Performance Evaluation of Wireless Sensor Networks Based On Zigbee Technology in Smart Home

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***Abstract*—Wireless Sensor Networks (WSNs) has diverse application domains such as smart home, smart care, industrial, etc. In this paper, we present a WSN system based on the ZigBee technology (IEEE 802.15.4) in Smart Home.**

To have a good sensor networks communication implanted in a smart home, studies of operating performance on this network is important. In this work, we investigate the performance of our ZigBee sensor networks. The study of performance is based on measurements of the Received Signal Strength Indicator (RSSI) in different parts of the Home. We will also discuss the impact of electromagnetic noise on the communication performance of a ZigBee Sensor Network in the presence of a motor with variable speed drive.

Keywords—Smart Home; WSNs; ZigBee; RSSI.

I. INTRODUCTION

The integration of smart devices and an intelligent network in a home can make it smart and also allows customers to manage energy in a way that is appropriate, cost effective and good for the environment. In the field of Smart Home, many applications benefit from the advantages inherent in the use of Wireless Sensor Networks including remote monitoring, continuous data recovery energy consumption, location, recall and management of temperature and humidity, motion detection, understanding and observation of the people's environment [1,2].

To better control energy consumption in the Smart Home, the Home Area Network (HAN) is used to collect sensor information from a variety of devices inside the home, and optionally sends control information to these devices. ZigBee is a high technology for the Smart Home network communication. It is designed to be able to get rid of electrical cabling inside home. ZigBee, as a wireless mesh networking scheme low in cost, power, data rate, and complexity, is ideal for Smart Home applications [3,4].

The structure of Wireless Sensor Networks in the smart home requires three different devices: Coordinator, Router and End Device (Figure 1). All home environments can then be monitored and the required data can be delivered to the coordinator. After the treatment of the data, the appropriate control commands are sent through coordinator to home appliances.

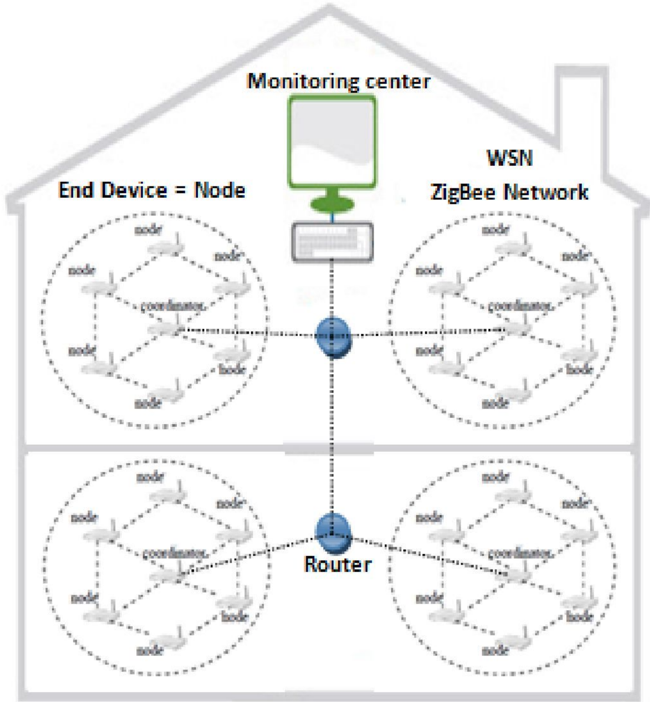

Fig. 1. Structure of Wireless Sensor Networks in Smart Home based on ZigBee Technology.

II. ZIGBEE TECHNOLOGY IN WIRELESS SENSOR NETWORKS

The ZigBee communication protocol is popularly adopted in wireless sensor networks (WSNs) [2,5], because it has low-power and low-cost characteristics [3], and therefore it is very suitable for the development and use of Smart Home. The physical layer of ZigBee protocol supports three frequency bands; a 2450 MHz band (with 16 channels), a 915 MHz band (with 10 channels) and a 868 MHz band (1 channel). The access mode for all these frequency bands is Direct Sequence Spread Spectrum (DSSS). The 2450 MHz band employs Offset Quadrature Phase Shift Keying (O-QPSK) for modulation while the 868/915 MHz bands use Binary Phase Shift Keying (BPSK). Table I summarizes the frequency bands and data rates of the ZigBee technology IEEE 802.15.4 [8].

TABLE I. ZIGBEE FREQUENCY BANDS AND DATA RATES

Band	**868 MHz**	**915 MHz**	**2450MHz**
Region	EU. Japan	USA	Worldwide
Channels	1	10	16
Data rate	20 kbps	40 kbps	250kbps

III. WSN BASED ON ZIGBEE TECHNOLOGY PERFORMANCE IN SMART HOME

A. Experimental setup

Figure 2 shows the experimental setup. In this experiment, our WSN test system based on the ZigBee technology in Smart Home consists of a client computer that provides a user interface for the system, a coordinator as data collector and multiple devices that provide sensor readings on ZigBee communication links.

The experimental system is divided into three main parts:

- A user interface communicates with the user via the computer and displays the results.
- A coordinator collects sensor readings to the user.
- An end device consists of two parts: sensor interface and ZigBee interface. The sensor used in this test is a temperature sensor.

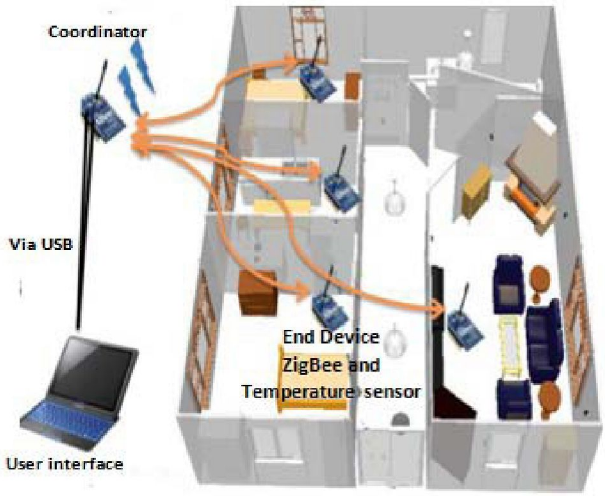

Fig. 2. Experimental setup

B. The Received Signal Strength Indicator measurements

1) Received Signal Strength Indicator (RSSI)

The Received Signal Strength Indicator (RSSI) indicates the signal power at the receiving end, is used to estimate the distance between the WSN nodes. It is a parameter to identify the incoming radio signal. The free space transmission equation [6,7,10] is given in Equation (1).

$$P_{RX} = P_{TX} \,.\, G_{TX} \,.\, G_{RX} \,.(\frac{\lambda}{4\pi d})^2 \qquad (1)$$

Where;

P_{RX} : Transmission power of sender

P_{TX} : Remaining power of wave at receiver

G_{TX} : Gain of transmitter

G_{RX} : Gain of receiver

λ :Wave length

d : Distance between sender and receiver

The Received Signal Strength (RSS) is converted to a Received Signal Strength Indicator (RSSI) in embedded devices, which is defined as ratio of the received power to the reference power P_{ref} [6]. The typically reference power represents an absolute value of P_{ref} =1mW [6].

The RSSI formula is shown as in Equation (2) as below;

$$RSSI = 10.\log\left(\left(\frac{P_{RX}}{P_{ref}}\right)\right) \text{ (dBm)} \qquad (2)$$

2) Recovery test by measuring the RSSI.

Our measurements are to detect the average value of RSSI obtained from the reception of 100 messages. Each measurement is an average of 5 repetitions of the same experiment to counteract the signal fluctuations caused by inside discoloration [7,8,9].

The experiments have been performed in an indoor environment with both Line-Of-Sight (LOS) and Non Line-Of-Sight (NLOS) conditions. The results are presented in Table II and Table III.

TABLE II. SIGNAL LOSS IN FREE SPACE

Distance between tow nodes	**Average Attenuation RSSI (dB)**
50 cm	0.00
2 m	11.55
3 m	14.17
6 m	20.87
9 m	24.95
11 m	29.60

TABLE III. SIGNAL LOSS WITH OBSTACLES.

Obstacles	**Average Attenuation RSSI (dB)**
Window (metal stores open)	1.03
Window (metal Stores closed)	3.92
Wall with door open	0.38
Wall with door closed	1.21
Wall with Brick	1.44
Between two floors	13.07

3) Discussion of results

The obtained measurements shows that other than the distance that separates two nodes, there are few other factors that degrade and have a negative impact on the RSSI values in the ZigBee communication network as reflections on metal objects, diffraction at edges, floors existing, etc...

IV. ZIGBEE SENSOR NETWORK IN THE PRESENCE OF A MOTOR WITH VARIABLE SPEED DRIVE

A. Experimental setup

To the previous experimental configuration used to measure RSSI, we will add a motor with variable speed drive and keeping a fixed distance between the end device (ZigBee / temperature sensor) and the coordinator. A spectrum analyzer HAMEG is added in order to test the efficiency of the signal transmission in the presence of the motor in both cases On and Off. The graphical user interface will be used to verify the temperature value measured with and without the perturbation due to the variable speed drive (Figure 3).

Fig. 3. Experimental environment

Figure 4 below represents the user interface in order to show the temperature values sent by the end device through the coordinator.

Fig. 4. User interface

B. Experimental results

In this analysis we focus on the 2.4 GHz band.

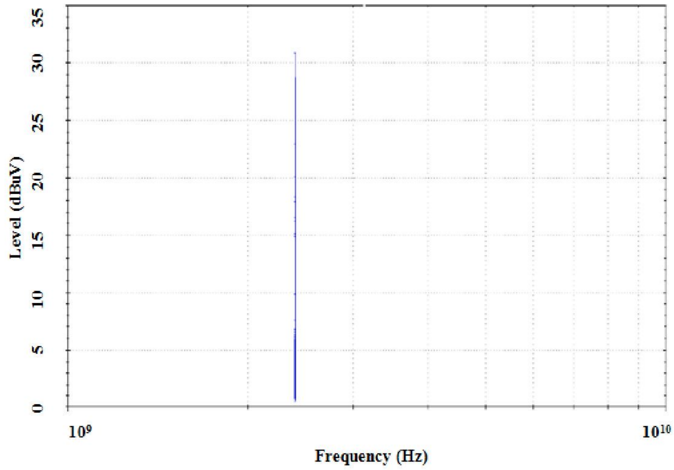

Fig. 5. Signal sent by the end device to the coordinator, Motor Off

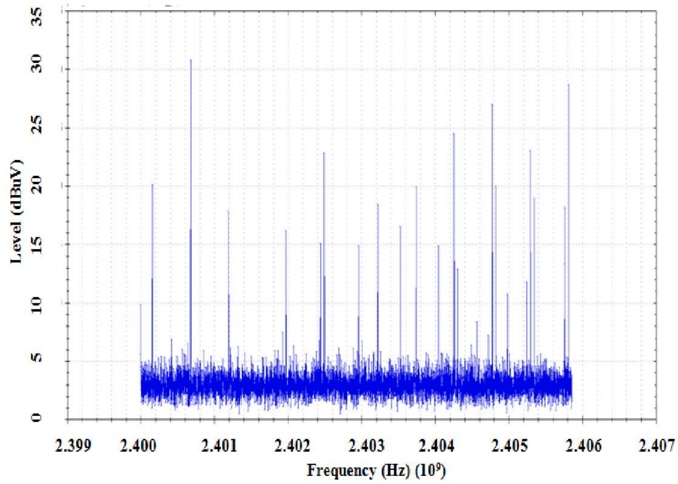

Fig. 6. Signal sent by the end device to the coordinator, Motor On

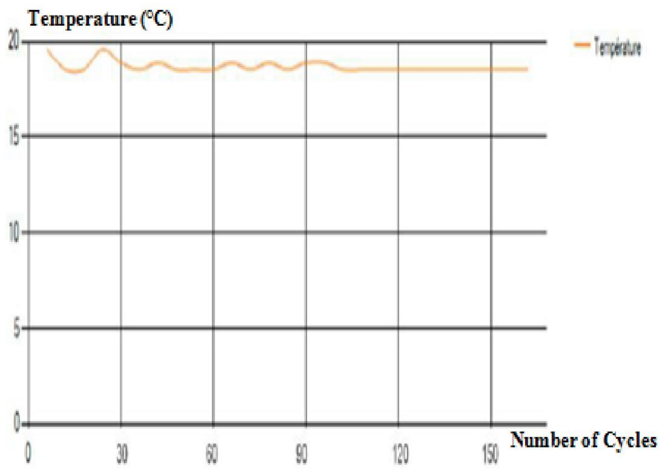

Fig. 7. Temperature values received by the coordinator, Motor Off

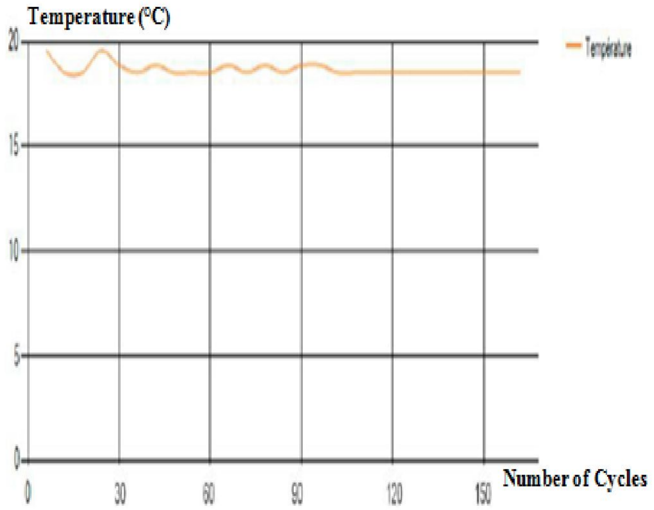

Fig. 8. Temperature values received by the coordinator, Motor On

C. *Discussion of results*

By comparing the results obtained in Figures 5 and 6, we note that the presence of a variable speed drive in a ZigBee communication network does not disturb the signal. This conclusion can be also confirmed with the temperature values received by the coordinator shown in Figures 7 and 8.

V. CONCLUSION AND FUTURE WORK

Our results from this experiment show some factors such as a function of distance between the end device and the coordinator and also some obstacles which affected to the RSSI performance. On the contrary, the presence of a variable speed drive does not obstruct the signal sent by the ZigBee modules. All in all, we believe that the quality of wireless link of WSNs based on ZigBee technology depends on the distance between nodes, the location of each sensor nodes and obstacles between them.

All these communication systems Wi-Fi, ZigBee and Bluetooth operate at the same frequency bands. However, the interference problem between ZigBee and other devices can occur. In this context, future research will be based on the possibility of coexistence between these different wireless protocols in a smart home.

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