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Image Transmission in Low-Power Networks in Mobile Communications Channel

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***Abstract*—**This paper studies a vital issue in wireless communications, which is the transmission of images over Wireless Personal Area Networks (WPANs) through the Bluetooth network. It presents a simple method to improve the efficiency of error control code of old Bluetooth versions over mobile WPANs through Interleaved Error Control Code (IECC) technique. The encoded packets are interleaved by simple block interleaver. Also, the paper presents a chaotic interleaving scheme as a tool against bursts of errors which depends on the chaotic Baker map. Also, the paper proposes using the chaotic interleaver instead of traditional block interleaver with Forward Error Control (FEC) scheme. A comparison study between the proposed and standard techniques for image transmission over a correlated fading channel is presented. Simulation results reveal the superiority of the proposed chaotic interleaving scheme to other schemes. Also, the superiority of FEC with proposed chaotic interleaver to the conventional interleavers with enhancing the security level with chaotic interleaving packet-by-packet basis.

***Keywords*—**Mobile Bluetooth terminals, WPANs, Jackes' model, Interleaving technique, chaotic interleaver

I. INTRODUCTION

THE WPANs technologies are employed in different fields such as the industrial, medical, home automation, and children monitoring fields. 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) [1-2]. In the paper improves the efficiency of the colored image transmission over Bluetooth network with proposing a mobile environment through many scenarios [3]. The Bluetooth technology operates within distance up to 100 meters. The structure of stations in different Bluetooth versions follows a piconet structure. Each piconet comprises up to seven Bluetooth devices working as slaves (S) and only one Bluetooth device as a master (M) station.

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Up to 10 piconets can exist within Bluetooth range [4].Bluetooth operates in the unlicensed 2.4 GHz ISM (Industrial Scientific Medical) frequency band, forming Ad-Hoc wireless network [5]. This band is also utilized by various wireless and radio technologies, such as IEEE 802.11b/g standard, IEEE 802.15.4 standard, cordless telephones, and even microwave ovens. Bluetooth employs the Frequency Hopping Spread Spectrum (FHSS) technique to mitigate the interferences caused by other wireless services, coexisting in the 2.4 GHz frequency band. The Bluetooth technology presents the industrial specifications of Wireless Personal Area Networks (WPANs), where it provides wireless media to connect and exchange information between devices. Bluetooth employs variable-size packets. These packets occupy different number of time-slots up to a maximum of five slots; each time-slot length is 625µs. Bluetooth v. 2.1 has brought EDR packets types. These EDR packets support gross air rates of 2 Mbps and 3 Mbps through Л/4-DQPSK and 8DPSK modulation respectively [6].

There are many of papers studied using Bluetooth in hospitals environments, control automations, and industrial application. All previous proposed applications may need transmission colored images. In this paper, we try to study the transmission of colored images over a mobile Bluetooth network and trying to improve the performance of colored image transmission. In our simulation, we use different techniques, such as interleaving techniques and error control technique. The transmission of image simulation is carried out using one of EDR Bluetooth packets [$2DH_3$]. $2DH_3$ packet is one of ACL link packets. This packet carries 3000 bits Payload (PL) uncoded data. In this paper, we proposed using default $2DH_3$ packet and proposed packets through using error control codes schemes, such as Hamming code [7].

The paper is organized as follows. In section II, Bluetooth packet format is discussed. In section III, the proposed modifications are presented. In section IV, the objective quality metrics are presented. The simulation assumption and the results are introduced in section V. Finally, the paper is concluded in section VI.

II. BLUETOOTH PACKET FORMAT

The standard packet format for old versions of Bluetooth is shown in Figure 1, while the format of EDR Bluetooth packets is given in Figure 2. The Bluetooth Packet contains three main fields AC, HD, and Payload field. The function of the access code (AC) is to identify the packets exchanged within a piconet, where each piconet has a unique access code.

The access code is used to synchronize the slaves in a piconet to their master. The main function of the header (HD) of the Bluetooth packet is to determine an individual slave address in the piconet by Logical Transport-Address (LT_ADDR) [8].

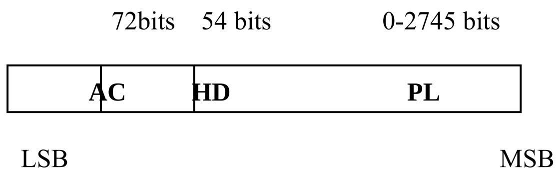


Fig. 1 Bluetooth classic packets format

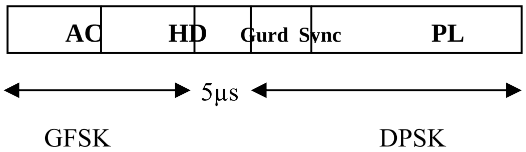


Fig. 2 Bluetooth EDR packet format

The last field of the Bluetooth packet is the payload. The functions of AC and HD are not changed in EDR packets. We focus in our study on a certain type of Bluetooth packets called ACL packets which refers to Asynchronous connectionless. Packets of the ACL payload may be one of two types; DMx and DHx. The M refers to medium data rate packets, while H refers to high data rate packets. The symbol x denotes the number of time slots between two hops in the frequency hopping system used [8]. It takes value 1, 3, and 5 referring to 1, 3, or 5 time slots between consecutive frequency hops. Always DMx packets are coded packets and DHx packets are uncoded packets [9].

III. Proposed Modifications

The transmission of multimedia contents 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 [10]. In this paper, we try to improve the transmission of images over the Bluetooth network with different interleaving schemes. Also we discuss the fragmentation process. We study the feasibility of data interleaving prior to transmission over Bluetooth networks. The paper presents a new chaotic interleaver and compares it to the traditional block interleaver [11].

In the simulation experiments, the error control scheme of old Bluetooth versions is combined and followed by the traditional block interleaver and the proposed interleaver. Also we discuss the fragmentation process in different cases. As shown in the next section, the fragmentation process determines the number of packets which will be transmitted. With increasing the number of packets the number of dropped packets may be increased. Using error control schemes let us decrease the length of segment, so the number of segments (packets) increased. We use an interleaving technique before transmission process. We use block interleaver, standard error control Bluetooth scheme, combined error control code plus interleaving (IECC technique), and chaotic interleaving (proposed).

A. Block Interleaver Scheme

The idea of block interleaving can be explained for image transmission with the Bluetooth network. After converting the image into a binary sequence, this binary sequence is rearranged into a matrix in a row-by-row manner, and then read from this 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. 3 (b) with shades. After de-interleaving as shown in Fig. 3 (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 [12], as shown in Fig. 3 (b) with shades. Fig. 3 (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.

B. Chaotic Interleaver scheme

As mentioned in the previous section, block interleavers are not efficient with 2-D error bursts. As a result, there is a need for advanced interleavers 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 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 $B(n_1,\ldots\ldots,n_k)$, denote the discretized map, where the vector, $[n_1, \ldots\ldots ,n_k]$, represents the secret key, S_{key}. Defining N as the number of data items in one row, the secret key is chosen such that each integer ni divides N, and $n_1 + \ldots\ldots + n_k = N$.

Let Ni = n1 + … + ni-1. The data item at the indices (r, s), is moved to the indices [13-17]:

$$B(r,s)=\left[\frac{M}{n_i}(r-M_i)+s \bmod\left(\frac{M}{n_i}\right), \frac{n_i}{M}\left(s-s \bmod\left(\frac{M}{n_i}\right)\right)+M_i\right] \qquad (1)$$

where $Ni \le q < Ni + ni$, $0 \le z < N$, and $N1=0$.

In steps, the chaotic permutation is performed as follows:

1- An $N \times N$ 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 left to right beginning with upper rectangles then lower ones.

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

Figure 4 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 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 Bluetooth system, a chaotic de-interleaving step is performed.

(a)

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)

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}

(c)

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}

Fig. 3 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

(a)

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)

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}

(c)

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}

Fig. 4 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

C. Simple Serial Concatenated Code

In this section, we discussed the proposed serial concatenated code. The data encoding process is followed by data interleaving technique [18]. For this purpose, we use two types of interleaver, the traditional block interleaver and the proposed chaotic interleaver. It is known that, the payload field of Bluetooth packet is encoded by Forward Error Control (FEC) scheme is a shortened Hamming code (15, 10), Fig. (5) gives Block diagram of the 2/3 FEC code implementation [19]. Each block of 10 information bits is encoded into a15 bit codeword. This code can correct all single errors and detect all double errors in each codeword. Fig. (6) gives block diagram of a simple concatenated code using 2/3 FEC and traditional block interleaving in Fig. (6-a) and using the proposed chaotic interleaver in Fig. (6-b) [20-21].

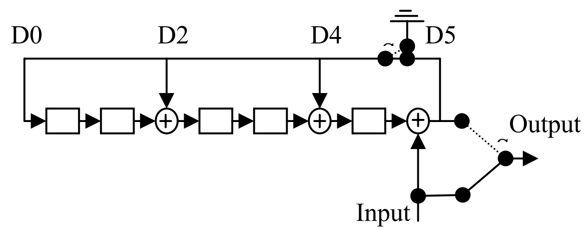


Fig. 5 Block diagram of the Hamming code (15, 10) implementation

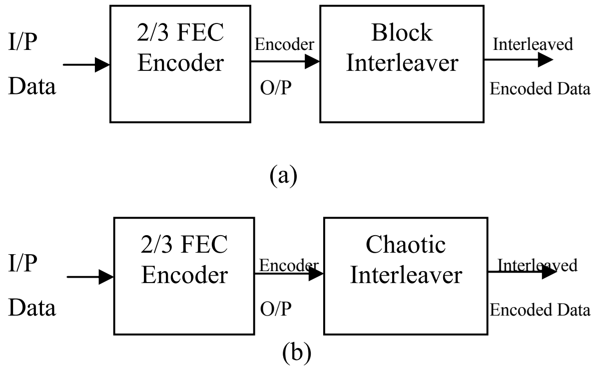


Fig. 6 Simple Concatenated Code a- using block interleaver, b- using chaotic interleaver

The operation of this technique can be described in the following. $Data_{Inputofencoder}$ and $Encoded\,(2DM_3)$ is the data of encoder input and encoder output, respectively.

$$Data_{Inputofencoder} = \{d_1, d_2, d_3, \cdots\cdots\cdots, d_{2000}\}$$

$$Encoded\,(2DM_3) = \{k_1, k_2, k_3, \cdots\cdots\cdots, k_{3000}\}$$

$$M = \begin{array}{c|cccccc} & C_1 & C_2 & \cdots & \cdots & C_{15} \\ R_1 & k_1 & k_{201} & \cdots & \cdots & k_{2801} \\ R_2 & k_2 & k_{202} & \cdots & \cdots & k_{2802} \\ R_3 & k_3 & k_{203} & \cdots & \cdots & k_{2803} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ R_{200} & k_{200} & k_{400} & \cdots & \cdots & k_{3000} \end{array}$$

Where, M refers to the register contents.

$Tx\,(2DM_3)_{IntBitStrean}$: The output of interleaver (encoded/interleaved) packet. The interleaver size (3000).

$$Tx\,(2DM_3)_{IntBitStrean} = \{k_1, k_{201}, k_{401}, \cdots\cdots, k_{3000}\}$$

The final form of bit sequence is transmitted over the wireless channel. The encoding/ interleaving process is carried out over every Bluetooth packets [22].

IV. Objective Quality Metrics For the Image

This section presents the error metrics which are used to evaluate the various proposed and standard techniques. The Peak Signal to Noise Ratio (PSNR) of the received images is used as an evaluation metric in this paper. The Mean Square Error (MSE) is the cumulative squared error between the received image and the original image. The mathematical formula for MSE is given in Eq. (9) [23].

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}\left[I(x,y) - I'(x,y)\right]^2 \qquad (9)$$

$$PSNR = 20x\,\log_{10}(255/sqrt(MSE)) \qquad (10)$$

where $I(x,y)$ is the original image, $I'(x,y)$ is the received image, and M, N are the image dimensions (600,600). The higher PSNR is good that means the SNR is higher. Also, the case of lower MSE means lesser error, from Eqs. (9-10) there is the inverse relation between the MSE and PSNR. The best technique is having a lower MSE and higher PSNR [24].

The second metric is used in this paper is measuring the degree of the correlation between the original and received images as given in Eq. (11) for different cases of our simulation [25].

$$C_r = corr(I(x,y), I'(x,y)) \qquad (11)$$

C_r is correlation coefficient, C_r =1 in the case of perfect correlation. As it approaches zero there is less of a relation, which means closer to uncorrelated.

Also, from the comparison purpose at different SNRs, the number of lost frames is studied with the channel SNR. In our work, MATLAB was used for carrying out the simulation experiments of different cases. The simulation results have been gotten by transmission of the image over different SNR values.

V. Simulation Results

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 in the Access code, header or the payload field. This is a realistic assumption to simulate the real Bluetooth system operation. A correlated Rayleigh fading channel is assumed. The channel model utilized is the jackes model [26-27]. The assumed mobile Bluetooth device velocity is 10 mile/hour, and the carrier frequency is 2.46 GHz. The Doppler spread is 36.6 Hz.

In the simulation experiments the Mandrill is used, as a standard image in Matlab. The original of simulation experiments images are shown in Fig. (7). The image binary sequences to be transmitted are fragmented to packets. The standard Mandrill image can be converted to binary sequence.

Fig. 7 Original Mandrill image (Its size 480x500)

In the simulation experiments, the image binary sequences to be transmitted are fragmented to packets. The Peak Signal to Noise Ratio (PSNR) of the received images is used as an evaluation metric in this paper.

The previous experiments and its results reveal the using of block interleaving technique as a tool for improving the colored image transmission is ineffective manner, also at low SNR chaotic interleaving gives a good effect on received colored image with enhancing the link security. Standard error control scheme of classic Bluetooth packets gives a little improvement on received image. This error control technique is ineffective completely in the image transmission over a mobile WPAN network.

In the first simulation experiments, the Mandrill image is transmitted over a correlated fading channel with Signal to Noise Ratio (SNR = 5 dB). The cases of no interleaving block interleaving, 2/3 FEC code, and 2/3 FEC code with chaotic interleaving are considered for comparison. The results of this experiment are shown in Fig. (16).

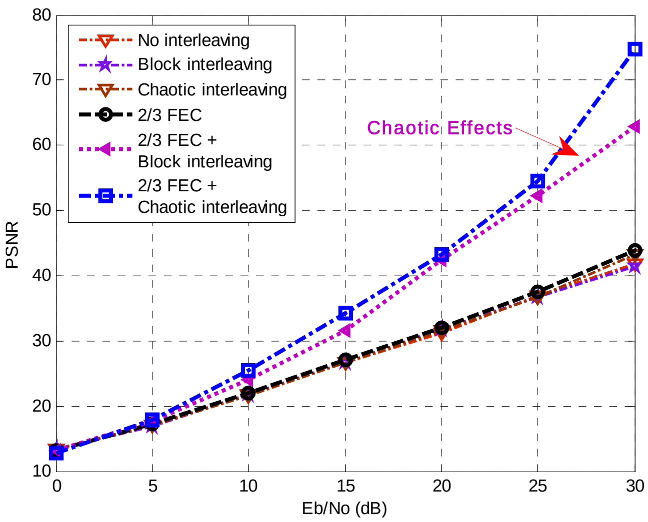
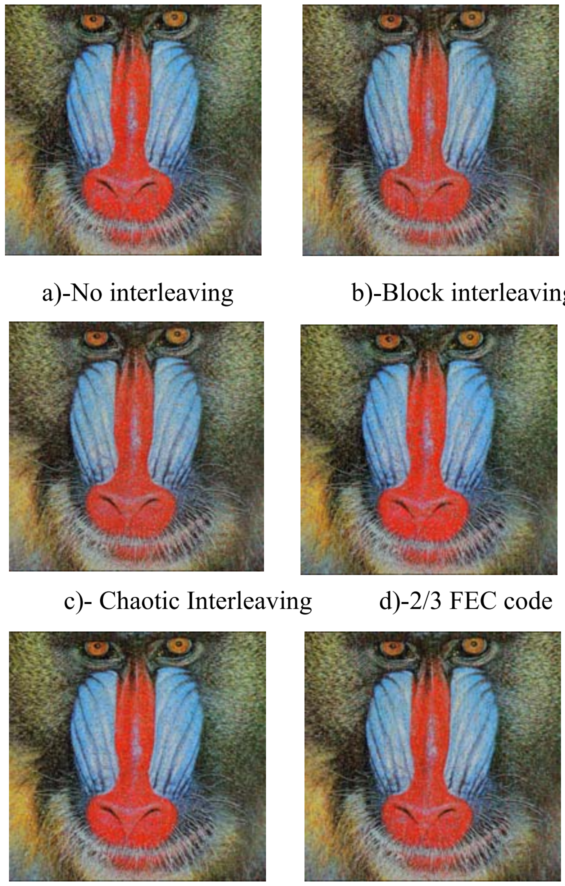


Fig. (8). PSNR vs. Eb/No of received Mandrill image over correlated fading channel.

Figure (8) gives the PSNR variation of the received Mandrill images with the channel SNR over the correlated fading channel. From these results, it is clear that the effect of all interleaving schemes and 2/3 FEC scheme is approximately equal at low SNR values. The effect of interleaving technique is ineffective. With increasing the SNR as shown in the results of the second experiment, the serial concatenated code using 2/3 FEC code and the proposed chaotic interleaver perform better than the other techniques. Also, 2/3 FEC code is ineffective as a error control scheme over a correlated fading channel.



a)-No interleaving b)-Block interleaving

c)- Chaotic Interleaving d)-2/3 FEC code

e)-IECC-1 technique f)-IECC-2 technique

Fig. 9 The received Mandrill image at SNR=5 dB over correlated Rayleigh fading channel cases: a)- PSNR=17.1dB, b)- PSNR=16.9dB}, c)- PSNR=17.1dB} d)- PSNR=17.2dB}, e)-) PSNR=17.5dB}, and f)PSNR=17.8dB}

Figure (9) gives the received images of this experiment. As shown in this figure, at very low SNR, the proposed technique is ineffective. Also, the error control scheme of the old Bluetooth version is inefficient with the image transmission in the mobile communication channels.

The previous experiment is repeated over the correlated Rayleigh fading channel at SNR=15 dB. The received images of this experiment are given in Fig. (10). As shown in these results, the proposed technique gives higher PSNR. Also, with increasing the SNR of the channel the proposed technique performs better than the traditional interleaver. The proposed chaotic interleaver can randomize the encoded bit stream more than the conventional manner of the block interleaver. Also, it has a secret key dedicated for every transmitted packet. That means it enhances the wireless link security.

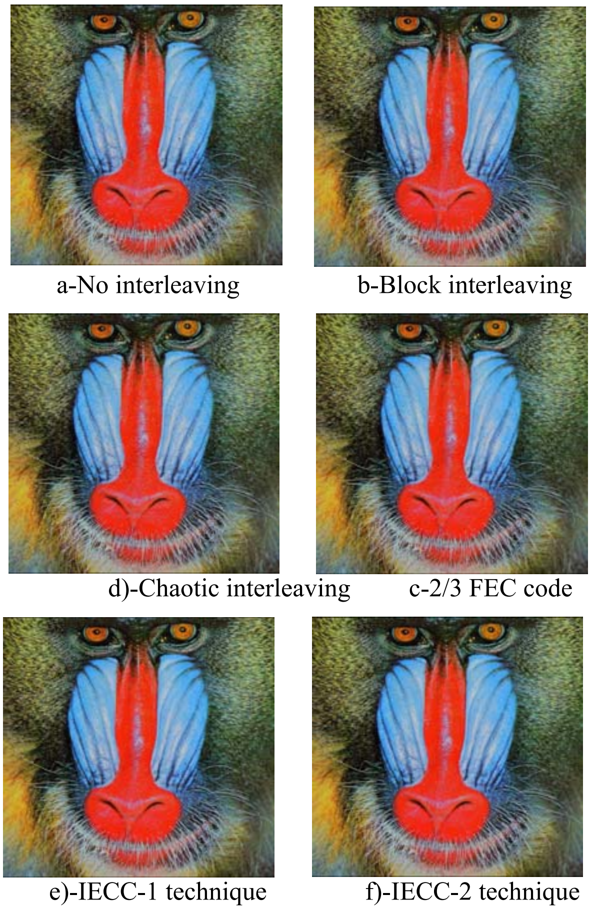


Fig. 9 The received Mandrill image at SNR=15 dB over correlated Rayleigh fading channel cases: a)- PSNR=26.5dB, b)-PSNR=26.7dB},c)-PSNR=26.76dB d)- PSNR=27dB}, e)-PSNR=31.6dB}, and f)-PSNR=34.2dB}

The correlation between the original image and received image is used as evaluation metric. Figure (11) gives the correlation coefficient values vs. SNR between original and received Mandrill image for all simulation cases. Also, the number of dropped frames is used as an evaluation metric, the results of the number of lost frame vs., SNR is given in Fig. (12).

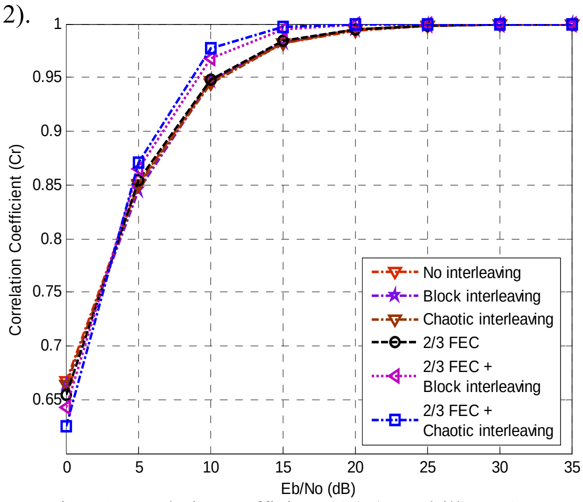


Fig. 11 correlationcoefficient (Cr) (Mandrill) vs. SNR over correlated fading channel

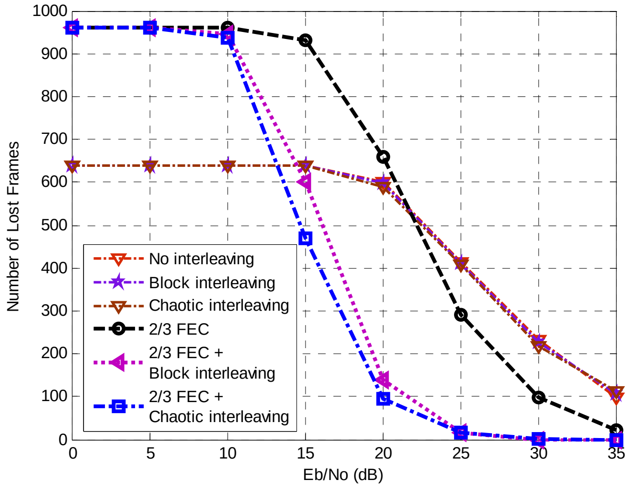


Fig. 12 The Number of Lost Frames vs. SNR of over correlated fading channel

Figure 12 gives the number of lost frames vs. SNR for the case of non-interleaved image [Uncoded $2DH_3$ packets], block interleaved image [Uncoded $2DH_3$ packets], chaotic interleaved image [Uncoded $2DH_3$ packets], non-interleaved image [Encoded $2DM_3$ packets using Hamming (15, 10) code], and IECC technique [Encoded/interleaved $2DM_3$ packets]. As shown in Figure 13, the number of dropped packets is decreased with using error control scheme. From Figure 12, the error control code of old Bluetooth versions reduces the NPL but it still inefficient solution for the image transmission improvement over mobile environment.

Figure (13) shows the number of frames vs. SNR. This figure appears the effect of traditional block interleaver and the proposed interleaver on the reduction of data lost. It is known, the cases of no interleaving and block interleaving the number of transmitted frames is equal. In the case of FEC and FEC/interleaving the number of frame is greater due to the redundant bits which are added to each frame.

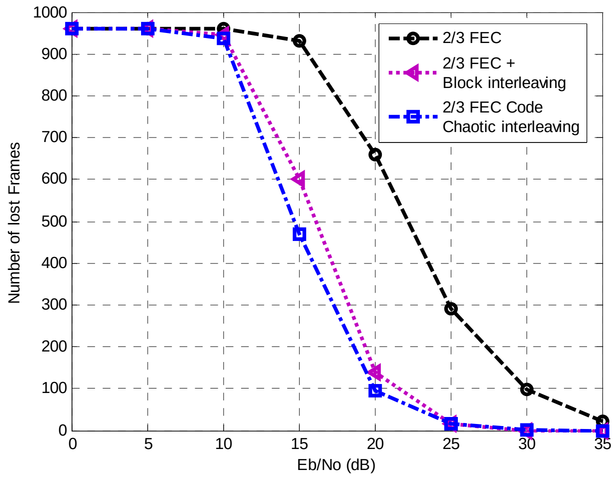


Fig. 13 The number of lost frames (Mandrill) vs. SNR over correlated fading channel

The paper makes a simple merging between the original

Bluetooth error control scheme and the conventional bit-level interleaver. This technique called Interleaved Error Control Code (IECC). The IECC gives good results over the correlated fading channel. It improves the PSNR and Cr values and reduces the NPL. A stand alone error control scheme of classic Bluetooth is inefficient; by IECC this error control scheme became powerful and more useful. Over mobile Bluetooth network, the proposed chaotic interleaver gives good performance at lower SNR values and enhances the security over Bluetooth network.

In the simulation experiments section the standard Mandrill image is used over the correlated Rayleigh fading channel. The experiment study the following, no interleaving, block interleaving, 2/3 FEC code, 2/3 FEC code using block interleaver (IECC), and 2/3 FEC code using the proposed chaotic interleaver (serial concatenated code).

The computer simulation experiments studied the proposed simple serial the concatenated code using with 2/3 FEC code and the proposed chaotic interleaver for efficient transmission of images over the Bluetooth networks. These experiments reveal the superiority of the proposed serial concatenated code with chaotic interleaver to other techniques over mobile Bluetooth network.

VI. Conclusions

The paper studies the transmission of colored JPEG image from mobile Bluetooth terminal to fixed one using EDR Bluetooth packets ($2DH_3$). In this paper, we use different techniques. The paper appears the inefficient of standard error control scheme of old Bluetooth versions that is over mobile network and improves its capability by simple IECC technique. Fragmentation process controls the number of segments, with using error control scheme the segment length be smaller and the number of packets increases, this may increase the number of dropped packets as shown in the experiments.

From the experiments, in mobile environment chaotic interleaving gives good effect on colored JPEG image transmission (at lower SNR) although it didn't decrease the number of loss packets. The standard error control code of classic Bluetooth versions is not effective in JPEG image transmission over mobile Bluetooth network. The chaotic interleaving technique can be used as a tool to enhance the Bluetooth security.

The paper improves the capabilities of standard error control code of Bluetooth by using simple bit-level interleaver. This merging technique called IECC. It improves the transmission images performance and gives a higher PSNR values and reduces the number of dropped packets. Also, the IECC enhances the Hamming code capabilities.

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