchart of the system operation, system designed based on monitoring zone, RFID reader zone, and RFID tag zone, different types of component used and software used in the purposed project.

Chapter 4 explains the results of the project and system analysis in terms of distance, latency, RSSI, and tag collection time.

Finally, Chapter 5 is the conclusion of the entire project and improvements for the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Before making any important design decisions, and to acquire a more circumspect view of this project, it is essential to perform relevant background research to understand the current state of the art, and a review of the previous works referring to the current research, beginning with RFID technology. Some awareness of the operation of RFID tag and reader technology is important to understand the limitations and possible applications of the finished project; this chapter will explore different tools that are available for implementation. The discussed topic includes the main RFID components.

2.2 RFID Background

For an outdoor localization system, Global Positioning System (GPS) was developed in the early 1970s for military applications and has increasingly used as a commercial location system today. However, the GPS signal is not sufficiently strong to work satisfactorily indoors, since, due to the multipath effect, the signals

unable to be received under dense canopies, which makes the process too expensive or excessively power-intensive [6].

Thus, GPS still lacks positioning accuracy in indoor-based location tracking and cannot offer a solution for indoor location-awareness applications [7]. Because of this weakness, RFID is more suitable for indoor use.

2.3 Radio Frequency Identification (RFID) Technology

A system based on RFID is made by tags and reader. The tag may be attached to an object for the identification purpose using Radio Frequency (RF) signals. A suitable radio transceiver is used to read the information stored in a tag. When in close proximity of a reader, it may respond to the signal of the reader and behaves as a transponder. There are divided into three tags: Active, passive and semi-passive.

Passive RFID tags do not have their own power supply and the reading capability ranges from few mm up to few meters. Meanwhile, active RFID tags have a powered battery but may have longer ranges and many active tags have ranges of tens of meters. The life of a battery is up to several years. Furthermore, active RFID tags may host larger memories and tend to store additional or other data sent by the transceiver. For semi-passive tags, they behave like passive tags in their exchange of information with the reader but would pick additional data using self-powered storage systems and sensors. Figure 2.1 shows the comparison between active, passive and semi-passive tags. There are a lot of works have been focusing on the development of active RFID especially for active RFID-based indoor positioning system for industrial environment, active-RFID system operating in heavy environment conditions to aid the production cycle of bentonite-coal dust mixtures for foundries and a low-power active RFID portable reader system [9] [12] [14].

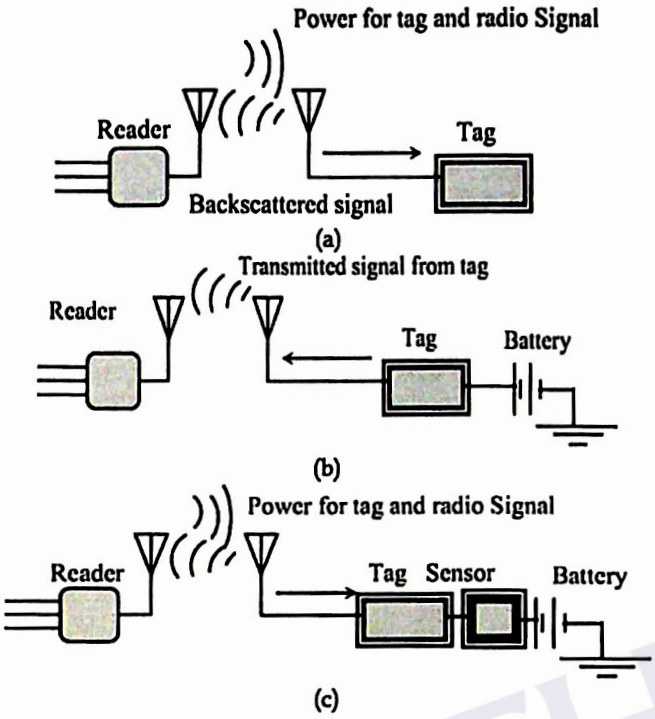

Figure 2.1 Communication between a reader and (a) passive tag, (b) active tag, (c) semi-passive tag [8]

2.3.1 Active RFID-based Indoor Positioning System for Industrial Environment

Active RFID system is commonly used to support indoor positioning system. Several methods such as ToA, RSSI, and TDoA have been proposed by previous researchers [9] to locate the RFID tags in an indoor environment. Each of the methods has its own advantages and disadvantages, which may affect the performance of the developed system. One of the methods proposed by Huang (2011) utilizes Time of Arrival (ToA) method based on absolute time arrival at a certain base station rather than the measured time reference between transmitting and receiving the signal on the other station. The method gives good agreement between delay and distance. Both agreements' readings increase simultaneously which make it good to guarantee the right location in a positioning system. Figure 2.2 represents ToA method. In contrast to ToA method, the Receive Signal Strength Indicator (RSSI) method purposed by Chang (2009) and Felix (2014) is lacking in performance unless the tags

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