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Energy Consumption and Battery life analysis of Zigbee Based Wireless sensor Node using Transmit power

[1]Rana S Mahajan, [2]Dr.Komal Kanojia, [3]Dr.Bharti Chourasia

[1]PhD scholar, [2]Assistant Professor,[3]Associate Professor
Department of Electronics and Communication Engineering
Sarvepalli Radhakrishnan University, Bhopal, India

Abstract

Zigbee based Wireless Sensor Network (WSN) technology is progressively used in the present day for remotely monitoring various services such as health, environmental parameters etc. However, until now, the Zigbee based WSN system has lacked in terms of effective power use. WSN is made up of portable or fixed battery operated devices. Low power consumption will improve battery life accordingly it enhances WSN life.The goal of this research is to find the optimal transmit power to minimize energy consumption of Zigbee based WSN under normal operation. Two network scenarios simulated using OPNET to find optimal transmit power and evaluate the performance of a basic WSN consisting of a ZigBee coordinator and an end device. The simulation result shows that there is no variation in results if the transmit power is reduced to 0.00078125 W from 0.05 W. This reduced transmit power will increase the battery life by 64 times.

Keywords: Wireless Sensor Network, Zigbee ,OPNET

1. Introduction

In today's world, wireless technology is continually evolving. A wireless sensor network (WSN) is made up of numerous nodes. Nodes in a WSN work together to complete a common job. Since nodes are typically battery-powered and run for longer durations without human intervention, energy efficiency becomes a significant concern. As a result, the wireless sensor network community has placed a strong emphasis on improving energy efficiency [1, 2].The lifetime of sensor nodes is also influenced by battery lifespan and the challengesfor recharge it[3]. The Zigbeeaims todevelop a low-power RF communication system. For connecting between tiny sizes devices that often perform nonintensive activities, such as performing occasional measurements or operating remote equipment in an automated setting, a special set of requirements have been adopted. The goal is to create low-power solutions that extend the battery's life[1].

Researchers are beginning to pay attention to Zigbee and other wireless systems because of their energy behaviour [2, 4]. The energy use of these systems is being studied, and measures are being done to optimize the systems by designing devices that use the least amount of energy [5, 6]. Despite the fact that ZigBee is a low-power standard,it still has a lot of opportunity for development [6]. As a result, a technology that can assess the true utilization of these kinds of systems is required[1].

Typically, developers have limited knowledge about overall energy expenditure. It is based on theoretical research and simulation techniques in the majority of cases. Furthermore, the information supplied generally relates to small activities, such as single instructions. This will be complicated to understand the energy behaviour of such a system if it develops sophisticated.

This paper describes a way for finding optimal transmit power to minimize the energy usage of a ZIGBEE system. The remainder of the paper is organized as follows. The next part presents a quick overview of MAC Layer in 802.15.4. The third section discusses Receiver Sensitivity. Section fourdescribes Range of WSN. Section fivegives overview of Power Consumption in IEEE 802.15.4. Section six contains the simulation resultsanalysis and discussions. Section seven concludes thiswork and outlines the extent of work to be completed in the future.

2. MAC Layer in 802.15.4

Many prospective benefits of adopting IEEE 802.15.4 are highly influenced by the implementation of the Medium Access Control (MAC) sub layer. It has two types of nodes: Full-Function Devices (FFD) and the Reduced-Function Devices (RFD). Coordinator and router are full function devices and end devices are reduced function devices [7, 8].

The MAC layer has two operating modes

1. Non Beacon Enabled mode
2. Beacon Enabled Mode

Non beacon mode is preferred when star topology is used and FFDs are powered by main source whereas beacon enabled mode is preferred when mesh or tree topology is formed and FFDs are powered by batteries. FFDs consumes less energy in beacon enabled mode as compare to non-beacon enabled mode.Currently, the most of ZigBee motes on the market are not equipped with beacons[7,8].

3. Receiver Sensitivity

Receiver sensitivity is the lowest received signal strength that results in a packet error rate (PER) with less than 1% [8,9]. The table 1shows receiver sensitivity required for different frequency bands and modulation techniques.

Table 1: Relationship between Frequency Bands, Modulation Methods, and Receiver Sensitivity

Frequency Bands (MHz)	Modulation Method	Receiver Sensitivity (dBm)
2400	All Supported	-85

868/915	BPSK	-92
868/915	ASK/OQPSK	-85

For transceivers operating at 2400 MHz, a receiver sensitivity of -85 dBm is needed, as given in table 1. When employing BPSK modulation, transceivers operating in the 868/915 MHz frequency band must have a receiver sensitivity of -92 dBm, while ASK/OQPSK modulation requires a sensitivity of -85 dBm[8].

The receiver sensitivity of -85 dBm equals to a signal having root mean square voltage of 12.6 uV when using a 50 Ohm single-ended antenna as given in [8] and calculated as in below equations:

$$\text{Signal Power} = 10^{\left(\frac{-85-30}{10}\right)} = 3.16\times10^{-12} = 3.16\,pW$$

$$\text{Signal Voltage} = \sqrt{P\times R} = \sqrt{3.16\times10^{-12}\times50} = 12.6uV$$

The received signal must have a minimum voltage of 12.6 V rmsto be recognized and identified and data must have a Packet Error Rate of less than 1% to be collected.To be compatible with IEEE 802.1.5.4, a receiver sensitivity must be at least -20 dBm, a PER of less than 1%, and output power of 3 dBm [8, 9].

4. RF communication Range Calculation

It's simple to devise a formula for calculating the distance between two wireless nodes. Range (distance between two nodes) can be calculated using the equation given below [8].

$$R = 10^{\left(\frac{P_o - F_m - \mathrm{P}_r - 10\times n\times\log_{10}(f) + 30\times n - 32.44}{10\times n}\right)}$$

Where R = range in meter, P_o (Transmit Power in dBm), P_r (receiver sensitivity in dBm), F_m (Fade Margin in dB), n (Path Loss Exponent), f (Frequency in MHz).

Using above equation we can calculate the range of WSN.

5. Power Consumption in IEEE 802.15.4

The lifespan of radio devices are going through idle mode, listen mode, transmit mode. As given in [10] the power consumption relationship among these modes can be derived as follow:

idle mode < transmit mode < listen mode

As shown above power consumption is more in listen mode as compare to other mode of operations. Reducing output power reduces current consumption and extend battery life in transmit mode.Less transmission power leads to lower energy usage, which leads to little heat. Lowering the temperature extends the life of the equipment [11].

6. Simulation Results, Analysis, and Discussion

6.1 Simulation Setup

Two scenarios are created and simulated using OPNET.In the simulation scenario, one node is employed with a ZigBee coordinator.The simulation parameters are set as shown in table 1 and figure 1. In scenario1 transmit power and receiver sensitivity is set to 0.05 W and -85 dBm respectively.In scenario2 transmit power is reduced to0.00078125 W to save the energy.

Table 1: Simulation Parameters

Simulation Parameters	Scenario1 Values	Scenario2 Values
Network Size	100X100 Meters	100X100 Meters
Transmission Bands	2450MHz	2450MHz
Packet Reception Power Threshold	-85 dBm	-85 dBm
Transmit Power	0.05 W	0.00078125 W
Simulation Time	60 Minutes	60 Minutes

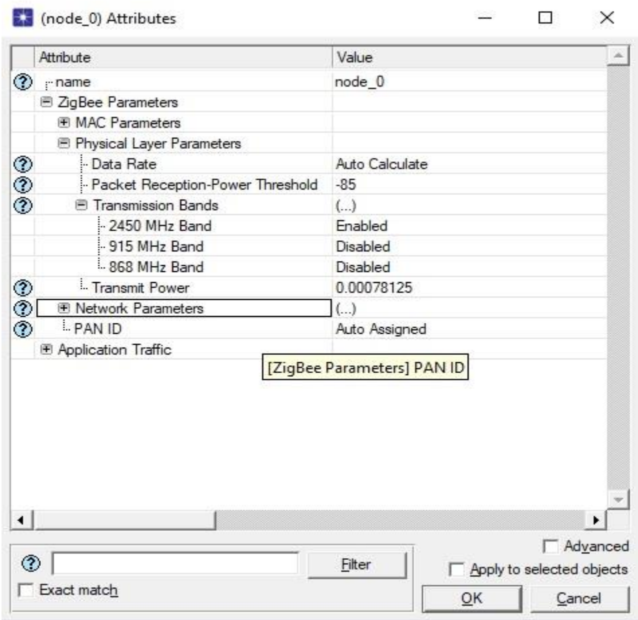

Fig.1 Node's Attributes Value

6.2 Result Analysis

To analyse the performance of Zigbee based WSN, MAC delay, throughput, Application end to end delay, signal to noise ratio, and power consumption evaluation parameters are used.

1. MAC Delay: Figure two shows that MAC delay is same in both scenarios.

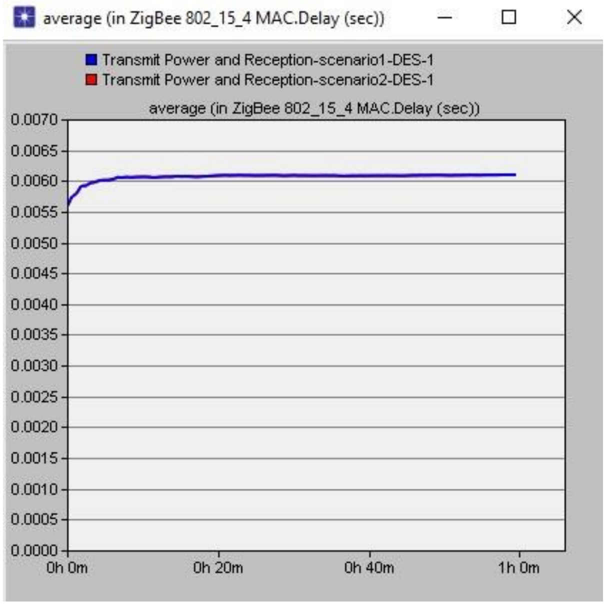

Fig. 2 MAC Delay for scenario1 and scenario2

2. Throughput: Figure threeshows that throughput is same in both scenarios.

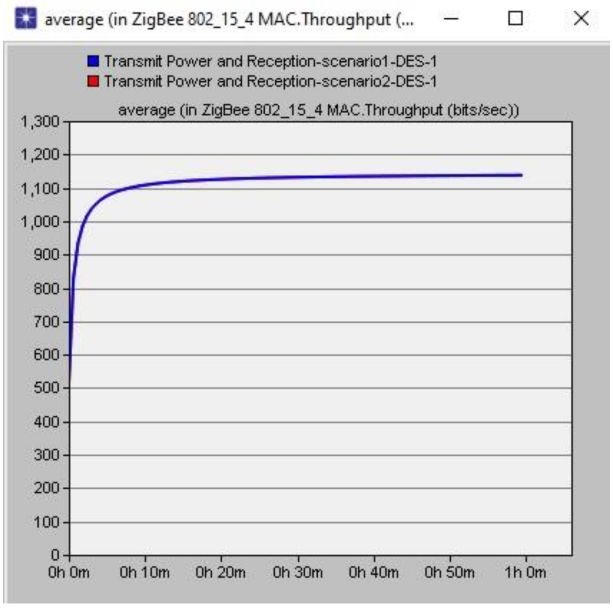

Fig. 3 Throughput for scenario1 and scenario2

3. Application End to end delay:Figure 4 shows that application End to end delay is same in both scenarios.

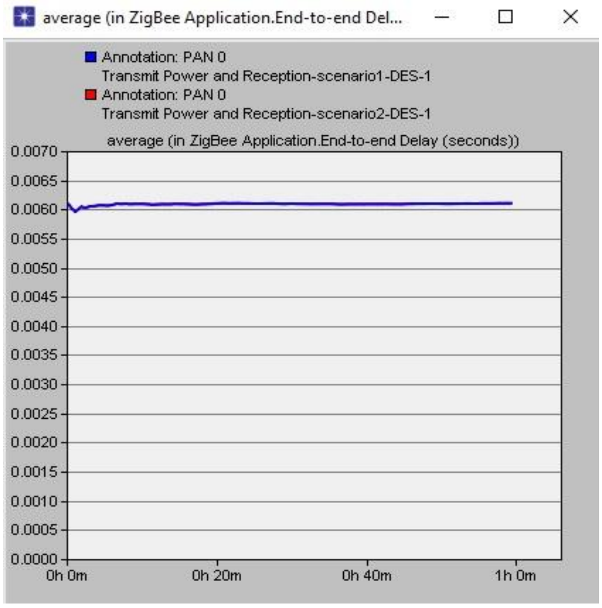

Fig. 4 Application end to end delayfor scenario1 and scenario2

4. Received Power: Figure five shows that receiver received power at 3564s simulation time, for scenario1 is 0.0125 W and for scenario2 is 0.0002 W.The result indicates that received power is higher in sceanaio1 as compare to scenario2.

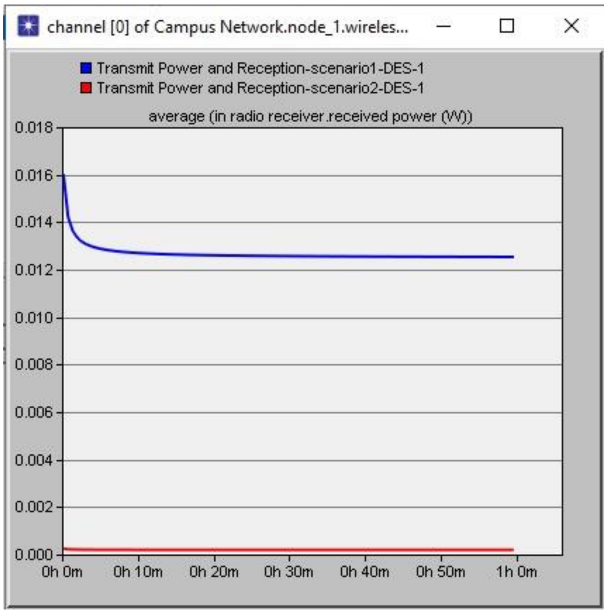

Fig. 5 Receiver Received Powerfor scenario1 and scenario2

5. Signal to Noise Ratio: Figure six shows that signal to noise ratio at 3564s simulation time, for scenario1 is 109.99 dB and for scenario2 is 91.93 dB. It indicates quality of signal is good in scenario1 as compare to scenario2.

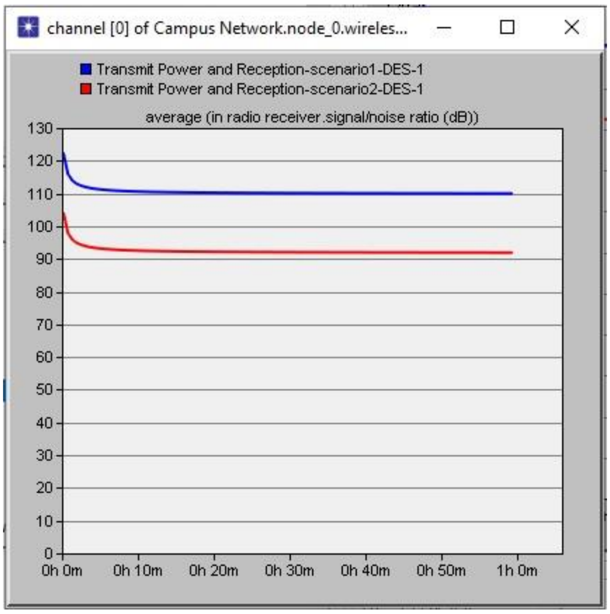

Fig. 6 Signal/Noise ratio for scenario1 and scenario2

6.3 Discussions

As shown in the equation below, power is the product of current and voltage.
Power (Watt) = Current (Ampere) * Voltage (Volt)
Because the operational voltage is (mostly) constant, so reducing the transmit power by 3dB or halving it; will reduce the current by half [11].

As shown in the equation below, battery capacity is the product of current and time.
Battery Capacity = Current (Ampere)* Time (hour)
By halving the current, you can double the battery life.The battery operated devices utilise power for purposes other than transmission and receiving, so the total battery life will not be exactly double [11].

In this work the transmit power is reduced to 0.00078125 W (scenario2) from 0.05 W(scenario1). As a result of the simulation findings and the preceding discussion, the following points have been discovered:

- Battery life will be nearly 64 times longer.
- For MAC delay, throughput, and end-to-end, we received the same result in both scenarios.
- Interference to other existing networks can be reduced by limiting transmitter power to the maximum required for a reasonable level of performance.

7. Conclusion

All devices in a Zigbee-based WSN run on batteries with a finite lifespan. As a result, one of the most crucial factors to consider is energy usage. To reduce the energy consumption and extend the battery's life, the transmit power is lowered or set to the bare minimum. The performance of WSN is identical when transmit power is dropped to 0.00078125 W and when transmit power is set to 0.05 W.

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