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Body Area Networks IEEE802.15.6 HBC Physical Layer Performances: Bit Error Rate and Message Integrity

Mohamed EDDABBAH[1], Charaf Eddine AIT ZAOUIAT[2], Mohamed MOUSSAOUI[3], Yassin Laaziz[4]

[1, 3, 4] Abdelmalek Essaadi University, ENSA, LABTIC laboratory, Tangier, Morocco

[2] IT&M Laboratory, ENSA, Cadi Ayyad University, Marrakesh, Morocco

eddabbah@gmail.com

ABSTRACT

IEEE 802.15.6 Wireless Body Area Networks (WBAN) is a new standard designed for wireless sensors that operate around or inside the body (human, animal or robot), this standard improves the sensors life time by optimizing communication protocols and reducing the network coverage to operate just around a body without affecting communication reliability. The current standard defines three physical layers, namely Narrowband physical layer (NB), Ultra-Wide Band physical layer (UWB) and Human Body Communication physical layer (HBC). In this paper, we evaluate the HBC physical layer performances, in terms of bit error rate (BER) for two different symbols correlation methods in the receiver, namely Hamming distance and Jaccard index (distance). Simulations prove that the vector symbols similarity model used in the receiver can influence information integrity.

Keywords: *IEEE 802.15.6, HBC, BER, Hamming, Jaccard*.

1 INTRODUCTION

The need of an innovative patient monitoring system has pushed the IEEE 802.15 working group 6 to propose a new wireless communication standard, designed for low power and short rang communication devices [1]. IEEE 802.15.6 Body Area Networks (BAN) is an emergent communication technique close to or inside, a human body. Similar to other PAN protocols as Zigbee IEEE 802.15.4 or Bluetooth IEEE 802.15.1, IEEE 802.15.6 can be classified as a very short rang communication protocol since it operates in the immediate environment around the human body or a part of the body [2][3]. The standard proposes three different physical layers (PHY); Narrowband PHY layer, ultrawideband PHY layer and Human Body Communication PHY layer. Each PHY layer can be used for a specific context in terms of distance, band and energy consumption [4][8]. The basic modulation schemes for the Narrowband physical layer are : DBPSK, π/4-DQPSK, π/8-D8PSK and GMSK, with a range rate varying from 75.9Kbps to 971.4 Kbps. For Ultrawideband physical layer two types of modulation/demodulation schemes are used: impulse radio (IR-UWB) and the Ultrawideband Frequency Modulation (FM-UWB) with non/differential coherent detection. The data rate varies from 0.2 Mbps to 12 Mbps. The human body communication physical layer (HBC) is based on Near Field Communication (NFC) standard [5], and uses a 5.25 MHz bandwidth centered on the 21MHz frequency for transmission of baseband digital signals on the body surface. The data rate varies from 164 kbps to 13125 kbps. To perform a remote patient monitoring system, it is evident to introduce a long range communication protocol like 3G/4G [7].

In this paper we evaluate the HBC physical layer performances, in terms of bit error rate (BER) for two different symbols correlation methods in the receiver, the first one is the Hamming distance, and the second one is the Jaccard index (distance). The rest of the paper is organized as follows: In Section 2, we describe the IEEE 802.15.6 Human Body Communication physical layer (HBC). The system model is presented in Section 3. The performance evaluation and results are discussed in Section 4. Finally, Section 5 concludes the paper.

2 IEEE 802.15.6 HUMAN BODY COMMUNICATION PHYSICAL LAYER

The human body can be used to transmit an electrical signal which gives a new method for biomedical data transferring based on the electric field communication (EFC fig 1) technology. IEEE 802.15.6 HBC uses this technology, with frequency centered at 21 MHz, to enhance wireless networks in terms of simplicity, reliability, power efficiency and security. The EFC is designed to provide simple design and robust performance for the HBC, because the transmitter uses only digital circuits and an electrode (instead of antenna), due to the fact that:

- human body has a permittivity of about 300 ~ 500 times better than air,
- The receiver is performed without linked radio frequency (RF) blocks (mixing, VCO, ADC / DAC, etc.) ,
- Low complexity implementation and low power consumption.

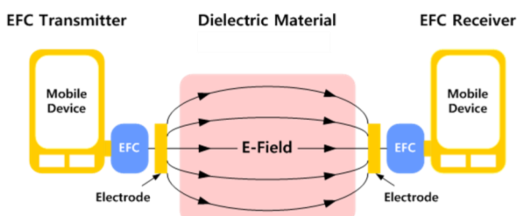

Fig. 1. EFC general concept

The EFC packet is composed of Preamble, SFD (Start Frame Delimiter), Header, and PHY Payload (PSDU). PHY Payload is composed of MAC Header, MAC Payload, and FCS (Frame Check Sequence). The packet structure with PHY Header fields is shown in Figure 2.

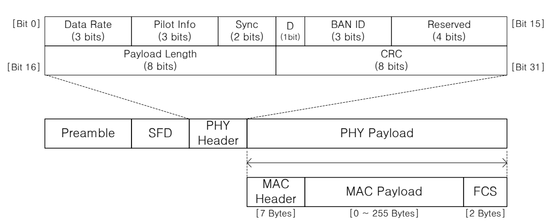

Fig. 2. EFC Packet Structure

The data passes through several blocks of the transmitter to form a packet. This packet will be sent to the receiver via the electrode; to rebuild the transmitted message the receiver will reverse the various transmitter blocks operations. The different blocks of the transmitter are (fig 3):

- Preamble Generation
- SFD/RI Generation
- Header Generator
- Serial-to-Parallel (S2P)
- FS-Spreader [FS = Frequency Selective]
- Pilot Generator
- MUX

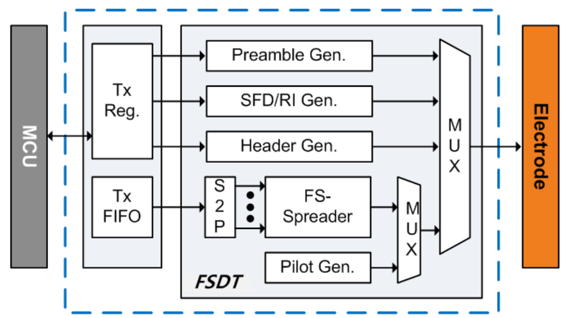

Fig. 3. EFC packet generator

2.1 PHY Preamble

The preamble sequence is used for synchroniza-tion. It is sent out four times (PR1 - PR4 Figure 4).

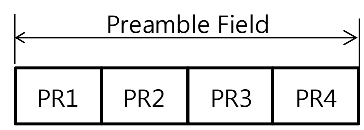

Fig. 4. Preamble Field

A preamble sequence is created from 128 bit gold code that will go through a block to perform the spreading operation.

2.2 Start Frame Delimiter (SFD)

SFD indicates the beginning of the packet, it is generated by applying FSC with SF of 4 to a 128-bits gold code sequence. Fig. *5. SFD/RI Signal Generation Block Diagram* and table 1 shows the SFD signal generation block.

Using "time offset", the SFD field can also indicate the transmitted packets data rate. With this "Rate Indicator" (RI), the receiver does not need to refer to the PHY header to detect the incoming packet's data rate. This allows the header along with the payload to be transmitted at the same high data rate increasing transmission efficiency.

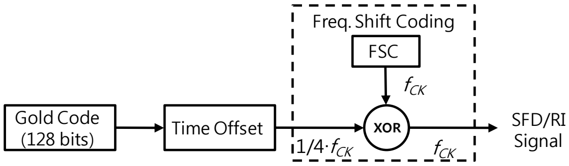

Fig. 5. SFD/RI Signal Generation Block Diagram

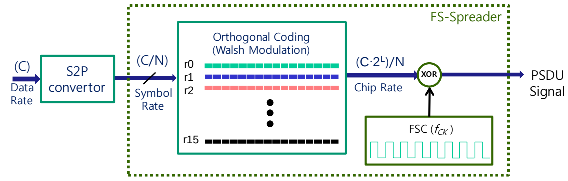

Fig. 6. S2P and FS-Spreader Block Diagram

Table 1: Gold Code Generation Polynomials for SFD

	Polynomial 1	Polynomial 2
Polynomial	$x^{10} + x^3 + 1$	$x^{10} + x^8 + x^3 + x^2 + 1$
Initial Values	[1:10] (0101100000)	[1:10] (0000100010)

2.3 PHY header

Sync Field

This field is for synchronization between the master device and slave nodes. When this field is set to 1x, the internal timing information is updated with the value of registers as below.

- 10 (frame sync): updated with the pre-set values of the slot and chip count registers. (used for every downlink frame that is sent in sync with the frame period)
- 11 (superframe sync): updated with the pre-set values of the frame, slot and chip count registers (used for Broadcast frames transmitted at a specified time in a superframe)

D Field

Dedicated mode allows 1:1 full bandwidth transmission between the master device and a particular slave device. D field indicates whether the current frame is transmitted in dedicated mode or not. Other slave devices, if any, stop any communication when this field is set to 1. Any new device attempting to join the BAN should wait until dedicated mode ends.

2.4 Serial to parallel *and FS-Spreader*

This block is responsible to encode 4 bits to 16 bits; The 16 bits are then supported by the FSC whose function is spreading bits. The Figure 6 shows the S2P and FS-spreader.

Table 2: Symbol-to-Chip Mapping

Symbol	Data B its	Chip
1	0000	1111 1111 1111 1111
2	0001	1010 1010 1010 1010
3	0010	1100 1100 1100 1100
4	0011	1001 1001 1001 1001
5	0100	1111 0000 1111 0000
6	0101	1010 0101 1010 0101
7	0110	1100 0011 1100 0011
8	0111	1001 0110 1001 0110
9	1000	1111 1111 0000 0000
10	1001	1010 1010 0101 0101
11	1010	1100 1100 0011 0011
12	1011	1001 1001 0110 0110
13	1100	1111 0000 0000 1111
14	1101	1010 0101 0101 1010
15	1110	1100 0011 0011 1100
16	1111	1001 0110 0110 1001

2.5 Pilot Signal

To prevent loosing synchronization due to clock drift, "Pilot" sequence can be inserted in PSDU as shown in **Error! Reference source not found.**. The same sequence used for SFD is used for pilot, and the pilot insertion interval is indicated in the "Pilot Info" field in PHY header.

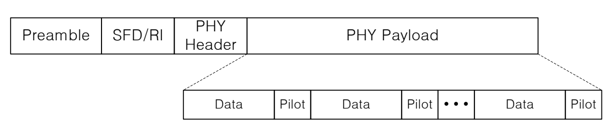

Fig. 7. Pilot Insertion in PSDU

3 PERFORMANCE EVALUATION AND RESULTS ANALYSIS

3.1 System model

In this work, we implement the different blocks of the HBC physical layer of the IEEE 802.15.6 standard.

Figure 8 shows the block diagram adopted to evaluate the performance of the base band PSDU frame transmission chain (transmitter/receiver) according to IEEE 802.15.6 standard. The coming PSDU frame (Physical Service Data Unit) is processed through the different blocks of the transmission chain.

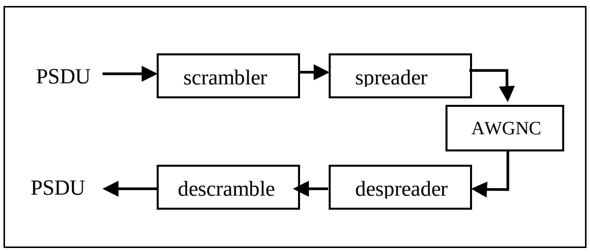

Fig. 8. PSDU transmission chain

In the simulation the EFC packet is sent to the receiver through a noisy channel. In Matlab code the channel is modeled by an additive white Gaussian noise.

At the reception, the EFC packet flows the reverse operations to recreate the PSDU. These operations are sequentially:

- Reverse Operation Header generator
- Operation reverse SFD / RI generator
- Operation reverse preamble generator
- Reverse Operation Spreading: Match each sequence of 16-bit to 4-bit sequence corresponding to the data bits (Table 2). But if the 16-bit sequence was affected in the channel it will be difficult to match them with the 4-bit sequence, in this scope we introduce our model to calculate the distance between the received 16-bit sequence from the channel and the stored 16-bit sequence in the despreader.

The utility of this distance is to compare the similarities and differences between two vectors (16 bits sequence).It is more likely that two similar symbol vectors represent the same binary data as two dissimilar vectors. In fact, the use of measuring distances is almost always an essential step for matching.

Mathematically, A distance is a function that describes the distance between two points of a set E. This distance is an application of $E \times E \to \mathbb{R}^{+}$ such that $\forall i, j, k \in E$:

where d is the distance between two vectors

- $d(i,j) = d(j,i)$
- $d(i,j) \geq 0$
- $d(i,j) = 0 \quad \rightarrow \; i = j$
- $d(i,j) \leq d(i,k) + d(k,j)$

In this one of the best-known application of these distance in FS-Spreader mechanism. In practice we can quote several distance that are used in dispreading, such as Euclidean distance, Chebychev distance , hamming distance and jaccard distance (or jaccard score). In this section we will only interested on hamming and jaccard distances .

A-Hamming distance

The Hamming distance, which takes its name from the famous computer scientist Richard hamming , is the measurement between two words in a code. For that it considers the number of bits that have changed in value between the first and the second word. otherwise, if we consider two binary vectors X (x1,....,xn) and Y (y1,.....,yn) with n attributes (0 or 1) the hamming distance between X and Y is given by

$$d(X,Y) = \sum_{i=0}^{i=n-1} (xi \oplus yi)$$

where $\oplus$ is the logical exclusive or (XOR), for example the hamming distance between 1011101 and 1001001 is 2 and the low the distance is the more the vectors are similar.

B- Jaccard index

The jaccard index or (score) is useful to study the similarity between binary vectors. Given two sequences X and Y, each with n binary attributes, each attribute can be 0 or 1. There was thus:

X= (x1,....,xn)

Y=(y1,.....,yn)

We define several quantities characterizing the two vectors:

E11 is the number of attributes that are 1 in X and Y

E00 is the number of attributes that are 0 in X and Y

E01 is the number of attributes that are 0 in X and 1 in Y

E10 is the number of attributes that are 1 in X and 0 in Y

Each pair of attributes must necessarily belong to one of four categories, such that:

$$\mathrm{E11} + \mathrm{E00} + \mathrm{E01} + \mathrm{E10} = \mathrm{n} \qquad \text{eq(1)}$$

The Jaccard index is defined as:

$$Ij = \frac{E11}{E11+E01+E10} \qquad \text{eq (2)}$$

using (Eq1) and (Eq2) we obtain:

$$Ij = \frac{E11}{n - E00}$$

So we need just to know the number of 0 attributes and 1 attributes to calculate the Ij and the more it is close to 1 the more the compared vectors are similar.

3.2 Results analysis

Because of noises presented on real channel, received symbols are not identical to the symbols provided by the source (occurrence of transmission errors). We define the error rate on symbols as the ratio of the number of erroneous symbols over the number of transmitted symbols. Similarly, we define the error rate on the bits (BER: Bit Error Rate) when the symbols are bits or binary words.

Simulations are performed by Matlab

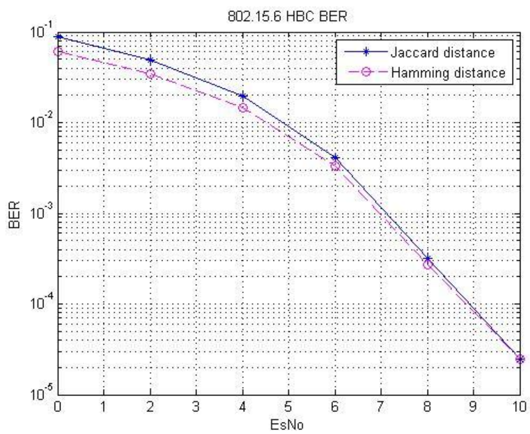

Fig. 8.BER for Jaccard distance AND Hamming distance

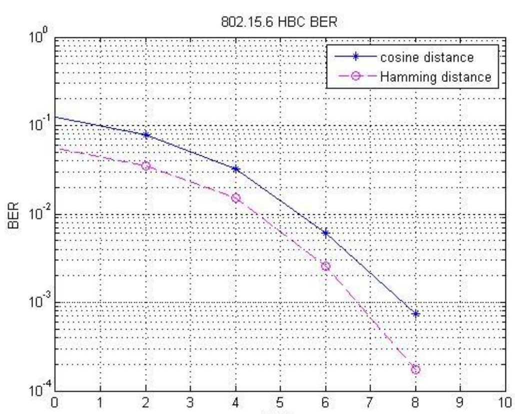

Fig. 9.BER for Cosine distance AND Hamming distance

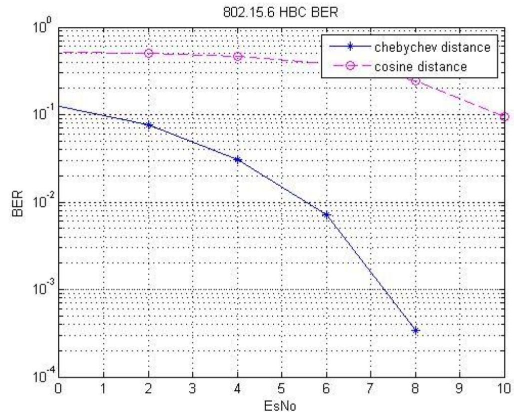

Fig. 10.BER for cosine distance AND chebychev distance

results shown in figures 8, 9 and 10 presents the performances of Jaccard index, Hamming distance, Cosine distance and chebychev distance, our study complete and simulate the HBC PHY of the standard IEEE 802.15.6 (receiver model),

4 CONCLUSION

IEEE 802.15.6 standard targets medical applications, thus the information integrity is an important challenge to complete. In this paper, we analyze the performances of IEEE 802.15.6 HBC physical layer in terms of message integrity and bit error rate (BER) in function of EsN0. Results show that the used distance metric, in the despreader, influence directly the BER and consequently the message integrity. In our simulations we prove that the Hamming distance gives best results in terms of BER for the same EsN0 level .

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