BER, Throughput, Energy Efficiency Performance Analysis of Proposed Different Systems in Wireless Sensor Network

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ABSTRACT
One of the major weakness of Wireless Sensor Networks is the energy consumption because of limited battery resource and battery replacement or recharging difficulty. The research presented in this paper aims to reduce the energy consumption in the physical layer because most the energy consumption occurred in this layer. This reduction will be achieved via the use of ZigBee transceiver standard at the physical layer under 2.4 GHz frequency band with the reduced complexity and lower power consumption than other techniques used in Wireless Sensor Network. Furthermore, such use will also enhance energy efficiency, bit error rate, and throughput of the wireless sensor network. In this paper, three different systems have been proposed according to the type of transceiver technique used in wireless sensor network. System1 uses ZigBee transceiver standard over the wireless sensor network without any additional technique whereas system2 uses ZigBee transceiver with Convolutional Coding over the WSNs model. On the other hand, system3 uses the ZigBee transceiver with both diversity techniques Virtual Multi-Input Multi-Output and with Convolutional Coding over the wireless sensor network model. The simulation of matlab results show that system3 achieves the best energy efficiency performance compared with the other two systems at lower quality of channel. System2 achieves the best energy efficiency performance at medium quality of channel, and system1 achieves better energy efficiency at high quality of channel.
Keywords: Wireless sensor networks (WSNs), IEEE 802.15.4, ZigBee, Convolutional Coding (CC) , Virtual Multi-Input Multi-Output (V-MIMO), Forward error correction (FEC).

INTRODUCTION
Wireless sensor networks have gotten a great deal of consideration in the late years. WSNs are typically composed of a large number of sensor nodes that are low cost, very tiny, limited energy resource and have multi-functional. The energy must be used efficiently that for long system lifetimes of wireless sensor network [1]. The terms of Bit Error Rate (BER) are used generally to studied reliability of the communication link. This greatly affects network performance in terms of energy, delay and throughput [2].

Wireless sensor networks require facile and simple error control schemes because of the low complexity request of (SNs). Forward error correction (FEC) and automatic repeat request (ARQ) are the key error control strategies in (WSNs). There have been some studies that consider the energy efficiency of error control techniques in (WSNs). The performance of Repeat- Accumulate codes in single hop WSN over Convolutional codes is studied [3]. Further work [4] discusses an optimum (FEC) scheme with minimum energy consumption in (WSNs).

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The energy efficiency of error control schemes for wireless sensor networks is evaluated for a Nakagami-m fading channel [5].

The ZigBee technology is designed to provide a simple and low-cost wireless communication and networking solution for low-data rate and low power consumption applications, such as home monitoring and automation, environmental monitoring, industry controls, and emerging low-rate wireless sensor applications[6].

On the other hand, the channel fading has a great effect on the reliability of data transmission and energy consumption in WSN. Diversity techniques ((V-MIMO) or cooperative communication) represents a potential candidate to combat the effects of channel fading by exploiting the diversity. The energy efficiency of V-MIMO schemes for (WSNs) is assessed for a Rayleigh channel fading. [7].

In this work, we consider a ZigBee IEEE 802.15.4 compliant sensor network for our study. Henceforth, in this paper a wireless sensor node based on Zigbee technology using IEEE 802.15.4 RF transceiver will be referred to as a transceiver of IEEE 802.15.4 Zigbee.

Theoretical Analysis

This section presents a brief overview of the ZigBee physicl layer technology, Convolutional code (CC), Virtual Multi-Input Multi-Output (V-MIMO), and energy efficiency

ZigBee Physical Layer (PHY)

The responsibility of (PHY) layer is to transceiver information by employing a selected radio channel and using a particular spreading and modulation technique. There are three different operational bands of frequency: 868 MHz , 915 MHz, and 2.4 GHz, [6,8].

The details of Zigbee transceiver work with 2.4 GHz band is as per the following: The modulation scheme of data used here is direct scuence spread spectrum-Minimum Shift Key (DSSS-MSK). Fig.1 is show the block diagram of the transmitter and the receiver of ZigBee system. It involves spreading and modulation of input bits. Incoming bits are grouped into four, so as to represent a Zigbee symbol. The DSSS signal has a data rate of 2 Mb/s. So Pseudo-random Noise (PN) sequence is chosen with 32 chips /symbol, so the chip rate achieved is of 2Mb/s. The incoming chip sequences is modulated the MSK modulator [7,8].

The transmitted signal was effect by multipath fading parameters and white noise when the signal passing through the channel. The ZigBee receiver station consists of number of blocks which is used to reverse perform operations of ZigBee transmitter. This contains block of demodulation, block of chip to ZigBee symbol (de-DSSS), and finally block of Zigbee symbol to bit regroup.

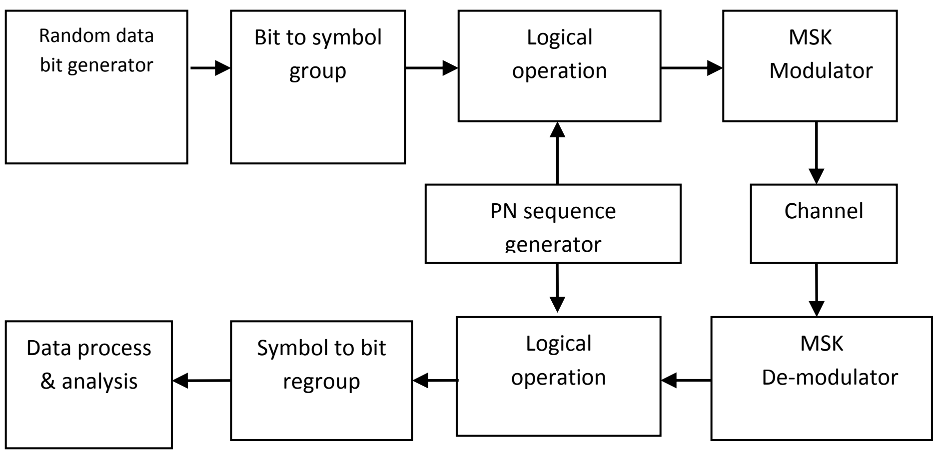

Figure (1) Block Diagram of ZigBee Transceiver

Convolutinal Code (CC)

Convolutional codes belongs to families of error correcting codes whose decoding simplicity and good performances, in particular for the Gaussian channel, without doubt, very much at the origin of their success. For a CC at every moment k the encoder delivers a block of N binary symbols ck = (ck,1, ck,2, . . . , ck,N), a function of the block of K information symbols dk = (dk,1, dk,2, . . . dk,K) current at its input along with preceding blocks. Convolutional codes consequently introduce a memory effect of the order m. The quantity ν = m + 1 is called the constraint length of the code and the ratio R = K/N is called the code rate. If K information symbols at the encoder input are found explicitly in the coded block ck, that is

$$c_k = (d_{k,1}, \ldots, d_{k,K}, c_{k,K+1}, \ldots, c_{k,N}) \qquad \ldots..(1)$$

then the code is known as systematic. The opposing case is known as non-systematic. The general diagram of an encoder with output K/N and memory m is as shown in Fig. 2. At every moment k, the encoder has m blocks of K information symbols in memory [9].

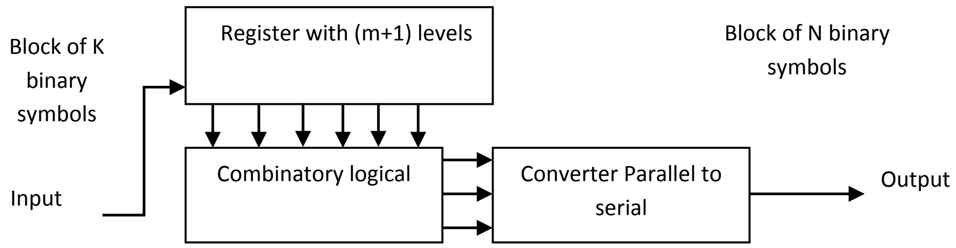

Figure (2) General Diagram of Convolutional Encoder [9]

Virtual Multi-Input Multi-Output (V-MIMO)

A new class of methods have the same advantage MIMO system called cooperative communication has been proposed that enables single antenna mobiles in a multi-user environment to share their antennas and generate a virtual MIMO transmitter that allows them to achieve transmit diversity. The end result is a set of new tools that improve communication capacity, speed, and performance; reduce battery consumption and extend the network lifetime; increase the throughput and stability region for multiple access schemes; expand the transmission coverage area; and provide cooperation tradeoff beyond source–channel coding for multimedia communications [7,10].

The processing performed at the receiver is important, where the signals arriving through the multiple paths are constructively combined. The nature of the processing that is applied to each signal during combining is a function of the particular design goals. If the goal is to linearly combine the signals so that the signal-to-noise ratio (SNR) is maximized at the resulting signal, then the resulting mechanism is called a maximal ratio combiner (MRC) [10,11].

Energy Efficiency

Energy efficiency is one key of (WSN) for enhanced lifetime of the network. The received signal is effected by multipath fayding of the (WSN) channel. The error level is increasing with unreliable links to a greater extent and hence, lowers life of battery [12,13].

Energy Efficiency without error control

The overall energy consumption for the data communication bits of a sensor node in single hop is produced by

= + . ……(2)

Where and is the energy consumed by the node for transmitting and receiving payload data packet, respectively [14].

The final equation for energy consumptions of payload bit is given by

$\frac{(I_{Tx}+I_{Rx}).V}{}$ …..(3)

Where V, I_{Rx}, and I_{Tx} are the voltage provided, current received, and current transmitted respectively, for radio frequency CCs2420s Zigbee transmitter and receiver [14]. Here, Rb is a bits rates of ZigBee standards and $L_{payload}$ is the numbers of bits payload to be transmitted in single packets.

Also, the total consumption of the energy [15] for data packets transmission including message Frame Check Sequence (FCS) and Header (H) through the wireless link is given by

$\frac{(I_{Tx}+I_{Rx}).V}{}$ …..(4)

= …….(5)

Hence, the energy efficiency expression can be written in terms of reliability and energy throughput as:

$\eta = \frac{}{} (1 \quad PER) \quad \frac{}{} (1 \quad PER)$ ……(6)

where PER is the Packet Error Rate.

The parameters utilized in this expression are depending on CC2420 IEEE 802.15.4 Zigbee transceiver chip and Texas Instrument's MSP430 Microcontroller with 10 KB [14].

The parameters of network utilized in the proposed simulation are occupied from the typical values as stated in the Table (1) [14].

Table (1) Network parameter [14]

Parameter	Value
V(v)	3.6
(mA)	21
(mA)	23
b(K ps)	250
Overhead H+FCS(byte)	11
ACK(byte)	7

Energy Efficiency with error control

The energy efficiency of error control schemes should be considered because of the strict energy constraints of wireless sensor networks. Wireless sensor networks require simple and facile error control schemes because of the low complexity request of sensor nodes. Forward error correction (FEC) is the key error control strategies in wireless sensor networks [4,15,16].

Energy consumption of FEC (E_{FEC}) can be given as:

. ...(7)

Using convolution code as a forward error correction techniques, encoding energy (E) and decoding energy (E) are considered to be negligibly small [12,16]. The energy efficiency of the rate-1/2 convolutional code is given by

$$= \frac{}{(\quad ata)} (1 \qquad)$$ …….(8)

$$\frac{}{}$$ ….…(9)

Energy Efficiency in Virtual MIMO

Energy consumption of virtual MIMO can be given by:

$$N.(E_{Rx}) + N(E_{Tx2} + E_{Rx})$$ …...(10)

Where E_{Tx1}, E_{Tx2}, E_{Rx}, and N is the transmitter consumption of the energy from the source and relay node, the receiver energy consumption and number of relay node, respectively.

If we consider the energy transmission from the source node and relay nodes are the same, the consumption of the energy of virtual MIMO can be given by [17]:

$$= (N+1).(E_{Tx} + E_{Rx}) + N.(E_{Rx})$$ …...(11)

The efficiency of energy in the virtual MIMO is the ratio of energy consumption of payload data packet direct communication to the energy consumptions of data packet (V-MIMO) and thus can be given by:

$$\frac{}{} .(1 - PER_{VMIMO})$$ ….(12)

The energy efficiency, according to equation (11) will be represented by:

$$\frac{(I_{Tx}+I_{Rx}).}{((I \quad _{Rx})+N.(I \qquad)).L} .(1 \qquad)$$ ......(13)

Proposed Systems

In this section, three different systems are proposed as an attempt to enhance the connectivity performance between the two sensor nodes of WSN. The bit error rate (BER) performance of different three systems are presented. The throughput and energy efficiency evaluation of the three systems are then introduced. This has been achieved by using ZigBee transceiver protocol (at the physical layer) without and with convolutional code (CC), and with ((V-MIMO) and (CC)) together.

Fig. (3) show the flowchart of ZigBee transceiver direct transmission (DT) data from source (S) node to destination (D) node (System1).

The error control is very important in WSN to improved reliability and energy efficiency. By using convolutional coding the number of error bits is decreased and re-transmission packet might be avoided and so the energy consumption decreased. In this paper the considered coding rate is CR= (1/2) is more suitable from the other ratio, because the convolutional code with rate equal to (1/2) is more active to detect the error. The time slot to transmit one packet with CR=(1/2) is double. However, Fig. (4) is shown the flowchart of (DT) algorithm of ZigBee transceiver with convolutional coding (systems2).

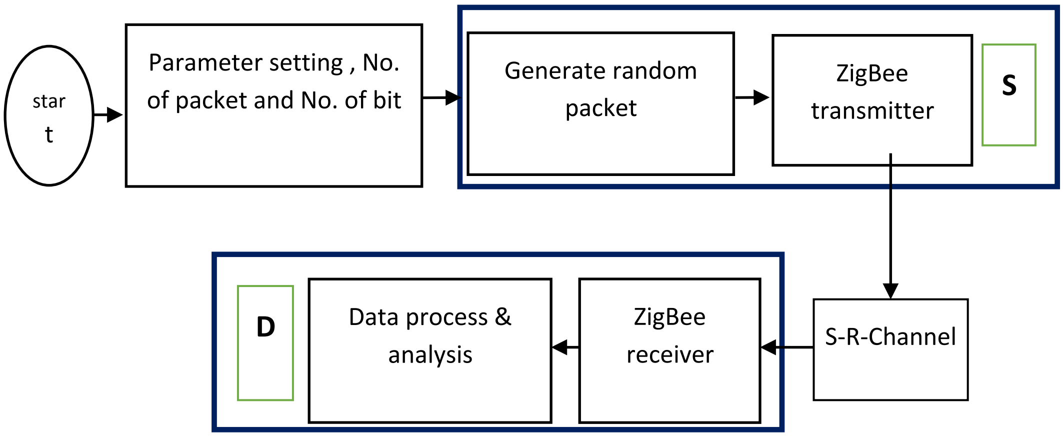

Figure (3) Flowchart of Zig Bee Transceive (System1)

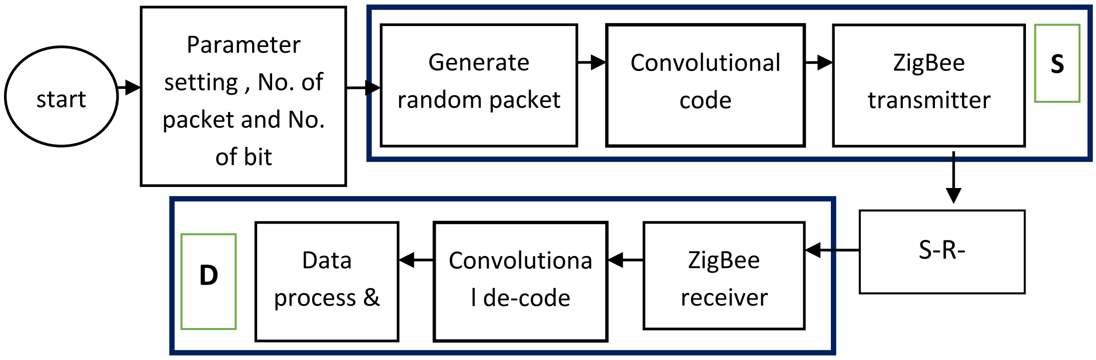

Figure (4) Flowchart of ZigBee Transceiver with (CC) (System2)

The V-MIMO in WSN needs a relay node between the transmitter and receiver node to improve reliability. Any node can receive data, decode and forward them to a destination node. This node is called a relay node. The cooperative transmission (CT) as a system model is shown in Fig. (5), it was assumed that, the number of nodes that can decode and forward data to the destination (D) node is one, and the links between (S) and (R) node and link between (R) and (D) node are better than the link between (S) and (R) node.

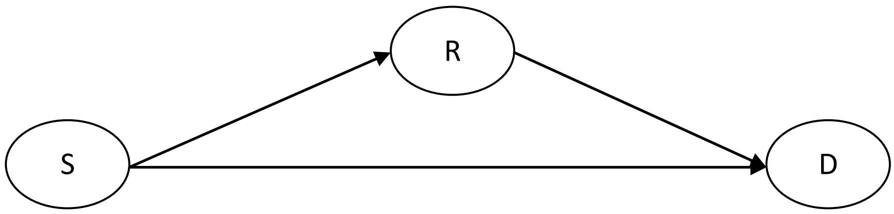

Figure (5) System Model

Fig. (6) show the flowchart of ZigBee transceiver with both (CC) and (V-MIMO) to transmit data from source (S) node to destination (D) node (System3).
System (3) has two Phase for transmission data from S to D. The first phase is to transmit data from S to (R and D). The second phase is to transmit data from R to D.

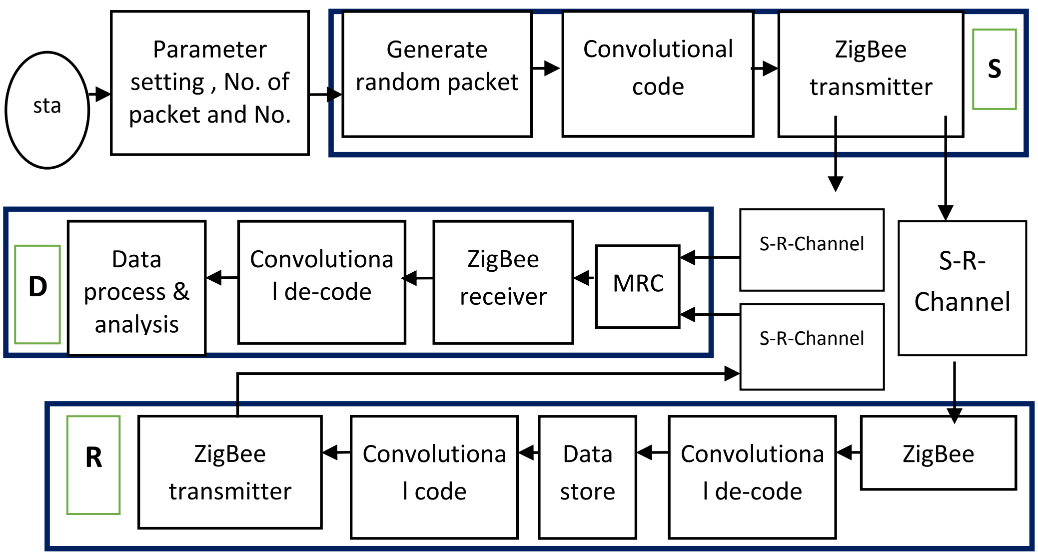

Figure (6) Flowchart of ZigBee Transceiver with both (CC) and (V-MIMO)

Result and Discussion

The simulations and Evaluation of wireless sensor network in MATLAB for the specified network parameters are performed and the performance of Proposed systems in terms of BER, throughput and Energy efficiency is studied as a function of the transmitted SNR.

Fig. (7) shows the BER performances of systems 1,2, and 3 over AWGN and Rayleigh channels. The results indicate that system 1 shows the worst performance compared with other systems. Systemn 2 gives an improvement in BER performance compared with system 1 because system 2 used convolutional coding technology and the worst BER performance compared with systems 3, and system 3 gives a good performance compared with other two systems because it used both (CC and V-MIMO) technology.

Fig. (8) and Fig. (9) shows the throughput and energy efficiency of systems 1,2, and 3, respectively, over AWGN and Rayleigh channels. The results indicate that system 3 achieves the best throughput and energy efficiency performance compared with the other two systems at lower SNR up to (-4 dB) in AWGN channel and at SNR up to (10 dB) in Rayleigh flat fading channel. System 2 achieves the best throughput and energy efficiency performance at medium SNR up to (0 dB) in AWGN channel and at SNR up to (20 dB) in Rayleigh flat fading channel, and system 1 achieves better throughput and energy efficiency at high SNR (from 1dB and more) in AWGN channel and at SNR (from 23 dB and more) in Rayleigh flat fading channel.

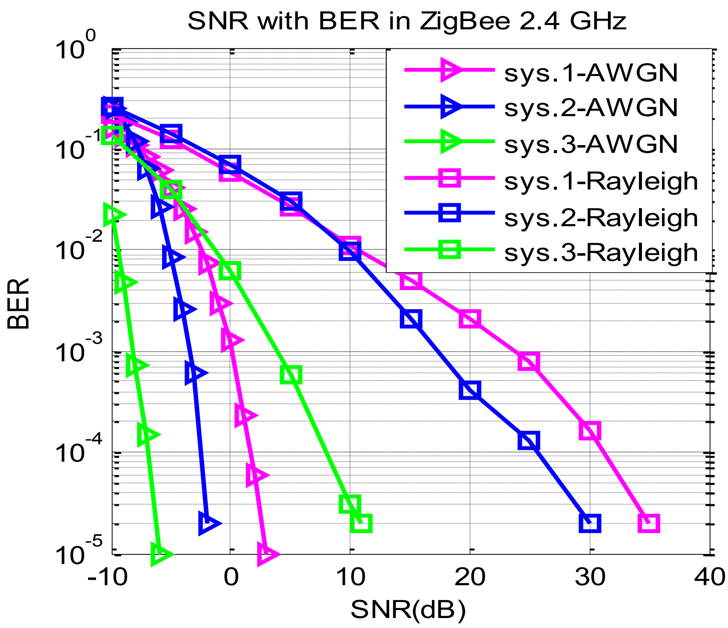

Figure (7) BER Performance of Different Systems

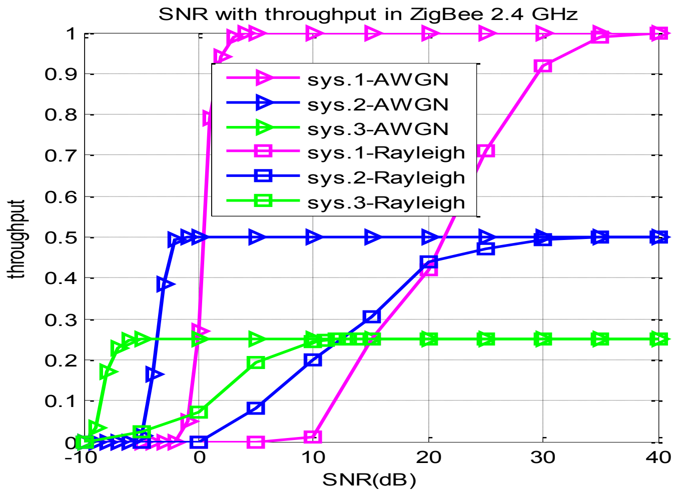

Figure (8) Throughput Performance of Different

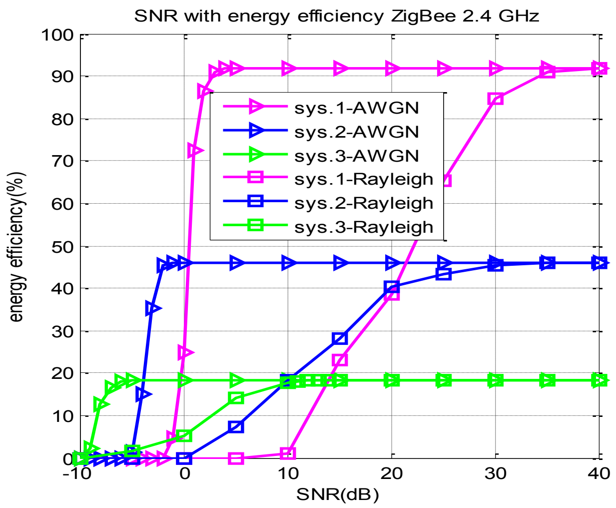

Figure (9) Energy Efficiency of Different Systems

CONCLUSION

Energy saving is a critical challenge in resource constrained WSNs. The use of some techniques such as (CC) and (V-MIMO), to improve the network performance (energy efficiency, BER, and throughput) of ZigBee compliant sensor network is proposed in this paper. These parameters are measured under various fading channel conditions such as AWGN and Rayleigh channel. Results of simulation (AWGN) channel, show that, system 3 (ZigBee transceiver with both ((CC) and (V-MIMO)) is a better system performance in energy efficiency, BER, and throughput in low quality of the channel (SNR up to -4dB). System 2 (ZigBee transceiver with (CC)) has a good system performance in energy efficiency in medium quality of the channel (SNR up to 0 dB). With the high quality of the channel (SNR from 1 dB and more), system 1 (ZigBee transceiver) has a good system throughput and energy efficiency performance compared with the other two systems. Results of simulation (Rayleigh) channel, show that, system 3 is a better system performance in energy efficiency, BER, and throughput in low quality of the channel (SNR up to 10 dB). System 2 (ZigBee transceiver with (CC)) has a good system performance in energy efficiency in medium quality of the channel (SNR up to 20 dB). With the high quality of the channel (SNR from 23 dB and more), system 1 (ZigBee transceiver) has a good system throughput and energy efficiency performance compared with the other two systems.

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