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Home Security System Using Zigbee

Norlezah Hashim*, Mohd Amir Hafifi Abdul Razak, Fakrulradzi Idris
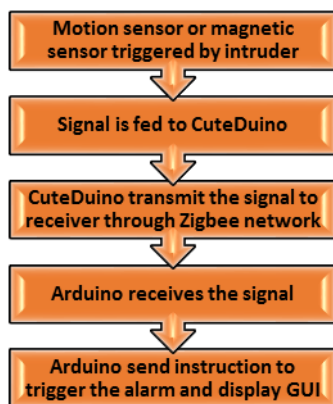
Faculty of Engineering Technology, Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka, Malaysia

*Corresponding author
norlezah@utem.edu.my

Graphical abstract

Abstract

This paper explains the design and implementation of home security systems using the most widely deployed enhancement to the 802.15.4 standard, which is better known as Zigbee. Home security systems nowadays are expensive and complicated to install. Two types of sensors were used in this project, motion sensor and magnetic door sensor. These sensors were used as the end device to detect any intruder. If any intruder bypasses the motion sensor or the magnetic door sensor, a signal will be sent to the system and the alarm will be triggered together with Graphical User Interface (GUI) display on a personal computer. The performance of the designed system was analyzed in terms of detectable range and delay. Result shows that the designed system is capable of detecting up to 22 meters of distance for indoor use at maximum delays of 15 seconds. The home security system using Zigbee has been successfully designed, implemented and analyzed.

Keywords: Zigbee, WSN, CuteDuino, Arduino, magnetic sensor, motion sensor

Abstrak

Kertas kerja ini menerangkan reka bentuk dan pelaksanaan sistem keselamatan rumah dengan menggunakan standard 802.15.4 atau lebih dikenali sebagai Zigbee. Kebanyakan sistem keselamatan rumah pada masa kini adalah mahal dan rumit untuk dipasang. Dua jenis pengesan digunakan dalam projek ini, pengesan gerak dan pengesan pintu magnetik. Pengesan ini digunakan sebagai peranti untuk mengesan penceroboh. Jika penceroboh memintas sensor gerak atau pintu magnetik, isyarat akan dihantar kepada sistem dan penggera akan dicetuskan bersama paparan Antara Muka Pengguna Grafik (GUI) pada komputer peribadi. Prestasi sistem telah dianalisis dan keputusan menunjukkan sistem ini mampu mengesan sehingga 22 meter dalam ruang tertutup (indoor) dengan kelewatan maksimum sebanyak 15 saat. Sistem keselamatan rumah dengan menggunakan Zigbee telah direka, dilaksanakan dan dianalisis dengan jayanya.

Kata kunci: Zigbee, WSN, CuteDuino, Arduino, pengesan magnetik, pengesan gerakan

1.0 INTRODUCTION

Nowadays, it can be seen that Wireless Sensor Networks (WSN's) are used in many applications such as disaster prevention and environmental monitoring. Analysis of WSN often includes the study of the network properties of wireless communication with small battery powered sensors [1]. The advantages of WSN comes from their potentiality for detailed monitoring in remote and hard to access locations where it is not practical to install conventional wired infrastructures. More attention is given to WSN that follows IEEE 802.15.4 standard for its advantages such as providing low data rate transmission, low energy consumption, ease in setting up the network and low costs together with smaller sensor size.

Zigbee is the most widely deployed enhancement to the 802.15.4 standard where the organization maintains, supports, and develops more protocols for advanced applications in defining additional communication features. The enhancements consist of authentication with valid nodes, encryption for security and data routing that allows mesh networking. With Zigbee, all nodes are able to communicate with each other and can be handled by a single Zigbee, wirelessly. Zigbee devices are restricted through a rate of 250 Kbps that make it suitable for low data rate transmission. Zigbee has many advantages; for example, its battery can stay up to few months depending on applications, making it perfect for install and forget devices such as small household systems [2].

The authors in [3] have developed a wireless remote-monitoring home security built with various sensors using Zigbee and GSM networks. The system has the ability to send images through MMS and SMS. The experimental result shows that the system has remote surveillance ability to ensure home safety. Another home security system, similar to the research in [3], was proposed in [4] where the system is suitable

for a typical small home network. The system can be monitored and controlled using GSM module. In [5], the researcher proposed a home security using a combination of Wireless Fidelity (Wi-Fi), Bluetooth and Infrared technology. Most of the systems proposed were excellent but far from being a low cost solution since it involved more than one technology embedded into one system. Compared to previous work, this paper presents the development and implementation of a low cost system for home security using two types of sensors and microcontroller development boards, Arduino and CuteDuino. The system proposed is analyzed in terms of detectable range and results to prove that the system is able to work perfectly for indoor environments and up to 22 meters of distance between the transmitter and the receiver.

The rest of this paper is organized as follows; section 2 briefly describes the methodology, software and hardware configuration and the experiment setup of the home security system using Zigbee, followed by the results and discussion in section 3. Finally, in section 4, the author concludes the findings of the paper.
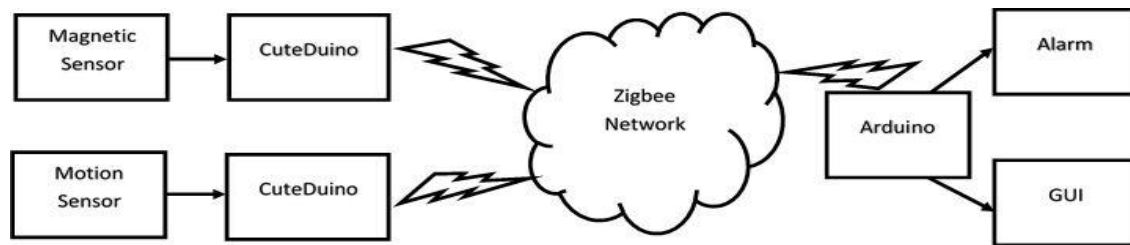

Figure 1 System block diagram

2.0 METHODOLOGY

Figure 1 shows the block diagram of the proposed home security system. The block diagram consists of two transmitters and one receiver. All components are communicating using a Wireless Sensor Network (WSN) standard, which is the IEEE 802.1.5.4. At the transmitter's side, two types of sensors namely magnetic sensor and motion sensor are connected to CuteDuino development board. CuteDuino is an Attiny85 based microcontroller development board where the microcontroller has the ability to use the familiar Arduino IDE software. At the receiver, the Arduino board is used to detect the signal sent by any of the two transmitters. When the system is activated and if the door attached to the magnetic sensor is opened or any movement is detected on the motion sensor, an alarm will be triggered to inform the house owner. The responses will be recorded on the GUI. Two types of messages will appear on the GUI which are: 'Door is open' and 'Motion is detected'.

2.1 Hardware Configuration

The hardware configuration consists of three main circuits. The transmitters, two Attiny85 based microcontroller development boards, which are known as CuteDuino, are used where it is cheaper, smaller, but less powerful than Arduino. The board is broken down into 10 individual pins and has 2 indication LEDs: Power and active high LED are connected to pin 1. It has 5 GPIO pins, but two are shared with the Universal Serial Bus (USB) interface. The other three pins have one analogue input and two PWM outputs. The USB has an extra analogue pin and a PWM pin, which can be used if the board does not need to be USB-connected to the computer after programming. This version runs on 5.0V and has an on-board voltage regulator that can also run on a 12V supplied to the "VIN" pin [6].

XBee module from MaxStream Inc. XBee module is used as the wireless device in this project. It is an IEEE 802.15.4 compliant radio based on carrier sense multiple accesses (CSMA), which can provide point to point, point to multipoint and also peer to peer communication. This module operates at 2.4 GHz

frequency band with data rate of up to 250 Kbps. The receiver sensitivity is -92 dBm [7]. XBee module types Series 1 is used where two of them are configure as routers while one module is used as a coordinator. Total pins for this module are 20 pins. Each pin has its own name and function. During this project development VCC, DOUT, DIN and GROUND pins are used.

The logic level converter is a step down converter from 5V signals to 3.3V signal. The logic level converter has 4 channels for each site. Each level converter has the ability to convert 4 pins on the high side to 4 pins on the lower side. This converter can be used with normal serial, I2C, SPI but not with analogue signal [8].

The magnetic door switch used in this project offers a cheaper method to monitor access doors that should remain closed. This sensor consists of two main components, a magnet and a switch with terminals to connect the signal wires. The magnet attaches to a door or access panel, while the switch attaches to the frame. When the door is closed, the two pieces should be within a half inches from each other. When the door opens, this distance increases, eventually toggling the switch. Figure 2 shows the schematic circuit for the first transmitter.
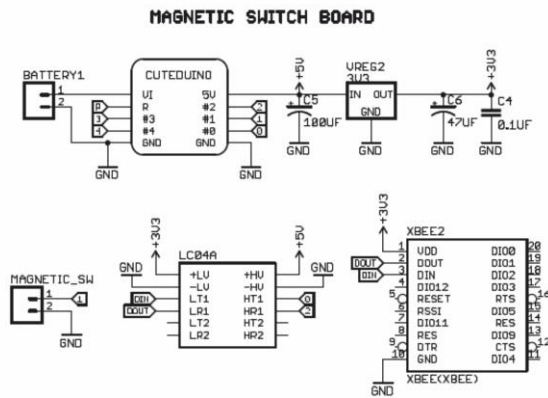

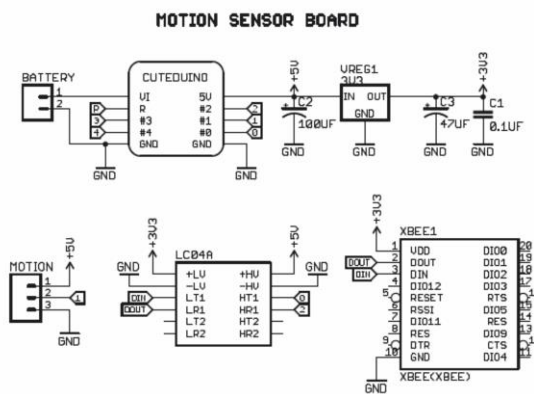**Figure 2** Schematic circuit for magnetic sensor

Figure 3 Schematic circuit for motion sensor

Figure 3 shows the schematic circuit for the second transmitter. In the circuit, the Passive Infrared (PIR) motion sensor has three pins, which are the VCC, output and ground [9]. The VCC pin is connected to the 5V pin at CuteDuino while the output pin from PIR sensor is connected to pin 1 of the CuteDuino. CuteDuino contains a programmable coding to operate and read the system. If motion is detected, condition 1 will be sent to the transmitter and then to the receiver. The buzzer is triggered if condition 1 is received and the words 'Motion Detected' will appear in GUI.

The Arduino Uno is a microcontroller development board based on the ATmega328 created by Atmel. It has a total of 14 digital input and output pins, a 16 MHz ceramic resonator, 6 analogue inputs, a power jack, an In Circuit Serial Programming (ICSP) header, a Universal Serial Bus (USB) connection and a reset button. In this project, Zigbee is attached on top of Arduino Uno allowing the Zigbee shield to be used as the receiver. The overview of receiver unit is shown in Figure 4.
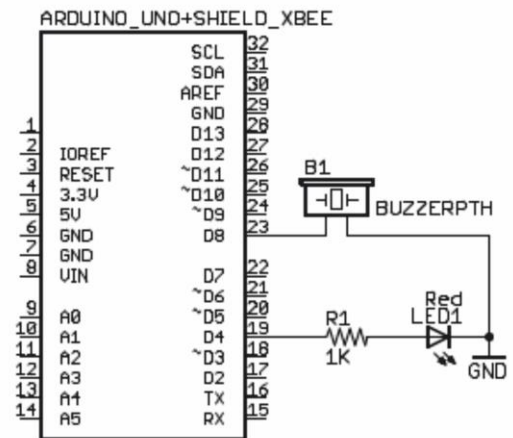

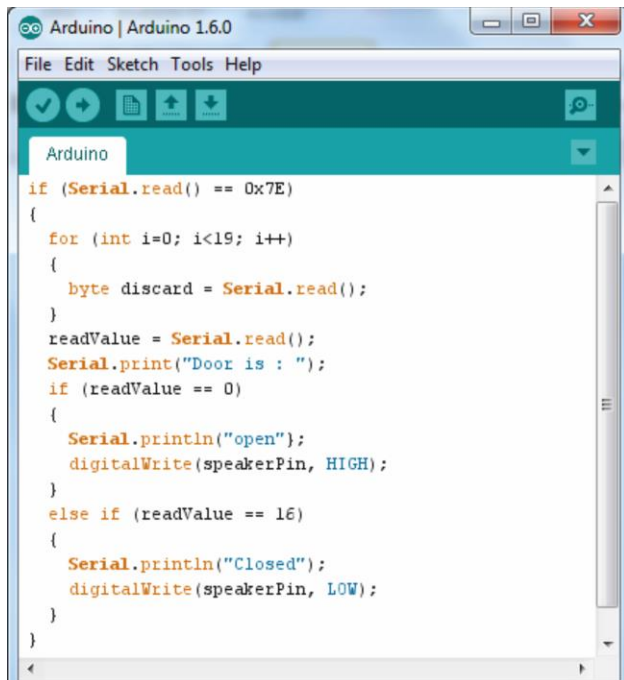**Figure 4** Schematic diagram for Arduino receiver

2.2 Software Configuration

The softwares used are the Arduino integrated development environment (IDE) software, X-CTU, and Processor integrated development environment (IDE) software. Figure 5 shows the overview of the IDE software. This software uses its own programming language, which is almost similar to C programming language.

XCTU is the configuration software for Zigbee. It is compatible with Windows and Mac OS, and this software is cloud integrated that allows configuration and management of Zigbee devices anywhere around the world. In terms of network configuration,

this software is used to configure each Zigbee so that they can communicate with each other.

Processing Development Environment (PDE) software was used to create the GUI for this project. The GUI is created to represent the data that have been collected by the receiver into a graphical or image form. When any sensor is interrupted, the signal will be sent from the transmitter to the receiver.

```
if (Serial.read() == 0x7E)
{
  for (int i=0; i<19; i++)
  {
    byte discard = Serial.read();
  }
  readValue = Serial.read();
  Serial.print("Door is : ");
  if (readValue == 0)
  {
    Serial.println("open");
    digitalWrite(speakerPin, HIGH);
  }
  else if (readValue == 16)
  {
    Serial.println("Closed");
    digitalWrite(speakerPin, LOW);
  }
}
```

Figure 5 Arduino IDE script for both transmitters

As the receiver receives '1', the GUI will pop up a message of alert. The programming flowchart to create the GUI is shown in Figure 6.
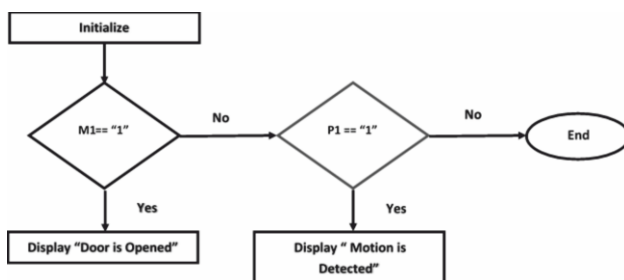

Figure 6 Programming flowchart for GUI

2.3 Experimental Setup

Two areas were selected for the experiment and analysis purposes. These are the laboratory corridor and main hall of a house. Figure 7 and 8 show the location of the experiment setups used for analysis. It can be seen that the laboratory corridor has bigger

space and less obstacles compared to the house. For wireless data transmission, space and area play an important role. Fewer obstacles would obviously allow faster data transmission. Analysis was conducted for several distances to analyze the time response between the transmitters and receiver.
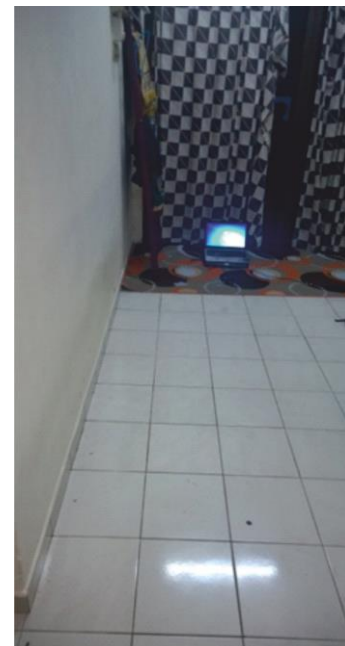

Figure 7 Laboratory corridor

Figure 8 Main hall of a house

3.0 RESULTS AND DISCUSSION

In this section, the prototype of the home security system is presented and the performance analyses of the sensors for various distances are shown. Figure 9 shows the overview of the completed home security system using Zigbee. The system consists of three main parts, namely, the magnetic door circuit, motion detector circuit and Arduino. The magnetic door and motion sensors are the end devices or nodes used in this project, which also behave as transmitters. At the receiver, Zigbee is attached on top of Arduino using the Zigbee shield. When the system is activated and if the door attached to the magnetic sensor is opened or any movement is detected on the motion sensor, an alarm will be triggered to inform the house owner. The responses will be recorded on the GUI. Two types of messages will appear on the personal computer, which are 'Door is open' or 'Motion is detected' depending on the signal received.
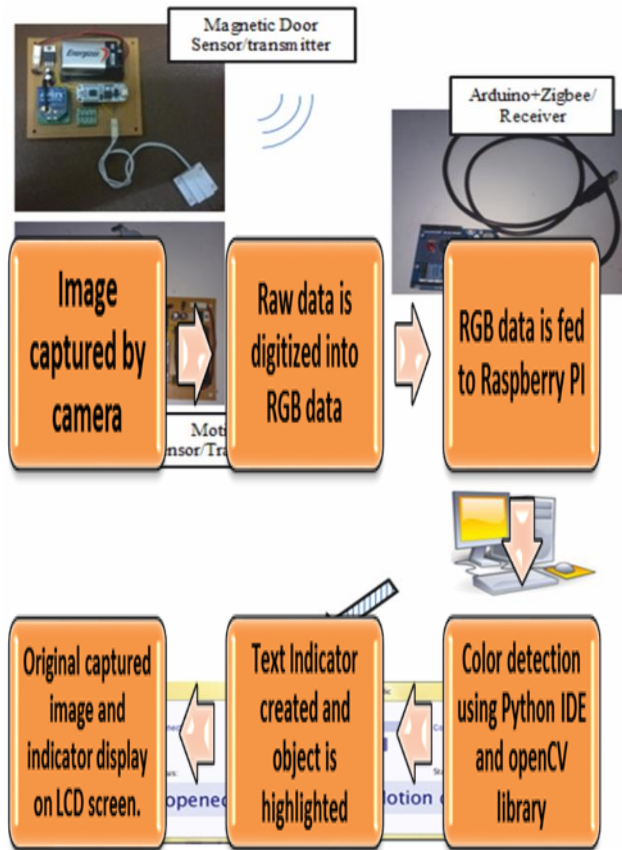

Figure 9 Overview of the home security system

Figure 10 shows the graph of delay versus distance between the laboratory corridor and main hall. From the graph, it can be seen that as the distance is increased, the delay increases as well. For the experiment conducted in the laboratory corridor, a significant delay was observed for distances of more than 36 meters. For the experiment conducted in the main hall, significant delay was observed for distances of more than 12 meters. The highest delay is observed at distances around 75 meters for the experiments conducted in the laboratory corridor. The data transmission is better in the laboratory corridor compared to the main hall. More obstacles are observed at the main hall compared to the laboratory corridor, which contributes to the results observed. Obstacles reduce the effectiveness of the Zigbee transmission due to path loss.

The same figure also explained the analysis of delay versus distance using a motion sensor. The motion sensor is a digital input while the magnetic door sensor is an analogue input. When the motion detector is used, additional delays of two seconds are added as the motion detector needs to get a snapshot of a still room, before detecting any movement after that period. From the graph, it can be seen that as the distance is increasing, the delay will increase as well. For the experiment setup in a laboratory corridor, significant delay was observed at a distance of more than 20 meters. For the experiment setup at the main hall, significant delay was observed at distances of more than 8 meters. The highest delay is observed at distances around 70 meters for experiments conducted in laboratory corridor. Again, the results observed at laboratory corridor are better compared to the main hall.

Comparing the two sensors, the motion sensor has more delay compared to the magnetic door sensor. The combinations of these two sensors are highly compatible. It can be placed around the house to detect any intruders. If the motion sensor does not detect the intruder movement, the magnetic door sensor will be a second sensor to detect the intruder.
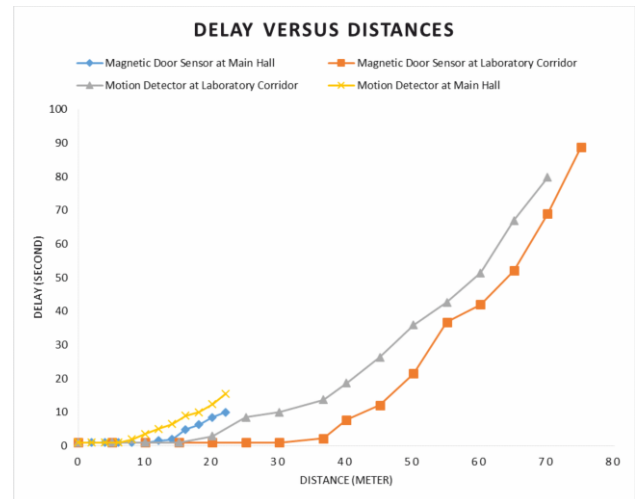

Figure 10 Performance of both sensors

4.0 CONCLUSION

The Home Security System using Zigbee has been successfully designed and implemented using Arduino and CuteDuino development boards. The features of every hardware components are tested at two different areas. This project is suitable to be implemented in any house or any closed buildings with the limitation of detection of 22 meters. In the future, more sensors can be added to cater for houses with more entrances. Different types of sensors can be included to the system to increase the efficiency of this system.

Acknowledgement

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