Enhancing the Image Transmission over Wireless Networks through a Novel Interleaver

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Abstract

With increasing the using of wireless technologies in essential fields such as the medical application, this paper proposes different scenarios for the transmission of images over wireless networks. The paper uses the IEEE ZigBee 802.15.4 for applying the proposed schemes. It is a Wireless Personal Area Network (WPAN). This paper presents a novel chaotic interleaving scheme against error bursts. Also, the paper studies the proposed interleaver with the convolutional code with different constraint lengths (K). A comparison study between the standard scheme and proposed schemes for image transmission over a correlated fading channel is presented. The simulation results show the superiority of the proposed chaotic interleaving scheme over the traditional schemes. Also, the chaotic interleaver packet-by-packet basis gives a high quality image with (K=3) and reduces the need for the complex encoder with K=7.

Keywords: Wireless networks, chaotic interleaving, medical applications

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1. Introduction

With the increase in utilization of wireless networks, there are two important factors that deserve consideration; power efficiency and throughput efficiency. Over the bad communications channel conditions, the different Forward Error Correction (FEC) schemes are used for enhance these factors [1]. This work focused on the most widely FEC technique is used in the wireless communications, it is the convolutional code. It can significantly improve the error performance of a communications system. The Viterbi algorithm is one of the most widely used decoding algorithms. It is optimal, but its complexity in both number of computations and memory requirement exponentially increases with the constraint length K of the code as discussed in section 3. So, practically, the constraint length K of the convolutional codes is limited with K<9. Hence, when codes with a longer constraint length are required in order to achieve a lower error probability, decoding algorithms whose complexity does not depend on become especially attractive [2][3].

In fact, the environment of mobile communication severs from the long burst error. These burst error in fast fading caused by multipath effect is the essential reason affecting the quality of mobile communication. The error control technique in mobile communication is not enough with existing the long burst error [4]. It is in need of effective error spreading tool for improving the error performance of the error correction techniques. The paper proposes a novel technique for achieve a lower error probability with lower K of the convolutional encoder. This technique depends on the data randomizing principle. It improves the error performance of the communications system more than the long K (i.e. K=7). There are many papers studied the interleaving technique effects on the convolutional codes. In [5], it studied the effects of interleaved convolutional code with code rate 1/2 and K=7 on the mobile image transmission. It studied the block interleaving technique with different degree on the transmitted image. The adaptive Viterbi (AV) decoding and interleaved convolutional code with its Viterbi algorithm are presented in [6] and [7] respectively. These papers present a modification in the Viterbi algorithm, where it has enough complexity. This paper presents flexible a novel chaotic interleaver for randomize the data; it improves the Viterbi decoding in case of the burst error.

In general, the interleaving technique, an efficient method for anti-fading, is raised to solve serious long-burst errors in some fading channels. Its principle depends on delivering the code sequences in interleaved form. So, long burst error can be separated into single random or short burst error as much as possible. This principle is employed for improve the capability of low K convolutional code. With the proposed technique the K=3 code performs better than K=7 code. The computer simulations are carried out with applying the proposed chaotic interleaver to the mobile communication channels using the widely used Jakes model. In this work, we studied the performance of the (2, 1, 7) convolutional codes with Viterbi decoding in image transmission system over the mobile channels compared it with the interleaved (2, 1, 3) convolutional codes using the traditional block interleaver and the proposed chaotic interleaver packet-by-packet basis. The experimental results of the computer simulations reveal that the proposed technique is efficient in image transmission over the mobile channels [8].

The paper is organized as follows. In section 2, ZigBee Review is introduced. In section 3, the proposed modifications are presented. In section 4, the simulation assumptions and the simulation results are presented. Finally, the conclusion is presented in section 5.

2. ZigBee Review

The short-range wireless networks such as Bluetooth and ZigBee are widely used in essential applications such as health care, medical applications, home automation, and environmental controls [9-10]. The ZigBee network is a Low-Rate WPAN (LR-WPAN) that is used for short-range, low power, and low-cost data communication. The structure of the ZigBee packet is shown in **Fig. 1**. The header contains three fields; a preamble of 32 bits for synchronization, a packet delimiter of 8 bits, and a physical header of 8 bits. The Physical Service Data Unit (PSDU) field contains a payload of 0 to 127 bytes length. The ZigBee network uses an error detection/retransmission technique. To ensure successful reception of data, an acknowledged frame delivery protocol is supported to increase transfer reliability [11].

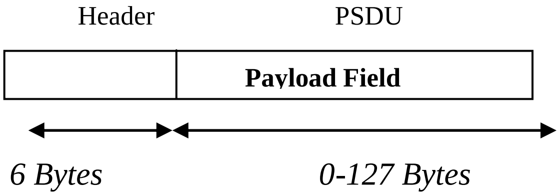


Fig. 1. ZigBee packet format.

Low power consumption in ZigBee networks can be achieved by allowing a device to sleep, which means waking into active mode for brief periods. Enabling such low duty cycle operation is at the heart of the ZigBee standard. ZigBee is built on top of the IEEE 802.15.4 standard. It offers the additional functionality to implement mesh networking rather than point-to-point networking found in most Bluetooth and Wi-Fi applications. The ZigBee specification document is short, allowing a small and simple stack, in contrast to the other wireless standards such as Bluetooth [12].

The IEEE 802.15.4 standard is intended to conform to established regulations in Europe, Japan, Canada, and the United States. It defines two physical (PHY) layers; the 2.4 GHz and 868/915 MHz band PHY layers. Although the PHY layer chosen depends on local regulations and user preference, only the higher data rate, worldwide, unlicensed 2.4 GHz Industrial, Scientific and Medical frequency band is considered. A total of 16 channels are available in the 2.4 GHz band, numbered from 11 to 26, each with a bandwidth of 2 MHz, and a channel separation of 5 MHz. The channel mapping frequencies are given in **Table 1**. LR-WPAN output powers are around 0 dBm. LR-WPAN typically operates within a 50-m range. The transmit scheme used is the Direct Sequence Spread Spectrum (DSSS) [13][14].

Table 1. IEEE 802.15.4 frequency bands and data rates

PHY (MHz)	Freq Band (MHz)	Mod.	Channels	Bit Rate (kbps)
868/915	868-868.6	BPSK	1	20
	902-928	BPSK	10	40
2450	2400-2483.5	O-QPSK	16	250

3. Proposed Modifications

The transmission of multimedia over unreliable data links has become a topic of paramount importance. This type of transmission must reconcile the high data rates involved in multimedia contents and the noisy nature of the channels, be it wireless or mobile. In this paper, there are different proposed scenarios to improve the transmission of images over the ZigBee network with different interleaving schemes. We study the feasibility of data interleaving prior to transmission over ZigBee networks. The paper presents a new chaotic interleaver and compares it to the traditional block and convolutional interleavers. The paper studies the effect of powerful error control scheme which is the convolutional codes on the image transmission with taking the mobility of the ZigBee device consideration. The convolutional codes is employed with different constrain lengths (K). It is known that the convolutional codes with longer K perform better than the other with shorter K. In fact, the computational complexity of the convolutional codes increases with the K increasing [15].

In a general convolutional code, the input information sequence contains $k \times L$ bits, where k is the number of parallel information bits at a time interval, and L is the number of time intervals. This results in $m+L$ stages in the Trellis diagram, m is the number of shift registers in the encoder and K=$m+1$. There are exactly $2^k \times L$ distinct paths in the trellis diagram. As a result, the ML sequence would have a computational complexity of O [$2^k \times L$]. The Viterbi Algorithm reduces it by performing the Maximum Likelihood (ML) search on a stage at a time in the Trellis diagram at each node. The number of nodes per stage in the trellis is 2^m . There for, the complexity of Viterbi calculations is O[(2^k)(2^m)($m+L$)] [16]. This significantly reduces the number of calculations is required to implement the ML decoding because the number of time intervals L is now a linear function not an exponent fraction in complexity [17]. With the increase in m and k the complexity increases exponentially. So, the paper tries to reduce the computational complexity through the proposed chaotic interleaver.
The computer simulation is based on binary non-recursive convolutional coding. The convolutional encoder uses a constituent encoder with K=3, 5, and 7, code rate 1/2 and generator polynomials, G= (5 7), (23 35), and (133,171) octal, respectively [18]. Also, the paper uses the proposed techniques for improve the capabilities of the encoder with short K by the traditional interleaving and the proposed interleaving techniques. It will be observed the proposed chaotic interleaver performs better than the traditional interleavers and it has security capabilities [18].

3.1 Block Interleaver Scheme

The block interleaving can be used for image transmission with the ZigBee network. After converting the image into a binary sequence, this sequence is rearranged into a matrix in a row-by-row manner, and then read from the matrix in a column-by-column manner. Now take a look at how the block interleaving mechanism can correct error bursts. Assume an error burst affecting four consecutive bits (1-D error burst) as shown in **Fig. 2 (b)** with shades. After de-interleaving as shown in **Fig. 2 (c)**, the error burst is effectively spread among four different rows, resulting in a small effect for the 1-D error burst. With a single-error correction capability, it is obvious that no decoding error will result from the presence of such 1-D error burst. This simple example demonstrates the effectiveness of the block interleaving mechanism in combating 1-D error bursts. Let us examine the performance of the block interleaving mechanism, when a 2-D (2 × 2) error burst occurs, as shown in **Fig. 2 (b)** with shades [19]. **Fig. 2 (c)** indicates that this 2 × 2 error burst has not been spread, effectively, so that there are adjacent bits in error in the first and second rows. As a result, this error burst can not be corrected using a single-error correction mechanism. That is, the block interleaving mechanism can not combat the 2 × 2 error bursts [20].

b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
b_9	b_{10}	b_{11}	b_{12}	b_{13}	b_{14}	b_{15}	b_{16}
b_{17}	b_{18}	b_{19}	b_{20}	b_{21}	b_{22}	b_{23}	b_{24}
b_{25}	b_{26}	b_{27}	b_{28}	b_{29}	b_{30}	b_{31}	b_{32}
b_{33}	b_{34}	b_{35}	b_{36}	b_{37}	b_{38}	b_{39}	b_{40}
b_{41}	b_{42}	b_{43}	b_{44}	b_{45}	b_{46}	b_{47}	b_{48}
b_{49}	b_{50}	b_{51}	b_{52}	b_{53}	b_{54}	b_{55}	b_{56}
b_{57}	b_{58}	b_{59}	b_{60}	b_{61}	b_{62}	b_{63}	b_{64}

b_1	b_9	b_{17}	b_{25}	b_{33}	b_{41}	b_{49}	b_{57}
b_2	b_{10}	b_{18}	b_{26}	b_{34}	b_{42}	b_{50}	b_{58}
b_3	b_{11}	b_{19}	b_{27}	b_{35}	b_{43}	b_{51}	b_{59}
b_4	b_{12}	b_{20}	b_{28}	b_{36}	b_{44}	b_{52}	b_{60}
b_5	b_{13}	b_{21}	b_{29}	b_{37}	b_{45}	b_{53}	b_{61}
b_6	b_{14}	b_{22}	b_{30}	b_{38}	b_{46}	b_{54}	b_{62}
b_7	b_{15}	b_{23}	b_{31}	b_{39}	b_{47}	b_{55}	b_{63}
b_8	b_{16}	b_{24}	b_{32}	b_{40}	b_{48}	b_{56}	b_{64}

b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
b_9	b_{10}	b_{11}	b_{12}	b_{13}	b_{14}	b_{15}	b_{16}
b_{17}	b_{18}	b_{19}	b_{20}	b_{21}	b_{22}	b_{23}	b_{24}
b_{25}	b_{26}	b_{27}	b_{28}	b_{29}	b_{30}	b_{31}	b_{32}
b_{33}	b_{34}	b_{35}	b_{36}	b_{37}	b_{38}	b_{39}	b_{40}
b_{41}	b_{42}	b_{43}	b_{44}	b_{45}	b_{46}	b_{47}	b_{48}
b_{49}	b_{50}	b_{51}	b_{52}	b_{53}	b_{54}	b_{55}	b_{56}
b_{57}	b_{58}	b_{59}	b_{60}	b_{61}	b_{62}	b_{63}	b_{64}

(a) **(b)** **(c)**

Fig. 2. Block interleaving of an 8 × 8 matrix.
(a) The 8 × 8 matrix. **(b)** Block interleaving of the matrix. **(c)** Effect of error bursts after de-interleaving.

3.2 Convolutional Interleaver Scheme

The convolutional interleaver is constructed by T parallel branches. Each line contains a shift register with a predefined length [21]. The input data is fed into the branches of the interleaver and the output data is taken from the outputs of these branches. In the computer simulations, the length of the interleaver input is 1024 bits, which is the length of the whole payload in ZigBee packets [22].

3.3 Chaotic Interleaver Scheme

The chaotic interleaver idea is presented based on the Logistic map in [23][24]. The Logistic map is defined as a typical example of a one- dimensional chaotic map. In [23], it is applied on the turbo code. In [24] the chaotic interleaver based on the logistic map is employed in the Bit-Interleaved Coded Modulation (BICM) technique. In this work, the proposed chaotic interleaver is presented based on a two-dimensional Baker map which is the powerful data randomizing tool. There are many researcher studied the chaotic Baker map as an encryption technique [25][26].

As cleared in the previous section, the block interleaver is not efficient with 2-D error bursts. As a result, there is a need for an advanced interleaver for this task. The 2-D chaotic Baker map in its discretized version is a good candidate for this purpose. After rearrangement of bits into a 2-D format, the chaotic Baker map is used to randomize the bits. The discretized Baker map is an efficient tool to randomize the items in a square matrix. Let B(n1,……..,nk), denote the discretized map, where the vector, [n1, ……. ,nk], represents the secret key, Skey. Defining N as the number of data items in one row, the secret key is chosen such that each integer ni divides N, and n1 + …….. + nk = N.

Let $N_i = n_1 + \ldots + n_{i-1}$. The data item at the indices (r, s), is moved to the indices [27][28][29][30]:

$$B(r,s)=\left[\frac{N}{n_i}(r-N_i)+s \bmod \left(\frac{N}{n_i}\right), \frac{n_i}{N}\left(s-s \bmod \left(\frac{N}{n_i}\right)\right)+N_i\right] \quad (1)$$

where $N_i \le r < N_i + n_i$, $0 \le s < N$, and $N_1=0$.

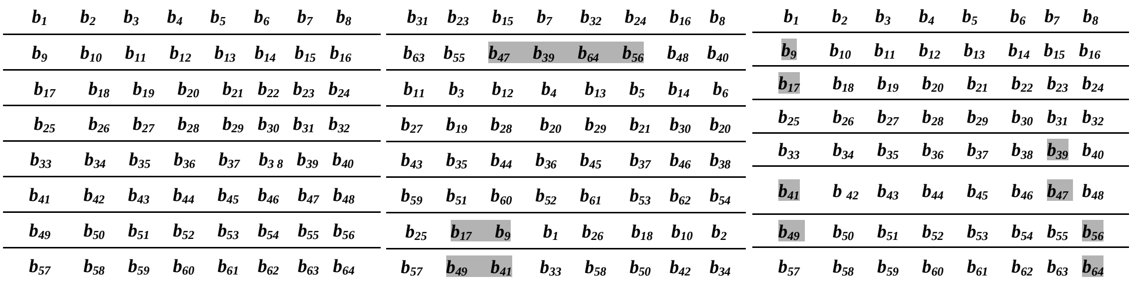
In steps, the chaotic permutation is performed as follows:

1- An N × N square matrix is divided into N rectangles of width n_i and number of elements N.

2- The elements in each rectangle are rearranged to a row in the permuted rectangle. Rectangles are taken from right to left beginning with upper rectangles then lower ones.

3- Inside each rectangle, the scan begins from the bottom left corner towards upper elements.

Fig. 3 shows an example for chaotic interleaving of an 8 × 8 square matrix (i.e. N = 8). The secret key, $S_{key} = [n_1, n_2, n_3] = [2, 4, 2]$. Note that, the chaotic interleaving mechanism has a better treatment to both 1-D and 2-D error bursts than the block interleaving mechanism. Errors are better distributed to bits after de-interleaving in the proposed chaotic interleaving scheme. As a result, a better Peak Signal to Noise Ratio (PSNR) of received images can be achieved with this proposed mechanism. Moreover, it adds a degree of security to the communication system. At the receiver of the ZigBee system, a chaotic de-interleaving step is performed.



b_{1}	b_{2}	b_{3}	b_{4}	b_{5}	b_{6}	b_{7}	b_{8}
b_{9}	b_{10}	b_{11}	b_{12}	b_{13}	b_{14}	b_{15}	b_{16}
b_{17}	b_{18}	b_{19}	b_{20}	b_{21}	b_{22}	b_{23}	b_{24}
b_{25}	b_{26}	b_{27}	b_{28}	b_{29}	b_{30}	b_{31}	b_{32}
b_{33}	b_{34}	b_{35}	b_{36}	b_{37}	b_{38}	b_{39}	b_{40}
b_{41}	b_{42}	b_{43}	b_{44}	b_{45}	b_{46}	b_{47}	b_{48}
b_{49}	b_{50}	b_{51}	b_{52}	b_{53}	b_{54}	b_{55}	b_{56}
b_{57}	b_{58}	b_{59}	b_{60}	b_{61}	b_{62}	b_{63}	b_{64}

b_{31}	b_{23}	b_{15}	b_{7}	b_{32}	b_{24}	b_{16}	b_{8}
b_{63}	b_{55}	b_{47}	b_{39}	b_{64}	b_{56}	b_{48}	b_{40}
b_{11}	b_{3}	b_{12}	b_{4}	b_{13}	b_{5}	b_{14}	b_{6}
b_{27}	b_{19}	b_{28}	b_{20}	b_{29}	b_{21}	b_{30}	b_{20}
b_{43}	b_{35}	b_{44}	b_{36}	b_{45}	b_{37}	b_{46}	b_{38}
b_{59}	b_{51}	b_{60}	b_{52}	b_{61}	b_{53}	b_{62}	b_{54}
b_{25}	b_{17}	b_{9}	b_{1}	b_{26}	b_{18}	b_{10}	b_{2}
b_{57}	b_{49}	b_{41}	b_{33}	b_{58}	b_{50}	b_{42}	b_{34}

b_{1}	b_{2}	b_{3}	b_{4}	b_{5}	b_{6}	b_{7}	b_{8}
b_{9}	b_{10}	b_{11}	b_{12}	b_{13}	b_{14}	b_{15}	b_{16}
b_{17}	b_{18}	b_{19}	b_{20}	b_{21}	b_{22}	b_{23}	b_{24}
b_{25}	b_{26}	b_{27}	b_{28}	b_{29}	b_{30}	b_{31}	b_{32}
b_{33}	b_{34}	b_{35}	b_{36}	b_{37}	b_{38}	b_{39}	b_{40}
b_{41}	b_{42}	b_{43}	b_{44}	b_{45}	b_{46}	b_{47}	b_{48}
b_{49}	b_{50}	b_{51}	b_{52}	b_{53}	b_{54}	b_{55}	b_{56}
b_{57}	b_{58}	b_{59}	b_{60}	b_{61}	b_{62}	b_{63}	b_{64}

(a) **(b)** **(c)**

Fig. 3. Chaotic interleaving of an 8 × 8 matrix.

(a) The 8 × 8 matrix divided into rectangles (Shaded bits are bits affected by error bursts). **(b)** Chaotic interleaving of the matrix. **(c)** Effect of error bursts after de-interleaving.

4. Simulation Results

In this section, the computer simulation results are presented. An important assumption used in the simulation is that a packet is discarded if there is an error in either the header or the payload field [31]. This is a realistic assumption to simulate the real ZigBee system operation. A correlated Rayleigh fading channel is used. The channel model utilized is the Jake's model [32]. The assumed mobile ZigBee device velocity is 10 miles/hour, and the carrier frequency is 2.46 GHz. The Doppler spread is 36.6 Hz. **Fig. 4** gives the original Cameraman image used in the experiments. The computer simulation section contains three groups of the experimental simulations.

4.1 The interleaving Techniques over a Correlated Fading Channel

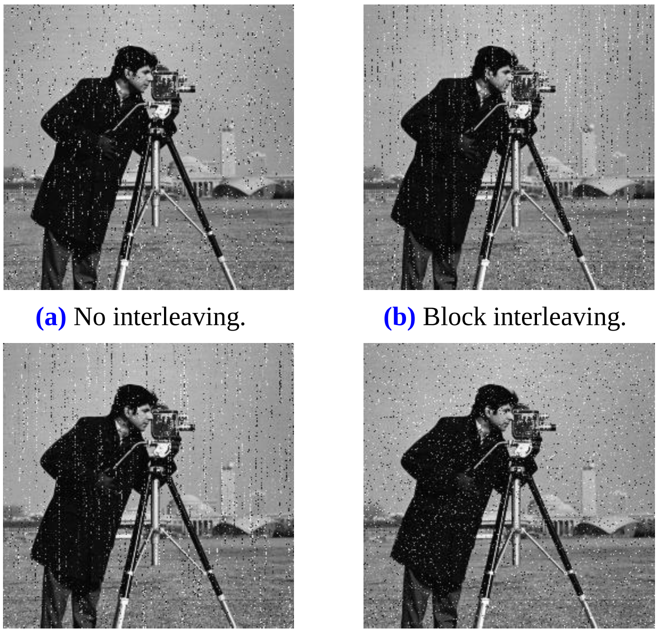
In this section, different scenarios are employed for the image transmission over the ZigBee network. The image binary sequence to be transmitted is fragmented into packets. The PSNR of the received images is used as an evaluation metric in this paper.

In the first computer simulation, the Cameraman image is transmitted over a correlated fading channel with Signal to Noise Ratio (SNR) = 10 dB. Three scenarios of no interleaving, block interleaving, convolutional interleaving and chaotic interleaving are considered for comparison. The results of this experiment are shown in **Fig. 5**. From these results, it is clear that the effect of all interleaving schemes is approximately equal at low SNR values.

Another experiment is repeated with SNR = 30 dB and the results are shown in **Fig. 6**. From these results, we notice that the chaotic interleaver outperforms the other interleavers at moderate to high SNRs.

For the comparison purpose, the variation of the PSNR of the received image, the number of lost frames and the Bit Error Rate (BER) with the channel SNR are studied and the results are shown in **Figs. 7** and **8**. From these results, it is clear the chaotic interleaver enhancement begins at medium SNR values.

Fig. 4. Original Camerman image.



(a) No interleaving. **(b)** Block interleaving.

(c) Convolutional interleaving. **(d)** Chaotic Interleaving.

Fig. 5. Received Cameraman image over a correlated fading channel at SNR =10 dB with (a) PSNR=21.3 dB, (b) PSNR=21.4 dB, (c) PSNR=21.1 dB, and (d) PSNR=21.5 dB.

(a) No interleaving. **(b)** Block interleaving.

(c) Convolutional interleaving. **(d)** Chaotic interleaving.

Fig. 6. Received Cameraman image over a correlated fading channel at SNR=30 dB with **(a)** PSNR=39.1 dB, **(b)** PSNR=41 dB, **(c)** PSNR=41.1 dB, and **(d)** PSNR=43.1 dB.

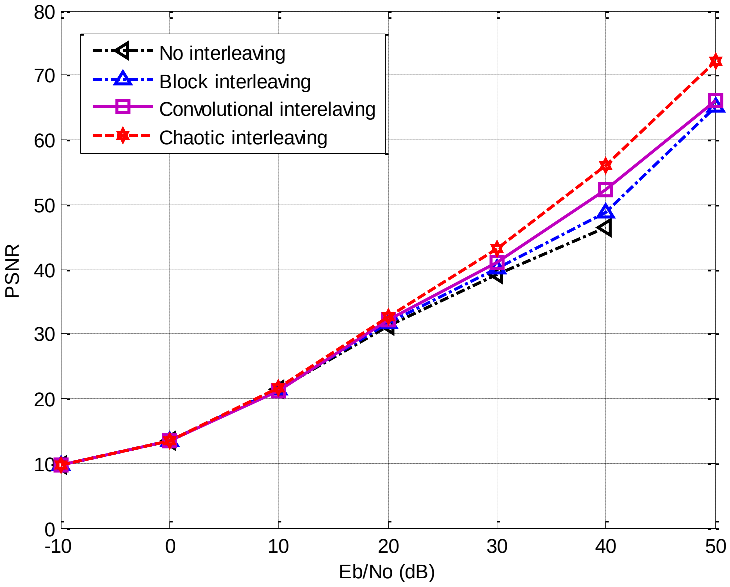


Fig. 7. PSNR vs. SNR for the received Camerman image over a correlated fading channel.

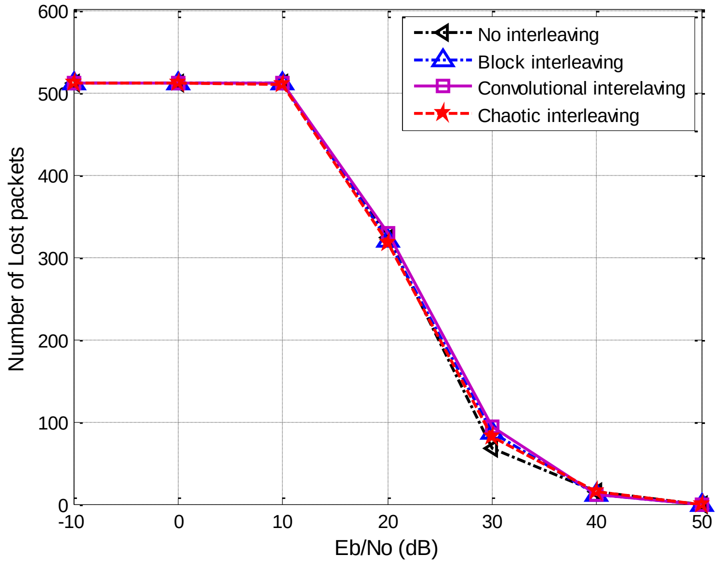


Fig. 8. Number of lost frames vs. SNR for the received Camerman image over a correlated fading channel.

As shown in these figures, the proposed chaotic interleaver does not decrease the number of lost frames, but it enhances the PSNR of the received images at medium to high SNR values. The proposed technique is a powerful randomize the adjacent error technique. So, it can be a tool for enhance the received images over the mobile network in the critical application cases such as hospital environment.

4.2 The Constraint Lengths Effects over a Correlated Fading Channel

This section is devoted for evaluate the different K of the convolutional encoder effects on the image transmission. As mentioned in section 3, there are three convolutional encoder with the different memory lengths (m=2, 4, and 6) with code rate 1/2 are considered in this section. In this computer simulation, the Cameraman image is transmitted over a correlated fading channel with SNR = 10 dB. Three scenarios of no interleaving, code rate 1/2 with K=3, code rate 1/2 with K=5 and code rate 1/2 with K=7 are considered for comparison. The results of this experiment are shown in **Fig. 9**. From these results, it is clear that the effect of the K length on the received image. The PSNR of the received image variation with the channel SNR is given in **Fig. 10**. This figure indicates the variation of the PSNR values with the different K of the convolutional encoder. With taking the computational complexity in the consideration, the PSNR improving with longer K can be inefficient. As shown in section 3, the complexity increases exponentially with K, that means the complexity of K=7 equals 16 times of K=3.

From these results, it is clear that the effect of the different K of the convolutional encoders is approximately equal at low SNR values. As shown in **Fig. 10**, with increasing the SNR values the convolutional code with the longer K performs better than others. So, it is can be say at moderate and high SNR the K=7 gives higher values of the received images PSNR with neglecting the complexity increasing. The paper improves the shorter K convolutional codes which have lower complexity through the interleaving techniques. The proposed chaotic interleaving technique is applied packet-by-packet basis.

(a) Code rate 1/2, K=3. **(b)** Code rate 1/2, K=5.

(c) Code rate 1/2, K=7.

Fig. 9. Received Cameraman image over a correlated fading channel at SNR=10 dB using the convolutional code rate 1/2 with different K, **(a)** PSNR=23.12 dB, **(b)** PSNR=23.35 dB, and **(c)** PSNR=23.73 dB.

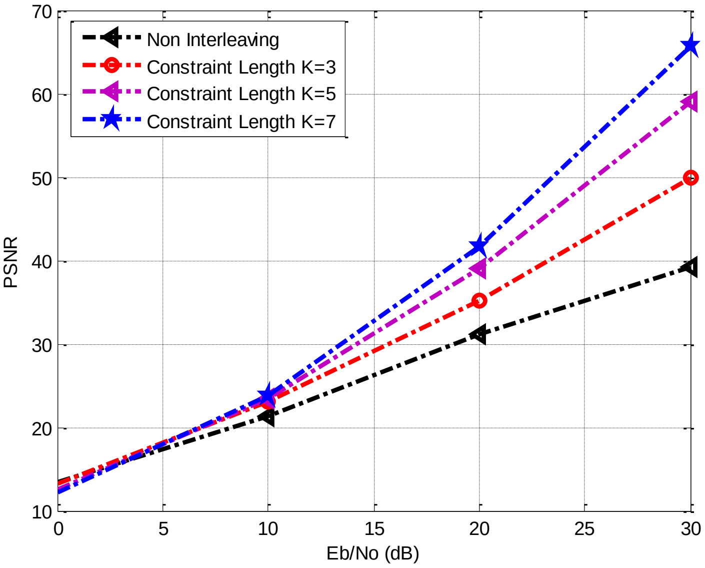


Fig. 10. PSNR vs. SNR for the received Camerman image over a correlated fading channel with different constraint length K.

4.3 The Complexity Reduction with the Proposed Chaotic Interleaver

This section studies the transmitted image through applying the proposed chaotic interleaver packet-by-packet basis. The computer simulations are carried out using different three scenarios. These scenarios of no interleaving, code rate 1/2 with K=3, block interleaving, and chaotic interleaving packet-by-packet basis are considered for comparison. The results of this experiment are shown in **Fig. 11**.

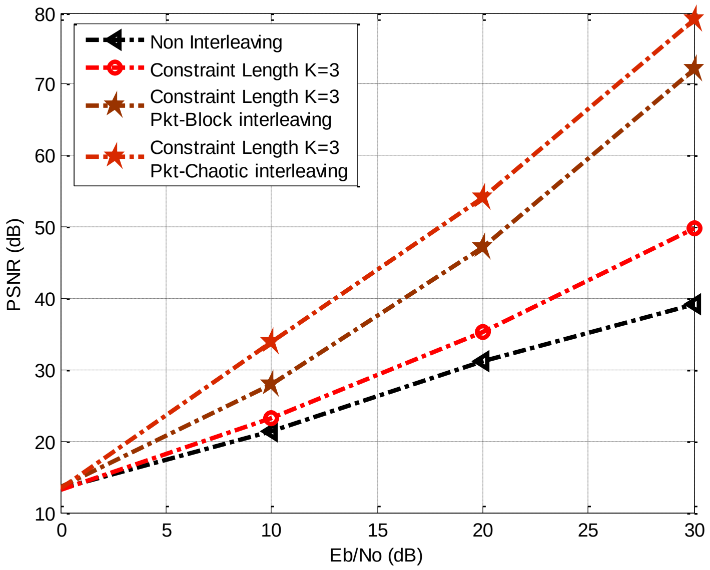


Fig. 11. PSNR vs. SNR for the received Camerman image over a correlated fading channel with different scenarios for the image transmission.

(a) No interleaving. **(b)** Block interleaving.

(c) Chaotic interleaving.

Fig. 12. Received Cameraman image over a correlated fading channel at SNR=10 dB using the convolutional code rate 1/2 and K=3 with the proposed techniques, **(a)** PSNR=23.12 dB, **(b)** PSNR=27.8dB, and **(c)** PSNR=33.85dB.

Fig. 11 shows the PSNR variation of the received image with the channel SNR. The received images are shown in **Fig. 12**, this figure reveals that the proposed chaotic interleaver packet-by-packet basis improves the error control code performance, where the convolutional code with code rate and K=3 gives performs better than the block interleaving.

With widely utilization of the ZigBee technology in sensitive fields such as a patient's service and monitoring the transmitted data and image must be in high quality and high secured. The proposed chaotic interleaver packet by packet basis randomizes the encoded packet by S_{key} as shown in section 3; the process of randomization reduces the happening of the burst errors in the received packet.

4.4 General Comparison

This section gives a comparison between the different Scenarios for image transmission over the ZigBee network based on the Number of Lost Packet percentage (NLP %) and the PSNR. **Fig. 13** shows the variation of the NFL% with the channel SNR for the Cameraman image transmission over a correlated fading channel for the different scenarios. This figure indicates the efficiency of the proposed chaotic interleaver. As shown in this figure, the chaotic interleaver on a packet-by-packet basis is effective at low SNR values for short constraint length convolutional encoders. Its performance is improved for reduce the NLP percentage.

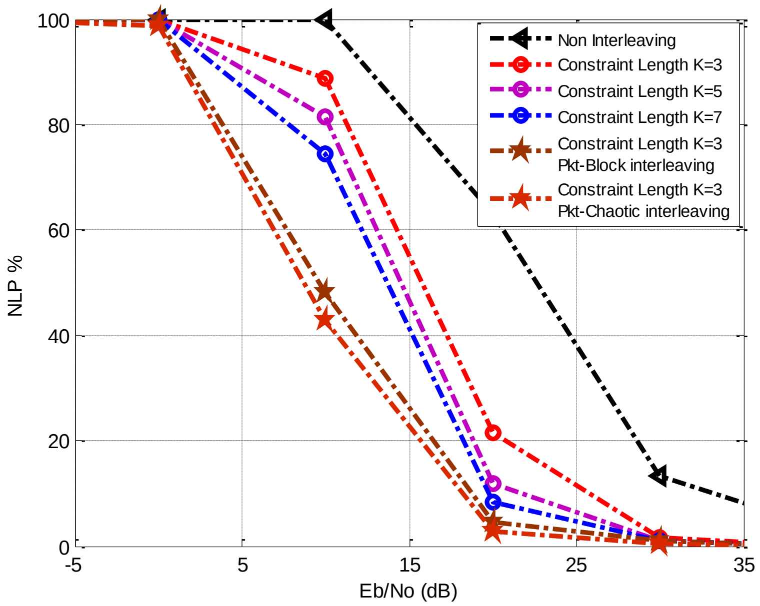


Fig. 13. NFL % vs. SNR for the received Camerman image over a correlated fading channel with different scenarios for the image transmission over the ZigBee network.

Fig. 14 shows the variation of the PSNR with the channel SNR for the Cameraman image transmission over a correlated fading channel for the different scenarios. It is clear that the received images with using the chaotic interleaver packet-by-packet basis have a higher the PSNR. The proposed technique with K=3 performs better that the long K encoder and increases the quality of the received images. The chaotic interleaver on a packet-by-packet basis is effective at low SNR values for short constraint length convolutional encoders. It performs better that the K=7 encoder at low SNR. In fact, the complexity increases exponentially with K, that means the complexity of K=7 equals 16 times of K=3. So, with the proposed technique, the performance is improved with the complexity is reduced. The chaotic interleaving is applied to the ZigBee packets, which is short packet (127 byes).

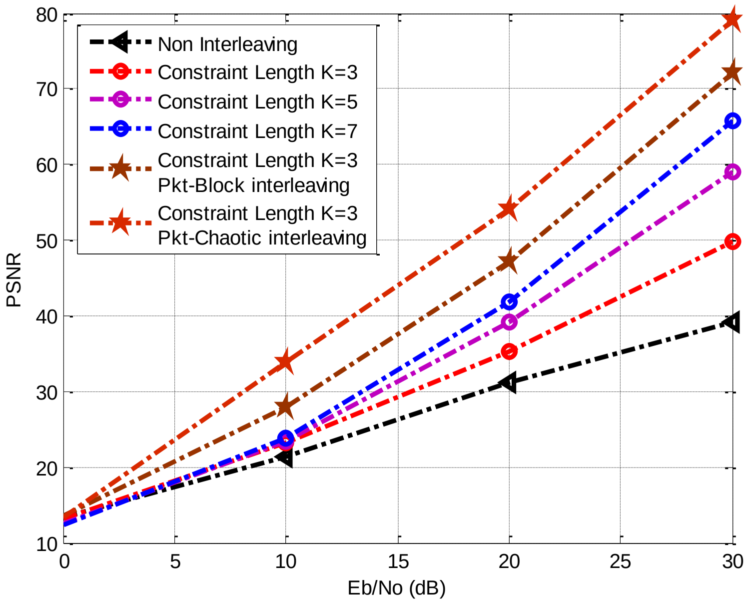


Fig. 14. PSNR vs. SNR for the received Camerman image over a correlated fading channel with different scenarios for the image transmission over the ZigBee network.

5. Conclusion

The paper presented a simple and efficient novel chaotic interleaver for the transmission of images over the ZigBee network. Also, it studied the proposed interleaver with the convolutional code as a proposed error control code for special applications of the ZigBee network using different constraint lengths. A comparison study between the proposed interleaver and the conventional interleavers has been presented. The computer simulation results have revealed the effectiveness of the proposed interleaver at medium and high SNR values. Also, the chaotic interleaver improves the performance of the convolutional code with short constraint length. It means the encoder with K=3 with the chaotic interleaver performs better than the encoder with K=7. In addition, the proposed scheme has the ability to enhance the security of the ZigBee network, because it permits the change of Skey from packet to packet. So, we can conclude that the chaotic interleaving scheme is suitable for ZigBee communication, especially, for the essential fields such as patients monitoring in the mobile case.

References

[1] V. Bhargava, D. Haccoun, R. Matyas, P. Nuspl, “Digital Communications by Satellite,” Wiley, 1981.

[2] Emad N. Farag, Mohamed I. Elmasry, “Mixed Signal VLSI Wireless Design Circuits and System, “1st Edition, Kluwer Academic Publishers, 1999.

[3] S. Lin, D.J. Costello, “Error Control Coding: Fundamentals and Applications,” Prentice-Hall, 1983.

[4] D.F. Yuan, Z.W. Li, A. Sui, J. Luo, “Performance of interleaved (2,1,7) Convolutional Codes in Mobile Image Communication System,” in *Proc. IEEE Wireless Communications and Networking Conference* (*WCNC ’00*), vol. 2, pp. 634-637, Sep. 2000.

[5] F. Chan, D. Haccoun, “Adaptive Viterbi Decoding of Convolutional Codes over Memoryless Channels,” *IEEE Transactions on Communications*, vol. 45, no. 11, Nov. 1997. Article (CrossRef Link)

[6] N. Benvenuto, L. Bettella, R. Marchesani, “Performance of the Viterbi Algorithm for Interleaved Convolutional Codes,” *IEEE Transactions on Vehicular Technology*, vol. 47, no. 3, Aug. 1998. Article (CrossRef Link)

[7] J.J. Kong, K.K. Parhi, “Interleaved Convolutional Code and Its Viterbi Decoder Architecture,” *EURASIP Journal on Applied Signal Processing*, vol. 2003, no. 13, pp. 1328-1334, 2003.

[8] A. Elkhazin, K. Plataniotis, S. Pasupathy, “Irregular Convolutional Codes in Multiantenna Bit-Interleaved Coded Modulation Under Iterative Detection and Decoding,” *IEEE Transactions on Vehicular Technology*, vol. 59, no. 7, Sep. 2010.

[9] ZigBee Alliance, http://www.zigbee.org/.

[10] B. Kai, P. Yong, “Performance Study on ZigBee-Based Wireless Personal Area Networks for Real-Time Health monitoring,” *ETRI Journal*, vol. 28, no. 4, Aug. 2006.

[11] J.-S. Lee, Y.-W. Su, C.-C. Shen, “A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi,” in *Proc. of the 33rd Annual Conference of the IEEE Industrial Electronics Society* (*IECON*), Nov. 2007.

[12] W. Guo, M. Zhou, “An Emerging Technology for Improved Building Automation Control,” in *Proc. of IEEE International Conference on Systems, man and Cybernetics*, pp. 337-342, Oct. 2009.

[13] The Wi-Fi Alliance, http://www.wi-fi.org/.

[14] B. Sidhu, H. Singh, A. Chhabra, “Emerging Wireless Standards - WiFi, ZigBeeand WiMAXs,” *World Academy of Science, Engineering and Technology*, vol. 25 2007.

[15] C. Xu, “Soft decoding algorithm for RS-CC concatenated codes in WIMAX system,” in *Proc. of Vehicular Technology Conference*, 2007.

[16] O. Gazi, A. Yılmaz, “Turbo Product Codes based on Convolutional Codes,” *ETRI Journal*, vol. 28, no. 4, Aug. 2006.

[17] M. Kaiser, W. Fong, M. Sikora, “A Comparison of Decoding Latency for Block and Convolutional Codes,” in *Proc. of ISCTA'09*, 2009.

[18] J. Hagenauer, L. Papke, “ Iterative Decoding of Binary Block and Convolutional Codes,” *IEEE Transactions on Information Theory*, vol. 42, no. 2, Mar. 1996. Article (CrossRef Link)

[19] S. H. Lee, E.K. Joo, “The Effect of Block Interleaving in an LDPC-Turbo Concatenated Code,” *ETRI Journal*, vol. 28, no. 5, Oct. 2006.

[20] G. Pekhteryev, Z. Sahinoglu, P. Orlik, G. Bhatti, “Error Protection for Progressive Image Transmission Over Memoryless and Fading Channels,” *IEEE Transactions on Communications*, vol. 46, no. 12, Dec. 1998.

[21] S. Vafi, T.A. Wysocki, “Application of Convolutional Interleavers in Turbo Codes with Unequal Error Protection”, *Journal of Telecommunication and Information technology*, Jan. 2006.

[22] S. Shiyamala, V. Rajamani, “A Novel Area Efficient Folded Modified Convolutional Interleaving Architecture for MAP Decoder,” *International Journal of Computer Applications*, vol. 9, no. 9, pp. 0975-8887, Nov. 2010.

[23] H. Zhang, L. Wang, Q. Yuan, H. Wang, L. Yu, “A Chaotic Interleaver Used in Turbo Codes,” in *Proc. of Int. Conference of Communications, Circuits, and Systems*, 2004.

[24] Z. Xuelan, L. Weiyan, F. Guangzeng, “Applying Chaotic Maps to Interleaving Scheme Design in BICM-ID,” *Chinese Journal of Electronics*, vol.19, no.3, July 2010.

[25] Y. Dong, L. Liu, C. Zhu, Y. Wang, “Image Encryption Algorithm Based on Chaotic Mapping,” in *Proc. of 3rd IEEE International Conference on Computer Science and Information Technology*, 2010.

[26] M. Salleh, S. Ibrahim, I.F. Isnin, “Enhanced Chaotic Image Encryption Algorithm based on

Baker's Map," in *Proc. of IEEE Conference on Circuits and Systems*, vol.2, pp.508-511, 2003.

[27] A.N. Lemma, J. Aprea, W. Oomen, L.V. de Kerkhof, "A Temporal Domain Audio Watermarking Technique," *IEEE Transactions on Signal Processing*, vol. 51, no. 4, pp. 1088-1097, 2003. Article (CrossRef Link)

[28] W. Li, X. Xue, P. Lu, "Localized Audio Watermarking Technique Robust Against Time-Scale Modification," *IEEE Transactions on Multimedia*, vol. 8, no. 1, pp. 60-69, 2006. Article (CrossRef Link)

[29] G. Voyatzis, I. Pitas, "Chaotic Watermarks for Embedding in the Spatial Digital Image Domain," in *Proc. of IEEE Int. Conference Image Processing*, vol. 2, pp. 432-436, Oct. 1998.

[30] R. Liu, T. Tan, "An SVD-Based Watermarking Scheme for Protecting Rightful Ownership," *IEEE Transactions On Multimedia*, vol. 4, no. 1, pp. 121-128, Mar. 2002.

[31] G. Pekhteryev, Z. Sahinoglu, P. Orlik, G. Bhatti, "Image Transmission over IEEE 802.15.4 and ZigBee Networks," in *Proc. of IEEE ISCAS'05*, May 2005.

[32] W.C. Jakes, "Microwave Mobile Communications," John Wiley & Sons Inc. Feb. 1975.

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