Reduction of Burst Errors Effects on the Image Transmission over IEEE 802.15.4 with Fragmentation Consideration

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Abstract—**In this paper, we study reducing effects of burst error and improving of image transmission over Zigbee systems. We try to improve the image transmission over mobile Wireless Personal Area Network (WPAN) using different interleaving techniques. This paper presents a proposed chaotic interleaving technique to improve a transmission of images over ZigBee (IEEE 802.15.4) wireless systems. Also, it proposes different interleaving technique for this purpose. The packet size of these WPAN is very small compared with the size of any image. That is leads to the needs of fragment of the image to small segments. Each on of these segments is carried over one packet. Also, the paper studies the effect of proposed chaotic interleaver on the transmission of image over ZigBee. The simulation experiments are carried over correlated and uncorrelated fading channels. The effect of interference is ignored in our simulations.**

Keywords-ZigBee Technology, Medical Application, Fading channel, Jackes model, and interleaving technique.

I. INTRODUCTION

With increasing utilization of wireless devices, especially Bluetooth and Zigbee devices, there are two important factors for all wireless systems power efficiency and efficient throughput. The most of the modern medical devices offer a kind of electronic data exchange interface. The wireless communications are available for medical services and health care equipments. The most common wireless technologies are very suitable for this purpose is Zigbee (802.15.4) and Bluetooth (802.15.1) [1].

IEEE 802.15.4 is a Low-Rate Wireless Personal Area Network (LR-WPAN) standard [1] aimed at providing simple, low-cost communication networks. LR-WPANs are intended for short-range operation and involve little or no infrastructure. The standard focuses on applications with limited power and relaxed throughput requirements, with the main objectives being ease of installation, reliable data transfer, low-cost and low-power. This allows small, power-efficient, inexpensive solutions to be implemented for a wide range of devices. Low power consumption can be achieved by allowing a device to sleep, only waking into active mode for brief periods. Enabling such low duty cycle operation is at the heart of the IEEE 802.15.4 standard.

Wireless networks can be developed based on the IEEE 802.15.4 or ZigBee protocol standard. ZigBee is built on top of the IEEE 802.15.4 standard and offers the additional functionality to implement mesh networking (rather than point-to-point networks found in most Bluetooth and Wi-Fi applications). The ZigBee specification document is short, allowing a small and simple stack, in contrast to other wireless standards such as Bluetooth.

The IEEE 802.15.4 standard is intended to conform to established regulations in Europe, Japan, Canada and the United States, and 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, for the purposes of this document only the higher data-rate, worldwide, unlicensed 2.4-GHz band will be considered.

A total of 16 channels are available in the 2.4-GHz band, numbered 11 to 26, each with a bandwidth of 2 MHz and a channel separation of 5 MHz. The channel mapping frequency is given in table 1. LR-WPAN output powers are around 0 dBm and typically operate within a 50-m range. The transmit scheme used is DSSS (see Section 2.1 for further details on DSSS).

Many of papers study the transmission of image over IEEE 802.15.4 [ ]. [7] Studies the fragmentation of image. Also, it studies the reasons of fragmentation in the image transmission over ZigBee network.

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

Table 1: IEEE 802.15.4 Frequency Bands and Data Rates

The paper is organized as follows. In section 2, ZigBee packet format is discussed. In section 3, the proposed modifications are presented. In section 4, Image fragmentation & transmission is discussed. In section 5, the simulation assumptions are given. The simulation results are introduced in section 6. Finally, the paper is concluded in section 7.

II. ZIGBEE PACKET FORMAT

Figure 1 gives the packet format of ZigBee in general form.

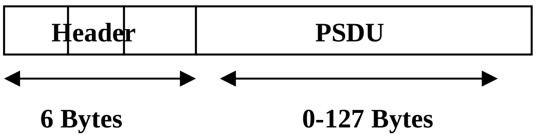

Figure 1: ZigBee packet format

The structure of ZigBee packet is shown in Figure 4. the header contains three fields preamble 32-bits for synchronization, packet delimiter 8-bits, and physical header 8-bits Physical Service Data Unit (PSDU) length. The PSDU field is data field (0-1016 bits) length. ZigBee uses error detection/retransmission technique. Bluetooth uses Forward Error Correction (FEC).

III. PROPOSED MODIFICATIONS

The transmission of multimedia contents over unreliable data links has become 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 our simulation, we try to improve the transmission of image over Bluetooth and ZigBee network through different interleaving schemes. Also we discuss the fragmentation process in different cases. We use an interleaving technique before transmission process. We use block interleaver, Convolutional interleaver, chaotic encryption (as interleaving), and chaotic interleaving (proposed).

A-. *Block Interleavers*

The method of data reading in case of block interleaver is column by column. In the case of this interleaver, the digital image is read column by column as shown in the figure. After this process, the matrix is read row by row and segmented to form Bluetooth packet and ZigBee packet.

B- Convolutional Interleavers

The second type of interleavers which is used in our simulation is Convolutional interleaver. Convolutional interleavers are introduced as no block deterministic interleavers that were investigated in some communication systems due to applying less memories in their structures compared with the block interleavers [10, 11]. Convolutional interleavers are constructed by T parallel lines; each line has different number of memories from other line. The construction of convolutional interleaver which is used in our simulation experiments is shown in Figure 4. This figure illustrates the convolutional interleaver with period T = 4 and space value M = 1 based on arithmetic sequence, the overall number of memories (delay) for the interleaver (T, M) is given by Equation. (1) [12]

$$S = \sum_{i=1}^{T} s_i = M + 2M + - - - + (T-1)M \qquad (1)$$

$$= \frac{T\,(T-1)M}{2} = 6$$

(our simulation case M = 1, T = 4)

In our simulation, the length of interleaver input is 256 bits (in the case of DH1). The length of interleaver input is 512 bits (in the case of 2DH1). These lengths are short data steam to decrease the interleaver delay.

C- Chaotic Interleaver

The third scheme in our simulation is chaotic map. In our simulation we use chaotic map for encrypting the transmitted image. After encryption the image segmented to Bluetooth packet and transmitted. Chaotic encryption of the encrypted image is performed using the chaotic Baker map. The Baker map is a chaotic map that generates a permuted version of a square matrix [17]. In its discretized form, the Baker map is an efficient tool to randomize a square matrix of data. The discretized map can be represented for an $M \times M$ matrix as follows (Han et al. 2006; Fridrich 1997; Qian et al. 2008; Huang and Lei 2008; Koduru and Chandrasekaran 2008; Usman et al. 2007):

$$B(r,s) = \left[\frac{M}{n_i}(r - M_i) + s \bmod\left(\frac{M}{n_i}\right), \frac{n_i}{M}\left(s - s \bmod\left(\frac{M}{n_i}\right)\right) + M_i\right] \qquad (2)$$

Where $B(r,s)$ are the new indices of the data item at (r,s), $M_i \le r < M_i + n_i$, $0 < s < M$, and *Mi* $M_i = n_1 + n_2 + \cdots + n_i$.

In steps, the chaotic encryption is performed as follows:

1. A $M \times M$ square matrix is divided into *k* vertical rectangles of height *M* and width n_i

2. These vertical rectangles are stretched in the horizontal direction and contracted vertically to obtain a $n_i \times M$ horizontal rectangle.

3. These rectangles are stacked as shown in Figure 3(a), where the left one is put at the bottom and the right one at the top.

4. Each $n_i \times M$ vertical rectangle is divided into n_i boxes of dimensions $M = n_i \times n_i$, containing exactly M points.

5. Each of these boxes is mapped column by column into a row as shown in Figure 3(b).

Figure 2 shows an example of the chaotic encryption of an (8 × 8) square matrix. The secret key, $S_{key} = (n_1, n_2, n_3) = (2, 4, 2)$.

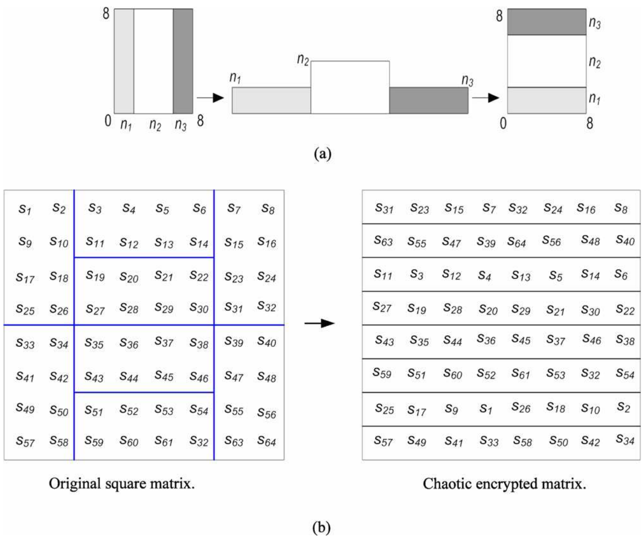

Figure. 2: Chaotic encryption.

(**a**) Discretized Baker map.
(**b**) Chaotic encryption of an 8×8 matrix

The last case in our simulation is called chaotic interleaving. In this scheme, the column of digital image is used to be input of chaotic map. That is means the encryption process is carried over column by column, separately. After columns encryption the image is reconstructed and segmented to Bluetooth packets. The image forms (256x256) square matrix. The secret key of encryption process, $S_{key} = (n_1, n_2, \ldots, n_{256})$ =(10,5,12,5,10,8,14,10,5,12,5 ,10,8,14, 10,5,12,5,10,8,14, 10,5,12,5,10,8,14).

IV. Image Fragmentation & Transmission

Due to the communication channel effects the Bit Error rate (BER) is much higher and the burst error is expected [ ]. Furthermore, the throughput may fluctuate due to time varying characteristics of wireless channel. This section studies the reasons of fragmentation and the number of segments in every case.

Our simulation experiments are carried out over the 2.4GHz band in the case of Bluetooth and ZigBee simulations. Due to the limits of the packets size the fragment of image is important for complete the transmission. The physical layer of ZigBee supports transfer of only small size packets limited to 127 bytes. This leads to fragmentation of bit streams of image. In our simulation, we assume the length of each segment is 127 bytes, in [ ] the length of each segment is 89 bytes. The size of the cameraman image 65536 bytes then the number of segment calculated from this equation

$$No\,Segments = \frac{65536 \times 8(ImageSize)}{1024(ZigbeePacketLength)}$$

In case of Bluetooth system, length of packet is 256 bits in the case of classic DH packet.

$$No\,Segments = \frac{65536 \times 8(ImageSize)}{256(DH_1)}$$

The case of EDR Bluetooth packets the length of packet is double of classic (2DH$_1$)

$$No\,Segments = \frac{65536 \times 8(ImageSize)}{512(2DH_1)}$$

The length packets in our simulation cases are proposed for simplify the simulation and fragment the image.

V. Simulation Assumption

In this section, the simulation environment used for carrying out our experiments is described. An important assumption used in the simulation is that a packet is discarded if there is an error ZigBee packet is discarded if there is an error in the header portion or the data field. This is a realistic assumption to simulate the real ZigBee system operation [13].

In our simulation experiments, a block-fading channel is assumed. It is a slow and frequency nonselective channel, where symbols in a block undergo a constant fading effect. That is means the Doppler spread equal zero (F_d=0). Also, in our experiments jack model used in the case of correlated Rayleigh fading channel. The mobile Bluetooth device velocity is 10 mile/hour, and the carrier frequency is 2.46 GHz. The Doppler spread is 36.6 Hz. The phase difference between the paths is given from Eq. (3). The Doppler spread is expressed in Eq. (4) [14].

$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v_c \Delta t}{\lambda}\cos\theta \qquad (3)$$

$$F_d = \frac{1}{2\pi}\bullet\frac{\Delta\phi}{\Delta t} = \frac{v_c}{\lambda}\bullet\cos\theta \qquad (4)$$

Figure 3: Original image. cameraman image

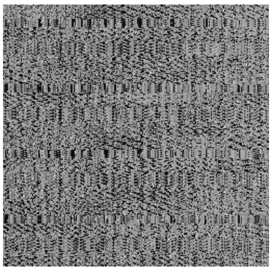

Figure 4: Encrypted

We will concentrate in our experiments on ZigBee packets with length (128 Bytes) for transmitting the image, and the results can be generalized for other short range wireless systems. In our simulation of ZigBee the length of data field is 128 bytes. The channel of simulation is correlated Rayleigh fading channel only. The image to be transmitted is transformed to binary data, which is segmented into packets and transmitted. After the packets are received the de-interleaving processes are made [15]. The obtained binary data is used to build the image again. The peak signal to noise ratio (PSNR) is evaluated between the original image and the received image.

The higher the PSNR means the more efficient the Bluetooth system performance. In our work, chaotic maps are used for two purposes; image encryption prior to transmission and random interleaving of the image bits after the pixels are transformed to bits [16]. Figures 3 and 4 show the cameraman image and its encrypted image using chaotic Baker map, respectively. MATLAB was used for carrying out our simulation experiments of different cases. The simulation results have been gotten by transmission of the image over different SNR values.

VI. Simulation Results

In this section, the performance of the proposed transmission of the image over correlated and uncorrelated Rayleigh fading channel is studied through simulation experiments. For the comparison purpose, using non-interleaving, Block interleaver, Convolutional interleaver, Chaotic encryption, and Chaotic interleaving (proposed) techniques are also simulated. In the case of correlated Rayleigh fading channel, we use jackes model in the simulation experiments.

As mentioned in simulation assumption section, the mobile terminal velocity is 10 mile/hour. The frequency carrier in our simulation is 2.46GHz. In our simulation experiments, ZigBee packet is used for image transmission. The channel model used for simulations is the jack model channel model [17]. ZiBee device has a mobile speed of 10 mile/hour. This speed corresponds to a Doppler spread of 36.63 Hz for a carrier frequency F_c = 2.46 GHz. This carrier frequency is one of 79 Bluetooth carriers. In the case of uncorrelated fading channel (slow fading channel) the Doppler spread equal zero (F_d = 0). In our simulation experiments, there are many experiments.

The following experiments are carried out for perform the image transmission over ZigBee network in correlated fading channel. The simulation is carried out by using jackes model. The image is transmitted over ZigBee with different interleaving types and without interleaving.

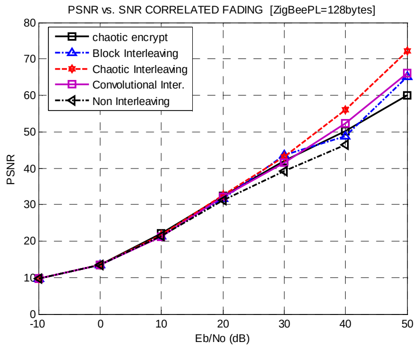

Figure 5: PSNR vs. SNR for ZigBee network

(a) **(b)**

(a): Chaotic Interleaving (PSNR=9.8dB)
(b): Non-interleaving (PSNR=9.7 dB).

Figure 6: Cameraman image ZigBee (PL=128 bytes) over correlated fading channel. (SNR=0dB).

As shown in Figure 6, there is a little difference between two images. The proposed technique didn't reduce the errors but it spread the errors.

Because of ZigBee do not use FEC except ARQ the interleaving spread the burst error over different places in image but that do not decrease the number of discarded packets. Figure 5 gives the PSNR of different cases vs. SNR values.

The following Figure 7 gives the result of the image transmission over ZigBee with using block and convolutional interleaving at SNR = 10dB. Also, Figure 8, and 9 give the No. Frame Loss (NFL) and Bit Error Rate (BER) of bit image streams. The numbers of frames are 512 frames. The length of total bits is 512*1024 Bits

(a) **(b)**

(a): Block Interleaving
(b): Conv-interleaving

Figure 7: Cameraman image ZigBee over correlated fading channel. (SNR=10dB).

As shown in these figures the image (b) [convolutional interleaver) is better than (a) (Block inetrleaver). So, the convolutional interleaver performs better than block interleaver over correlated fading channel.

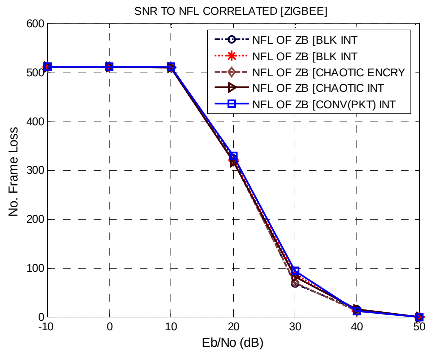

Figure 8: NFL vs. SNR over correlated fading channel

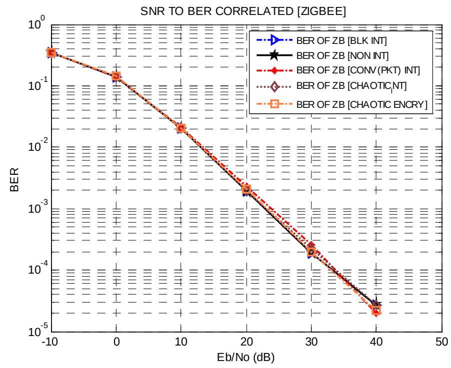

Figure 9: BER vs. SNR over correlated fading channel

As shown in Figure 8 and 9 the performance of different cases is very closed. That means the number of error nearly the same. Because of the interleaving techniques spread the burst errors the final received image may be improved as shown in our results**.**

VII. CONCLUSIONS

This paper studies the reduction of burst errors effects on the image transmission over IEEE 802.15.4. We propose using different interleaving techniques for this purpose. Our experiments results reveal using the proposed chaotic interleaving improve the received image. Also, the convolutional interleaver performs better than block interleaver. On other hand, over ZigBee the interleaving techniques did not reduce the error. But the interleaving spread the error only that leads to reduce the effect of burst errors on the received image.

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