PHYSICAL INTRUSION DETECTION AND HOME-OFFICE AUTOMATION SYSTEMS USING HARVESTED RADIO FREQUENCY ENERGY

BY

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ABSTRACT

With the rapid growth of wireless network sensor (WSN) technology, the improvement of low data rate, low cost, low power consumption and long battery life of ZigBee wireless sensor networks has been reported. The use of wireless sensor technology has proliferated in various fields namely; military security, environmental monitoring, medical and home automation. There is an emerging application for ZigBee sensor technology for indoor perimeter security and physical intrusion detection. Hence, the scopes of this research work is to develop a ZigBee-based system that can double as an alarm for detection of physical presence of an individual in a confined indoor environment or for automation in office environment. The developed systems work in two phases; an offline learning phase and an online active phase, while utilizing freely available Radio Frequency for Wi-Fi and ZigBee. A statistical profiling is used to identify a purposely emptied room and then using a time-widow statistical analysis, the system monitors the indoor environment to detect physical intrusion. Variance, standard deviation and kurtosis are found to be excellent candidates to indicate the slightest changes in the RF field. These received signal strength indicator (RSSI) fluctuations are used also to switch ON/OFF appliances, lighting and air conditioning in a room, office, and classroom and laboratory environment. The antenna orientation, separation distance between transmitter and receiver, vertical positioning of sensors and radio signal irregularities are studied to refine and improve the accuracy of the developed system. Results achieved for the alarm indicate a physical intrusion detection accuracy of 100% for a separation distance of less than 5 meters. Further separation severely degrades the accuracy performance and limits the flexibility of placement of sensor nodes. However, when doubling as a control switch for electrical appliances, the system performed well for a large room with more than 50 meters separation distance between transmitter and receiver utilizing the existing Wi-Fi signals around campus.

خلاصة البحث

مع النمو السريع لتكنولوجيا شبكة الاستشعار اللاسلكية (WSN) ، فإن معدل البيانات المنخفضة، التكلفة القليلة، استهلاك طاقة قليلة وعمر البطارية الطويلة لشبكات الاستشعار اللاسلكية ZigBee تمت تحديثها. انتشر استخدام تكنولوجيا الاستشعار اللاسلكية في مختلف المجالات وهي: الأمن العسكري، الرصد البيئي، والتشغيل الآلي الطبي و المنزلي على سبيل المثال لا الحصر. هناك تطبيق ناشئ لتكنولوجيا الاستشعار ZigBee وهو أمن المحيط داخلي وكشف التسلل المادي. بالتالي، فإن هذه هي نطاقات دراسة أطروحة. إن الهدف من عمل البحث هو تطوير نظام قائم على ZigBee الذي تم مضاعفته كمنبه للكشف عن الوجود المادي للفرد في البيئة المغلقة المحصورة، ومفتاح التحكم للأجهزة في جميع أنحاء المكتب. تعمل النظم المطورة على مرحلتين، مرحلة تعلم غير نشطة و مرحلة نشطة مع استخدام ترددات راديو متاحة بحرية مثل Wi-Fiو ZigBee. يتم استخدام التنميط الإحصائي لتحديد غرفة أفرغت عمدا ثم باستخدام التحليل الإحصائي لنافذة الوقت ، يراقب النظام البيئة الداخلية للكشف عن التعدي المادي. لقد تم إيجاد التباين، والانحراف المعياري والتفرطح كمرشحين جيدين للإشارة إلى أدنى التغييرات في مجال RF. استخدمت تقلبات مؤشر قوة إلاشارة (RSSI) أيضا لتشغيل أو إغلاق الأجهزة، الإضاءة وتكييف الهواء في الغرفة، المكتب، الفصول الدراسية والمختبرات في الحرم الجامعي للجامعة الإسلامية العالمية ماليزيا فرع جومباك. تمت دراسة اتجاه الهوائي ،المسافة الفاصلة بين المرسل والمستقبل، تحديد الموقع الرأسي لأجهزة الاستشعار وشذوذ إشارات الراديو لصقل وتحسين دقة النظام الذي تم تطويره. تشير النتائج التي تحققت للمنبه إلى وجود دقة كشف التسلل المادي بنسبة 100٪ لمسافة فصل أقل من 5 أمتار. إن المزيد من الفصل يقلل بشدة من دقة الأداء ويحد من المرونة من وضع عقد الاستشعار. ومع ذلك، عندما المضاعفة كمفتاح التحكم للأجهزة الكهربائية، ادى النظام بشكل جيد بالنسبة لغرفة كبيرة مع ترك مسافة فصل أكثر من 50 مترا بين المرسل والمتلقي باستخدام إشارات Wi-Fi في جميع أنحاء الحرم الجامعي.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Computer and Information Engineering)

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……..
Md. Noor B. Salleh
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WSN	Wireless Sensor Network
RSSI	Received Signal Strength Indicator
RF	Radio Frequency
WPAN	Wireless Personal Area Network
MAC	Medium Access Address
PCA	principal components analysis
SOHO	Small Office Home Office
LQI	Link Quality Indicator
PIDAS	Physical Intrusion Detection Alarm System
NIC	Network Interface Card

LIST OF SYMBOLS

λ	Wavelength
Pr	Received Power
Pt	Transmitted Power
G	Gain
Rx	Receiver
Tx	Transmitter

CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

Wireless communication has become a very common research topic over the last years. Wireless sensor networks have become extraordinary important to human and it have the potential to increase human ability to develop user-centric application to monitor and prevent harmful events. The existence of low cost low-power sensors, radios and embedded systems can enable the development of distributed sensor networks to provide information to the users in different environment and it will offer them control over stopping from occurring (Ali, Arezou, & Hamid, 2006). The use of wireless sensor technology can be used for various aspects such as medical, to environment and military. There is one possible usage which is home security. In addition, a wireless sensor network (WSN) could be useful in detecting the presence of an intruder. RSSI stands for received signal strength indicator. Basically, RSSI is the measure of the power level which a radio frequency (RF) device such as Wi-Fi is receiving from the radio arrangement at a given time and location. When the RSSI is higher, the quality and speed of the communication is better through the radio segment. RSSI is executed and widely-used in 802.11 standards. The received power can be calculated from RSSI (Benkic, Malajne, Planinsic, & Cucej, 2008).Therefore, the use of the Received Signal Strength Indicator (RSSI) can determine the movement or the mobility of an intruder.

The human presence detection can be obtained using the method of radio irregularity as efficient human presence detection sensor in smart homes or green home have been presented by (B. Mrazovac, M. z. Bjelica, et al. 2012). Thus, this paper is the

benchmark paper of my research. This dissertation is significant because using ZigBee- sensor technology and Wi-Fi harvested radio frequency are cheap, simple and yet effectives to utilize as control appliances for ON/OFF switches as well as to save energy and money in large scale. In addition, nowadays, everyone is interest about green technology.

1.2 PROBLEM STATEMENT

The development of wireless sensor network (WSN) technology has led to many beneficial things. There are many wireless sensor technologies such as Wi-Max, Wi-Fi, Bluetooth, Infrared and GPS have been used for different purposes. However, ZigBee-sensor technology is a low cost, low data rate, low power consumption and longer battery life is used in various aspects and fields from industrial, home security, manufacturing and it supplies chain management to control, identify and track location, human, animal or object. Many researchers and products in the market do use the Radio Frequency signals for various applications including previous studies on detection of the presence of individuals or other objects. However, most of the researches are complex and use sophisticated circuitry and control hardware in conjunction to reading the RSSI from the RF signal. Furthermore, the ideas presented in the literature are not concrete as they demonstrated the concept of using RSSI in their study only. Radio Frequency (RF) Energy Harvesting keeps a bright future for generating a small amount of electrical power to drive partial circuits in wirelessly communicating electronics devices. In addition, reducing power consumption has become a major challenge in wireless sensor networks. As a vital factor affecting system cost and lifetime, energy consumption in wireless sensor networks is an emerging and active research area. Furthermore, most of these systems were using

information that is actually encoded into a standardized system like ZigBee and Wi-Fi and purposely created, hence, requiring a complete modem at the receiver side. Few, if any, has resorted to use the RSSI information only in order to identify and detect intrusion. Thus, there are thousands of surveillance alarms systems such as camera, CCTV and so on to provide safety and security to the people but it is expensive to put CCTV or camera in every office and room. The quest is to find a low cost, simple, yet effective approach to home networking and physical intrusion detection alarm system promises to save energy and cost in large numbers and doubles the function of the system, making it applicable to many scenarios.

1.3 RESEARCH OBJECTIVES

The objectives of this research project can be highlighted as follows:

1. To investigate the state of the art in the open literature on physical intrusion detection and home automation systems.
2. To develop a new simple RSSI-based physical intrusion detection and home automation systems utilizing harvested RF energy.
3. To evaluate and validate the developed system in real-life environment.

1.4 RESEARCH METHODOLOGY

To achieve the objectives of this project, the following method is to be taken into consideration:

- Literature review: to learn and read about the current and similar research that has been done on radio frequency identification and received signal strength indicator (RSSI). To identify the useful technique that the past researchers had obtained and try to improve the existing method. This may facilitate to choose

the best hardware or software that has to be used in this project after evaluating the advantages and disadvantages of each research work.

- Learn the usage of the software development, experiment set-up, software configuration and Matlab software and to develop the statistical profiling of the studied environment.
- Develop an offline phase for system training and an online phase for monitoring and alarm trigger and/or ON/OFF control trigger for home automation.
- Test the system in a realistic indoor environment.
- Write down the work into full thesis and publish research papers

Detailed methodology is presented in Chapter 3.

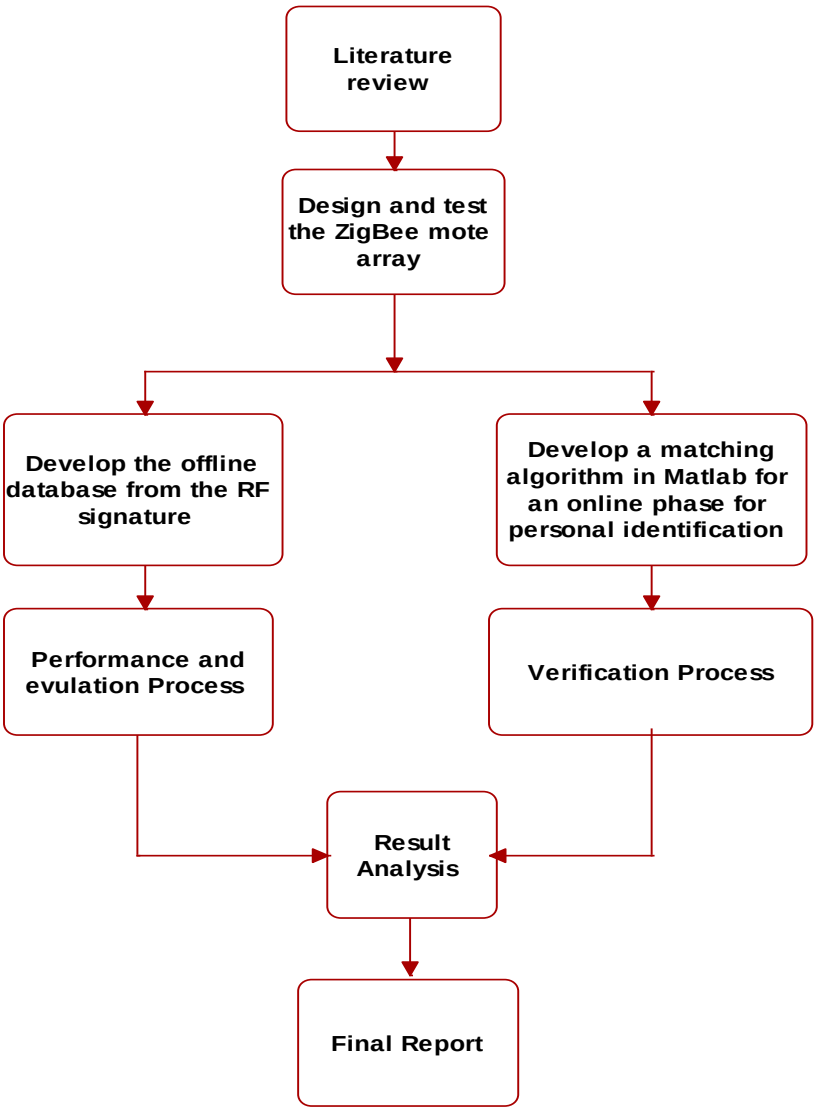

Figure 1-1 Flow Chart of the research methodology

1.5 RESEARCH SCOPE

The primary goal of this research is to detect physical intrusion in an indoor environment such as room, office, lab or classroom. The research scope of this thesis is limited to providing the proof of concept of the system and to test it for alarm trigger and ON/OFF control for home automation.

1.6 DISERTATION ORGANIZATION

This research is organized into five chapters. The goal of this thesis is to develop a radio frequency identification that identifies an individual in a closed environment such as room.

The first chapter gives a brief introduction about radio frequency identification and received signal strength indicator (RSSI), and then it illustrates the problem statement of the personal identification for radio frequency followed by the research objectives, methodology and research scope. Chapter 2 comprises of overview of the radio frequency identification and received signal strength indicator and gives the related work or literature review that had been done on radio frequency identification and RSSI. Chapter 3 presents the design of the proposed model which is based RSSI and its mechanism. Chapter 4 shows the result and the discussion. Conclusion and recommendation for future work are presented in Chapter 5.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the literature review focuses on the up-to-date research is presented. In fact, the aim of this research is detect physical intrusion by a set of peoples using the same indoor environment (room, lab) by using their received signal strength indicator (RSSI) signature mapped. This chapter is divided into two (2) main parts: first is the overview of ZigBee, RSSI and RF identification, second part is about the related work that the researchers have reported so far in this research area.

2.2 ZIGBEE OVERVIEW

ZigBee is a wireless communication technology that is mostly used for wireless sensor network.. The technology defined by ZigBee specification is planned to be simpler and less expensive compared to other WPANs (Wireless personal area network) such as WI-MAX and Bluetooth. The target of ZigBee is at radio frequency (RF) applications which require low data rate, low cost, low power transmission, and longer battery life in a secure networking. Furthermore, the physical layer and media access control layer of ZigBee are the two layers that follow the IEEE 802.15.4 on wireless personal area network (WPAN). The main applications of ZigBee sensor node are simply focused on sensor and automatic control. ZigBee is a typical wireless communication technology which is widely used in various aspects such as military security, environmental monitoring, medical and home automation. Even though the

ZigBee standard development is still under progress, the ZigBee marked is open for various applications such as:

- **Home control:** Heating, security, ventilation, Air-conditioning, light control and access control
- **Personal Health care**: Patient monitoring and fitness monitoring centers
- **Industrial Control:** Asset management, process control and energy management
- **Building automation:** automatic meter reading (AMR), security, lighting control and access control
- **Consumer electronics:** remote control
- **Environment:** Environment monitoring and home security

As ZigBee that is based on IEEE 802.15.4 works on both physical and MAC layer. The ZigBee overview is shown in the figure below.

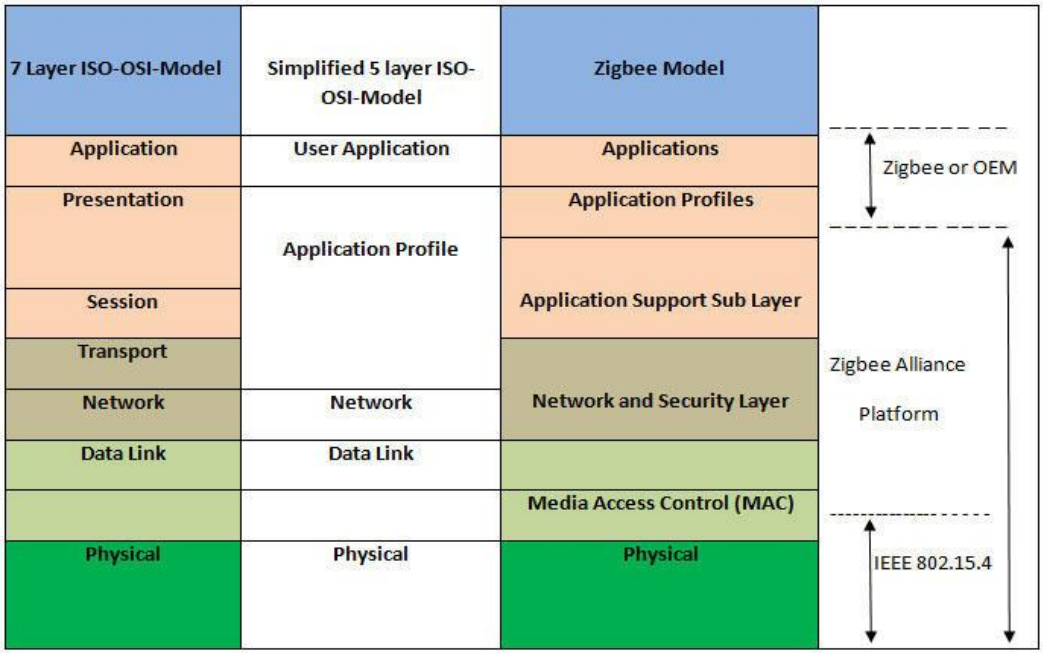

Figure 2-1 ZigBee overview

2.2.1 IEEE 802.15.4 Physical layer (PHY)

IEEE 802.15.4 standard for physical layer uses three frequency bands which are 868 MHz, 915 MHZ and 2.4 GHz bands .Its data rates are of 20 kb/s for 868 MHz, 40Kb/s for 915 MHz and 250 Kb/s for 2.4 GHz respectively. The number of channels in 2.4 GHz band is 16 channels, 10 channels for 915 MHz band and 1 channel in the 868 MHz band. In addition, the PHY layer covers the physical interface between a data transmission device and a transmission medium or network which is located at the end of ZigBee's architecture, comprising the radio frequency (RF) transceiver along with its control mechanism (Dusan, 2007). The low data rate of the 868 and 915 MHz of the physical layer can be changed into better sensitivity and larger coverage area, but reduce the number of nodes in a given area. While, the 2.4 GHz physical layer can be utilized to obtain higher throughput and lower latency or lower duty cycle. The figure below shows the IEEE 802.15.4 channel of the three frequency bands.

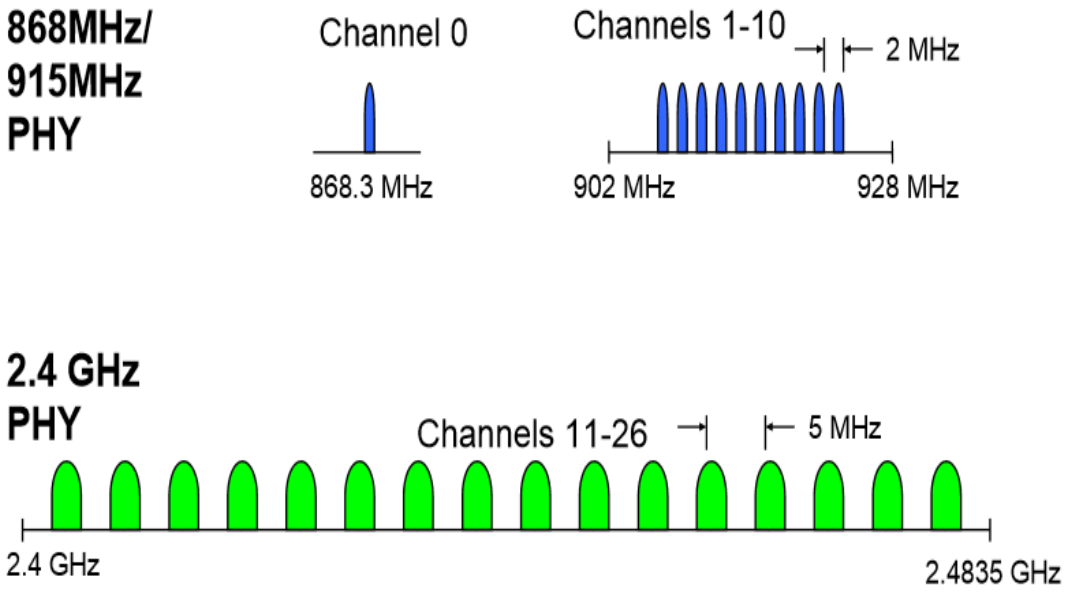

Figure 2-2 The IEEE 802.15.4 channel structure