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

A thesis is submitted in
fulfillment of the requirement for the award of the
Degree of Master of Electronic Engineering with Honours

Faculty of Electrical and Electronics Engineering
University of Tun Hussein Onn Malaysia

JANUARY 2018
Particularly for

Beloved parents

(Hashim Bin A. Bakar & Musalmah Binti Omar),
sister (Maria Fatinah Binti Hashim), brother (Muhammad Syahmi Bin Hashim),
supervisor (Dr Farhana Binti Ahmad Po’ad),
bestfriend (Nurul Amiera Binti Mohd Isa)

&

Friends, as well as those who have helped me through this thesis adventure.
ACKNOWLEDGEMENT

First and foremost, I am thankful to God for always giving me strength and hope throughout this whole important semester. A big appreciation for allowing me to complete this thesis.

A successful implementation of the project of ‘Design and Implementation of Portable Active RFID Reader System In Multihop Wireless Sensor Network For Indoor Tracking’. My gratitude to my family for being the backbone when I was in University of Tun Hussein Onn Malaysia. Without continues supports and prayers from them, it would had been difficult to cope with all the difficulties.

I would like to thank my supervisor, Dr Farhana binti Ahmad Po’ad who had given me guidance and never tired of giving advice during the implementation of this project. Thanks too to all the lecturers who had helped me during a year an a half I studied in the university to earn a master in.

As well as gramercy to my best friend, Nurul Amiera Binti Mohd Isa for being always cheering me up whenever I faced such difficulties during the entire master’s journey. I would not know what I would do without her.

My appreciation to all of my friends who had been supportive and given me a hand in completing this project. Lastly, a special thanks to those who had involved directly or indirectly in finishing this project.
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 analyze 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 ali 2.4 GHz pembaca aktif RFID dibangunkan untuk mengatasi masalah tersebut. Dengan itu setiap projek objektif telah pun tercapai: membangunkan sistem mudah ali 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 platformnya. 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.
CONTENTS

TITLE

DECLARATION

DEDICATION

ACKNOWLEDGEMENT

ABSTRACT

ABSTRAK

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

LIST OF APPENDICES

CHAPTER 1 INTRODUCTION

1.1 Background of Study 1

1.2 Problem Statements 3

1.3 Project Objectives 3

1.4 Scopes of Study 4
1.5 Overall Thesis Organization

CHAPTER 2 LITERATURE REVIEWS

2.1 Introduction

2.2 RFID Background

2.3 Radio Frequency Identification (RFID) Technology

2.3.1 Active RFID-Based Indoor Positioning System For Industrial Environment

2.3.2 Active-RFID System Operating In Heavy Environment Conditions To Aid The Production Cycle Of Bentonite-Coal Dust Mixtures For Foundries

2.3.3 A Low-power Active RFID Portable Reader System

2.4 RFID Tag

2.5 Wireless Sensor Network (WSN)

2.5.1 Embedded RFID Tracking System For Hospital Application Using WSN Platform

2.5.2 A New WSN Paradigm for Environmental Monitoring and Data Collection

2.5.3 RFID and WSN Based Integrated Maternity Ward Monitoring System

2.6 WiFi

2.6.1 A Performance Study of Zigbee Broadcasts In Coexistence with Wi-Fi
### 2.6.2 Hybrid Wireless Communication System Using ZigBee and WiFi Technology in the Coalmine Tunnels

### 2.7 UWB

#### 2.7.1 UWB Transmission Measurement and Modeling for Indoor Localization

#### 2.7.2 Study of UWB Indoor Localization using Fingerprinting Technique with Different Number of Antennas

#### 2.7.3 0.5-20GHz UWB Distributed Combiners for Multi-Antenna Receivers

### 2.8 ZigBee

### 2.9 Summary

### Chapter 3 Methodology

#### 3.1 Introduction

#### 3.2 Project Flowchart (Part 1)

#### 3.3 Project Flowchart (Part 2)

### 3.4 Overall System Flowchart

#### 3.5 Hardware Development

##### 3.5.1 RFID Reader

##### 3.5.1.1 RFID Reader (Receiver Part)

##### 3.5.1.2 RFID Reader (Transmitter Part)

#### 3.5.2 RFID Tag
CHAPTER 4 RESULT AND ANALYSIS

4.1 Introduction 50
4.2 Data Displayed 50
4.3 The Method of System Performances 51
4.3.1 Range Test and RSSI 52
4.3.2 Throughput and Tag Collection Time 54
4.4 Summary 55

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Objective Assessment 56
5.2 Recommendation 57

REFERENCES 58

APPENDICES
LIST OF TABLES

2.1 Differences Between Active And Passive RFID Technologies 12
2.2 CCR in various controlled interference source 18
2.3 The comparison between the previous works and this purpose work 27
3.1 Pins connection between Arduino board and XBee module 37
3.2 Serial/USB port parameters for each XBee module 42
3.3 XBee function set for each XBee module 43
3.4 Identity setting for each XBee module 43
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>An Architecture Of Networked Smart Nodes</td>
<td>2</td>
</tr>
<tr>
<td>2.1</td>
<td>Communication between a reader and (a) passive tag, (b) active tag, (c) semi-passive tag</td>
<td>8</td>
</tr>
<tr>
<td>2.2</td>
<td>ToA uses an absolute time arrival at a certain base station</td>
<td>9</td>
</tr>
<tr>
<td>2.3</td>
<td>Frame for a reader system of MSP430F449</td>
<td>11</td>
</tr>
<tr>
<td>2.4</td>
<td>RFID based tracking system for hospital application</td>
<td>14</td>
</tr>
<tr>
<td>2.5</td>
<td>Testing for a battery discharge</td>
<td>15</td>
</tr>
<tr>
<td>2.6</td>
<td>Sample screenshot for Application Software</td>
<td>16</td>
</tr>
<tr>
<td>2.7</td>
<td>Cluster-tree topology in a coalmine tunnel</td>
<td>19</td>
</tr>
<tr>
<td>2.8</td>
<td>UWB’s generic sensor network architecture</td>
<td>20</td>
</tr>
<tr>
<td>2.9</td>
<td>The trilateration method</td>
<td>21</td>
</tr>
<tr>
<td>2.10</td>
<td>The min-max method</td>
<td>22</td>
</tr>
<tr>
<td>2.11</td>
<td>Off-line phase using UWB fingerprinting technique with MRMSE</td>
<td>23</td>
</tr>
<tr>
<td>2.12</td>
<td>On-line phase using UWB fingerprinting</td>
<td>24</td>
</tr>
</tbody>
</table>
technique with MRMSE

2.13 4-to-1 combiner schematic 25

2.14 ZigBee’s standard and IEEE 802.15.4 26

2.15 Developing ZigBee in active RFID devices 26

3.1 Master Project 1 flowchart 30

3.2 Master Project 2 flowchart 31

3.3 Project operation system flowchart 33

3.4 System block diagram 34

3.5 Block diagram of components used for each zone in an overall system design 35

3.6 Flowchart of hardware development 36

3.7 Connection between the XBee module and Arduino Mega board 38

3.8 Connection between the XBee module and Arduino Uno board 39

3.9 Connection between the XBee module and Arduino Uno board 40

3.10 Connection between XBee module mounted on XBee starter kit to the computer in the monitoring zone 41

3.11 Flowchart of software development using XCTU 43

3.12 Flowchart of software development using Arduino IDE 44
| 3.13 | Schematic of Digi XBee Series2 Pro module | 45 |
| 3.14 | A schematic diagram of Arduino Uno Rev3 | 46 |
| 3.15 | A schematic of Arduino Mega 2560 | 47 |
| 3.16 | A schematic diagram of Cytron XBee Shield | 48 |
| 3.17 | A 9V battery | 48 |
| 3.18 | A summary of methodology process | 49 |
| 4.1  | Same Received Data Is Displayed | 51 |
| 4.2  | The Setting button provides different tests on a system performance such as Distance and Throughput | 52 |
| 4.3  | Coor-Tx Range Test | 53 |
| 4.4  | Rx-Tag Range Test | 53 |
| 4.5  | Coor-Tx Throughput Test | 54 |
| 4.6  | Tag-Rx Throughput Test | 55 |
# LIST OF SYMBOLS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
<td></td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
<td></td>
</tr>
<tr>
<td>Coor</td>
<td>Coordinator</td>
<td></td>
</tr>
<tr>
<td>Tx</td>
<td>Transmitter</td>
<td></td>
</tr>
<tr>
<td>Rx</td>
<td>Receiver</td>
<td></td>
</tr>
<tr>
<td>AT</td>
<td>Abbreviation Of Attention</td>
<td></td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
<td></td>
</tr>
<tr>
<td>ATND</td>
<td>Abbreviation Of Attention Node Discovery</td>
<td></td>
</tr>
<tr>
<td>TTF</td>
<td>Tags Talk First</td>
<td></td>
</tr>
<tr>
<td>DH</td>
<td>Destination High</td>
<td></td>
</tr>
<tr>
<td>DL</td>
<td>Destination Low</td>
<td></td>
</tr>
<tr>
<td>RSSI</td>
<td>Receive Signal Strength Indicator</td>
<td></td>
</tr>
<tr>
<td>TDoA</td>
<td>Time Difference of Arrival</td>
<td></td>
</tr>
<tr>
<td>ToA</td>
<td>Time of Arrival</td>
<td></td>
</tr>
<tr>
<td>WSN</td>
<td>Wireless Sensor Network</td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
<td></td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
<td></td>
</tr>
<tr>
<td>SoC</td>
<td>System on Chip</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Recognition</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
<td></td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communication</td>
<td></td>
</tr>
<tr>
<td>PIR</td>
<td>Passive Infrared</td>
<td></td>
</tr>
<tr>
<td>SNF</td>
<td>Social Network Forensics</td>
<td></td>
</tr>
<tr>
<td>WiFi</td>
<td>Wireless fidelity</td>
<td></td>
</tr>
<tr>
<td>CCR</td>
<td>Clear Channel Rate</td>
<td></td>
</tr>
<tr>
<td>UWB</td>
<td>Ultra-wide Band</td>
<td></td>
</tr>
<tr>
<td>CDF</td>
<td>Cumulative Distribution Function</td>
<td></td>
</tr>
<tr>
<td>LOS</td>
<td>Line of Sight</td>
<td></td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit</td>
<td></td>
</tr>
<tr>
<td>RF-PCB</td>
<td>Frequency-Printed Circuit Board</td>
<td></td>
</tr>
<tr>
<td>CSSDA</td>
<td>Cascaded Single-Stage Distributed Amplifier</td>
<td></td>
</tr>
<tr>
<td>SMA</td>
<td>SubMiniature version A</td>
<td></td>
</tr>
<tr>
<td>PHY</td>
<td>Physical</td>
<td></td>
</tr>
<tr>
<td>MAC</td>
<td>Medium Access Control</td>
<td></td>
</tr>
<tr>
<td>FFD</td>
<td>Full Function Devices</td>
<td></td>
</tr>
<tr>
<td>RFD</td>
<td>Reduced Function Devices</td>
<td></td>
</tr>
<tr>
<td>PAN</td>
<td>Personal Area Network</td>
<td></td>
</tr>
</tbody>
</table>
### LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Gantt Chart Master Project 2</td>
</tr>
<tr>
<td>B</td>
<td>Tag Code</td>
</tr>
<tr>
<td>C</td>
<td>Rx Code</td>
</tr>
<tr>
<td>D</td>
<td>Tx Code</td>
</tr>
</tbody>
</table>
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.

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].
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
being weakened. The RSSI technique figured the relationship between radio signal strength and distance [10]. The other method purposed by Chang (2009) utilizes the Time Difference of Arrival (TDoA) method based on ToA method for calculating transmission time and receiving time of an RF signal to attain a reference point. The method is then continued by Chin-Sheng (2009) with obtaining a new traveling time by transmitting a signal from the transmitter to receiver. This purposed work shows that multiple transceivers will be deficient in the system performance due to present of tag collision from the energized multiple tags. All methods used will give their own weaknesses: delay of data receive, high consumption of power, crash and missing data [11].

![Figure 2.2](image.png)  
Figure 2.2  ToA uses an absolute time arrival at a certain base station [9]

2.3.2 Active-RFID System Operating in Heavy Environment Conditions to Aid the Production Cycle of Bentonite-coal Dust Mixtures for Foundries

An active-RFID system operating in heavy environment conditions to aid the production cycle of bentonite-coal dust mixtures for foundries is developed by Gragnani et al. (2016) [12]. This application uses self-powered RFID tags, which broadcasts its own signal to provide information to the reader. The work aims to create a system that can help users to handle, mix and crush the bentonite-coal in a crusher for the realization of foundry compounds. This system uses WiFi based on IEEE 805.11 network and is implemented in a small portion of a shed to enable
communication and synchronization with the management software placed in the office. The WiFi-based location system is not suitable for this work due to limited in covering the working area as WiFi network is too expensive the metal structure of the shed inhibits the use of GPS systems. This system believe to develop a system that rather than not reading, might give rise to false positives to be filtered out later through an algorithm implemented. This system also proved to be more effective and the performances shows an improvement in the reliability of the production process [13].

2.3.3 A Low-power Active RFID Portable Reader System

A low-power active RFID portable reader system develops by Shu-qin et al. (2008) [14] uses system level power reduction which running at frequencies of 433/868/915MHz ISM band. The system uses System on Chip (SOC) peripheral driving circuits which function to cutting down the complex driving circuits of traditional Liquid Crystal Display (LCD) display. The algorithm implemented in this work is expected able to increase the performance of the system including improving the address matching, checking, anti-collision, real-time calculation, identification and lastly data display. The suggested system gave beneficial upon a simple structure, low power loss, and low cost. The proposed application able to develop a successful RFID reader system which can provide as simple structure system, low cost and power loss [14].
2.4 RFID Tag

A tag has a recognition (ID) stored in its memory that is represented by an identification string. The reader is able to examine the IDs of the tags in the neighborhood by running a simple protocol over the wireless channel. RFID tags can be either active device or passive device. While both active and passive devices use RF energy to communicate between a tag and a reader, the methods for powering the tags are different. Passive RFID tags are inductively powered by the reader, and this power allows it to transmit its information back. On the other hand, active RFID tags are self-powered, containing a battery within the tag and establishing a connection with a reader independently [15]. Thus, active devices employ an onboard power source for the purpose of tag information acquisition, reading range, and reliability and these features are the main advantages of the active tag as compared to the passive RFID tag [16]. Table 2.1 shows the technical differences between active and passive RFID technologies.
### Table 2.1: Differences between active and passive RFID technologies [17]

<table>
<thead>
<tr>
<th></th>
<th>Passive RFID</th>
<th>Active RFID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag power source</td>
<td>Energy transferred using RF from the reader</td>
<td>Internal to tag</td>
</tr>
<tr>
<td>Tag battery</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Availability of power</td>
<td>Only in the field of reader</td>
<td>Continuous</td>
</tr>
<tr>
<td>Required signal strength</td>
<td>Very high</td>
<td>Very low</td>
</tr>
<tr>
<td>Signal strength from tag to reader</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Read range is a consideration of RFID performance that can be deeply affected by the selection of tag, antenna, or frequency [17]. The read range can also be improved altered by the communication frequency used between the reader and tag. The choice of antennas for both tag and reader offers some flexibility in increasing the performance of the system and having these alternatives allows the user to modify the RFID system according to the needs of the application. One of the challenges of developing an active RFID system is how to prolong the lifetime of the active RFID tags. Due to an active tag is self-powered, the lifetime of the tag mainly depends on the lifetime of the battery. Thus the difficulties faced by communication protocol designers are related to how to achieve high-end adaptive energy efficiency and throughput, as nodes are waking and sleeping in the network. The terms “waking” and “sleeping” refer to the activity of the tags. When a tag wakes, it transmits its data packet asynchronously; then it returns to idle or sleep mode. Furthermore, an active tag can be programmed to sleep or wake up according to the occurrence of specific events, and can asynchronously transmit its information to the reader; consequently, the active tags do not need to be continually listening for a signal from the reader, which also prolongs battery life. Lastly, the modern-day active RFID tag ICs support many transmission powers, and a tag can reduce its transmit power according to the reader’s commands [18].

### 2.5 Wireless Sensor Network (WSN)

A Wireless Sensor Network (WSN) allows low-power, low-cost, and wireless multifunctional sensor devices that communicate over short distances and are small in size [19]. Sensing and communication are the two major functions of the WSN,
while energy conservation and routing mechanism are two hot topics due to their affection on the performance of the system [20]. A WSN is composed of a significant number of sensor nodes that can be deployed on the ground, in the air, in vehicles, or inside buildings [21]. A sensor node consists of a sensor to monitor and control physical parameters at different locations, a radio transceiver, a microcontroller (MCU), and a power source. There are a lot of works have been focusing on the WSN especially for an embedded RFID tracking system for hospital application using WSN platform, a new WSN paradigm for environmental monitoring and data collection and RFID and WSN based integrated maternity ward monitoring system [22] [24] [26].

2.5.1 Embedded RFID Tracking System for Hospital Application Using WSN Platform

An embedded RFID system for patients monitoring is developed by Renuka et al. (2013) [22], which introduces the integration between ZigBee based on IEEE 802.15.4 Standard module, GSM network module and bio-sensor module to observe the body temperature as well as performing identification and monitoring purposes. It is proposed due to the countless number of patients and items located in a hectic environment of the hospital. The developed system supported the long-life battery with low cost of implementation since it consumed minimal power and allowed reliable data delivery between remote devices [23]. The system works by measuring the human physiological signals connected to the ZigBee module which transmitted to the RFID reader connected to Personal Computer (PC) for data collection. When the measured signals are over the standard value, a short message will be sent to the doctor via Global System for Mobile Communication (GSM) network. Figure 2.4 shows the architecture of the proposed patient monitoring system.
2.5.2 A New WSN Paradigm for Environmental Monitoring and Data Collection

A researcher named, Dines et al. (2012) [24] considers the effectiveness of a new paradigm for environmental monitoring and data collection. A comparison is done between WiFi and ZigBee modules, the classified range of signal and battery utilization under different sensor and radio configurations. This new paradigm employed the availability of open-source hardware and off-the-shelf commodity microcontroller components. It also may show a low threshold entry point into a fully autonomous sphere, compelling and data collection systems of self-managed environmental. The component used such as Arduino Uno managed to develop the basis of paradigm which was having a big accessories range, available widely and helped by the much active development community. Star topology is the perfect network used for monitoring operation of 20-25 motes. Meanwhile, Advanced topologies did not give such advantages for the case scale. WiFi-based systems were found easily to incorporate with existing networks and support an accessibility where it found challenging to match with different protocols. Based on the change to larger capacity and inexpensive SLA batteries as well as solar power charging units, this allowed service times of wireless motes to expand indefinitely at a suitable collection of field data. Figure 2.5 shows a battery discharge over 40 hour period in a sleep algorithm which gives benefits on reducing the data capture and transmission time to
5 minutes within an hour as well as extending a service time up to 20 days for the moth [25].

![Graph showing battery discharge](image)

Figure 2.5 Testing for a battery discharge [24]

### 2.5.3 RFID and WSN Based Integrated Maternity Ward Monitoring System

An integrated maternity ward monitoring system based on RFID and WSN technologies is developed by Hussian et al. (2013) [26]. This application uses Passive Infrared (PIRs) as a trigger based video motes sensors established at different concealed points, placed all over the nursery ward and newborn babies. WSN is applied for data hoping between motes to extend the radius of communication and a customized application is developed to monitor and supply the Social Network Forensics (SNF) as a forensic tool to display incident analysis.
2.6 WiFi

Wireless fidelity (WiFi or Wi-Fi) is traditionally operated at a band of 2.4GHz, where it is a technology based on IEEE 802.11 [27]. WiFi is generally used in video game consoles, handphones, personal computers, digital cameras, smart televisions and modern printers that able to connect the internet via WLAN and wireless access point. Each node operates in an ad-hoc mode that provides communication between devices without the rule of which device is talking first to access point. 

There are a lot of works have been focusing on the WiFi especially for a performance study of ZigBee broadcasts in coexistence with WiFi and hybrid wireless communication system using ZigBee and WiFi technology in the coalmine tunnels [28] [29].
2.6.1 A Performance Study of Zigbee Broadcasts In Coexistence with Wi-Fi

A performance study of ZigBee broadcast in coexistence with Wi-Fi is done by Zhang et al. (2014) [28]. The purposed work is performed by using the methods of broadcast in ZigBee and CCR. Both methods affect the performance of the system.

The broadcast in ZigBee method is done by constantly transmitting the broadcast frame starting from the originator node. Each transmission process will result in the reproduction of broadcast frame, thus creating a broadcast wave as well as making a more reliable ZigBee broadcasts due to its high chance of the interference survival.

Clear Channel Rate (CCR) or interference benchmarking index method is to evaluate the interference levels by calculating a successful possibility of transmitting a ZigBee packet in a given length in a channel occasionally occupied by outer interference. The CCR method shows the relation between ZigBee packet length and its CCR value under interference source. The longer the length of ZigBee packet, the lower the value of CCR. The obtained value from CCR is then tested with transmitter power that impacts the ZigBee network. The performance of the reliability of ZigBee network is tested by applying higher transmitter power of all nodes, higher transmitter power on the originator node only and interactions between ZigBee broadcast and WiFi. The result proves that higher transmitter power increases the reliability of transmission.
Table 2.2 CCR in various controlled interference source [28]

<table>
<thead>
<tr>
<th>Data stream</th>
<th>16 Byte</th>
<th>32 Byte</th>
<th>64 Byte</th>
<th>127 Byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>no Wi-Fi</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Idle Wi-Fi</td>
<td>95</td>
<td>95</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>10 UDP * 3Mbps</td>
<td>65</td>
<td>60</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>10 UDP * 7Mbps</td>
<td>55</td>
<td>50</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>10 UDP * 10Mbps</td>
<td>45</td>
<td>40</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>1 TCP</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>10TCP</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>20TCP</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

2.6.2 Hybrid Wireless Communication System Using ZigBee and WiFi Technology in the Coalmine Tunnels

A hybrid wireless communication system in the coalmine tunnels using ZigBee and WiFi is developed by Tao et al. (2011) [29]. The purposed work monitors the coalmine tunnel that provides reliable and flexible communication due to its multifunction communication wireless system. This application chooses a frequency of 2.4GHz due to its acceptability in most countries [30]. A rectangular tunnel as used in this application work affects the radio propagation [31]. The hybrid wireless communication system is tested based on node coverage. With a strong waveguide effect from radio propagation along the coalmine tunnel, the coverage is approximately from 10m to 100m. Due to that, ZigBee nodes for monitoring are not necessary to have full coverage in which monitor devices locate at the specific locations in the coalmine tunnel. Cluster-tree topology is formed when adjusting the RF power of full-function device and reduced function device in order to have various transmitting range [32]. The system of the hybrid using ZigBee and WiFi technology has the ability to monitor the gas, provide wireless communication, personnel management, video surveillance as well as strong anti-disaster which making the system to be a multifunction wireless system in the coal mines.
2.7 UWB

Ultra-wide Band (UWB) uses a standard of IEEE 802.15.3 which is generally use for a high-speed wireless communication technology and applicable for an indoor short-range wireless communication technology [33]. It has the ability to provide low power consumption, high throughput as well as low-cost implementation [34]. The important aspect of UWB is its bandwidth is more than 110Mbps which making it compatibles with many applications in multimedia. Besides, it acts as a cable replacement for a higher speed serial bus. Figure 2.5 represents an example of WSN using UWB link to pass data from tags to the corresponding reader and then the reader forwards the date to WLAN via ad-hoc functionally with around 10 meters reading field. But, there is a typical composition occurs in UWB downlink reception from the base station to tag which also using more power [35].
Other than that, vital data rate from workstation to tag is much lower. Applying UWB in an RFID system gives a benefit of using low transmission time which is due to its design that is for short and high data rates applications [36]. Nonetheless, the power consumption is much higher than WiFi and Bluetooth. UWB gives disadvantages of limited memory and computational capacity. From that, it affects its suitability in sensor networking applications.

There are a lot of works have been focusing on the UWB especially for UWB transmission measurement and modeling for indoor localization, the study of UWB indoor localization using a fingerprinting technique with a different number of antennas and 0.5-20GHz UWB distributed combiners for multi-antenna receivers [37] [38] [40].

### 2.7.1 UWB Transmission Measurement and Modeling for Indoor Localization

Ultra-wide Band (UWB) transmission measurement and modeling for indoor localization is implemented by [37]. This work applies trilateration and min-max methods using received signal strength (RSS) and ToA parameters. The target position is found between the distance of transmitter (Tx) and receiver (Rx) antennas based on the trilateration and min-max method. The trilateration method is to find
positions by using at least three Tx antenna. Both parameters of RSS and ToA are utilized to determine the distance between Tx and Rx antennas. Due to that, Rx antenna is evaluated by the intersection of the cross of three lines. Figure 2.9 shows the intersections of two circles. The min-max method is to find the position Rx antenna by evaluating the intersection of three boxes. Figure 2.10 shows the box from each Tx antenna. Therefore, the distance error of approximated distances is represented based on cumulative distribution function (CDF). The work proves that trilateration method provides better accuracy than min-max method. In contrast to the method used, ToA parameter provides better accuracy than RSS parameter.

Figure 2.9  The trilateration method [37]
2.7.2 Study of UWB Indoor Localization using Fingerprinting Technique with Different Number of Antennas

UWB indoor localization using a fingerprinting technique with a different number of antennas is developed by Vinicchayakul et al. (2016) [38]. This work uses fingerprinting technique based on the IEEE 802.15.4a standard (UWB) in terms of the required antennas number with the environment of the line of sight (LOS). In contrast to the common method that requires multiple antennas, fingerprinting method will only be needing two or more antennas by using UWB technology [39]. This application is achieved by using UWB localization method which consisting of UWB transmitted signal model, UWB radio propagation parameters, UWB fingerprinting technique and Euclidean distance error. The UWB transmitted signal model uses rectangular passband waveform to find the received signal in time domain. Meanwhile, the UWB radio propagation parameters method is to estimate the delay time from the first path loss. The UWB fingerprinting technique consists of two phases: off-line-phase is where UWB radio propagation parameters are collected in the database in each location and on-line-phase is where a user demands the location of a person by using UWB radio propagation parameters as well and
comparing the parameter between the phases of off-line and on-line to evaluate the present location. With the present of matching parameter or pattern, minimum root mean square error (MRMSE) is used as the algorithm in fingerprinting process. Figure 2.11 and Figure 2.12 represent the UWB fingerprinting technique with MRMSE for both off-line and on-line phases. The Euclidean distance error is to estimate the localization. The performance of the work is analyzed in terms of location accuracy, errors of maximum and mean distance of path loss parameter with three Tx antennas, distance errors of path loss parameter at each coordinate and the number of location errors of the path loss parameter with Tx antennas. The location accuracy has a high accuracy of 96.67%. On the other hand, the error of maximum distance of path loss parameter with three Tx antennas is higher than an error of mean distance of path loss parameter with three Tx antennas. The distance errors of path loss parameter at each coordinate show more error areas. The performance of a system depends on the number of location errors of path loss parameter with three Tx antennas which the result illustrates x-axis has more amount of location errors than y-axis. Therefore, a better localization is achieved using the parameter of the delay time of UWB standard. Unfortunately, only a pair of antennas is required to determine the areas accurately.
2.7.3 0.5-20GHz UWB Distributed Combiners for Multi-Antenna Receivers

0.5-20GHz UWB distributed combiners for multi-antenna receivers is developed by Testa et al. (2016) [40]. The work is achieved by applying distributed amplifier techniques using a 2-to-1 combiner and a 4-to-1 combiner based on the distributed combiner integrated circuit (IC). Figure 2.13 shows the schematic of 4-to-1 combiner by combining 3 2-to-1 combiners. These combiners undergo fabrication process in a radio frequency-printed circuit board (RF-PCB) which is based on 250μm thick Rogers substrate using relative dielectric-constant of 3 as well as embedded between two copper metal layers that are used for routing [41]. The cascaded single-stage distributed amplifier (CSSDA) generates a gain of 17dB for signal amplification and IC generates a path gain of 20dB. The performance of both combiners is tested by calibrating a vector network analyzer up to the SMA-interface (SubMiniature version A-interface) of the boards. Consequently, a 2-to-1 combiner may generate a gain of 10dB at 20GHz over 3dB, while 4-to-1 combiner may generate a gain of 20dB at 20GHz. The work is found to have the ability to control the device functionality towards high frequencies using SMA-connectors as well as S-Parameter (scattering-parameter) approves quantifying the combing path gain [40]. The system is certified by the combination of signals at various frequencies which results in no availability of distortions and intermodulations and the combiners performance in a multi-antenna system that results in combiner’s support on narrow-band and wide-band antenna arrays.
REFERENCES


2006


43. IEEE Standards for Local and metropolitan area networks–Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs), 2011.


45. Shu-Chiung Hu , Cheng-Kuan Lin, and Yu-Chee Tseng, Automatic Parameter Selection for the ZigBee Distributed Address Assignment Mechanism, *2013 IEEE*


