Active Channel Quality Driven Data Rate (ACQDDR) for Improving Throughput over Wireless Link

M. A. M. Mohamed El-Bendary**, A. E. Abu El-Azm*, N. A. El-Fishawy*, A. Hagagg**, F. Shawky* and F. E. Abd El-Samie*

* Faculty Electronic Engineering, Menouf.

* *Faculty of Industrial Education, Helwan University

***Abstract* — Channel Quality Driven Data Rate (CQDDR) is employed to selects the packet size by Received Signal Strength Indicator (RSSI) over Bluetooth network according to channel conditions. This paper tries to improve the throughput over Bluetooth system in classic and Enhanced Data Rate (EDR) packets. The paper studies the adaptive Bluetooth packet format according to CQDDR decision which determines when it can extend the payload (PL) of transmitted packets. This paper proposes transmitting uncoded Access Code (AC) and the header (HD) as optional packets type. Many of proposed packets format are studied in additive White Gaussian Noise (AWGN) and fading channels. Our simulation experiments reveal the capability of extension the PL length by 8 bytes for classic BT and 16 bytes for EDR BT. Also, the experiments reveal ineffectiveness of error control schemes of AC and HD in the case of uncoded packets (DH1). That means in good channel condition the redundant bits can be added to exceed the length of the PL.**

Index Terms* — *Bluetooth, ACQDDR, throughput, fading channel.

I – INTRODUCTION

With increasing utilization of wireless devices specially Bluetooth devices, there are two important factor for all wireless systems power efficiency and efficient throughput. In Bluetooth system there are many types of packets. These packets are chosen to transmit by channel conditions which are detected by RSSI in the receiver. Using a long packet size will increase the throughput of system. A long packet is used in the case of good channel. In the case of a bad channel, small packet size is used in transmission process this will decrease the throughput of system.

Bluetooth has emerged as a wireless communication technology aiming at achieving the interconnection between computer peripherals in an efficient manner. it is a short range communication system. It operates within distance of 10-100 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 as a master (M) station. The limited number of slaves leads to an address field of no more than three bits. A slave can be a member in more than one piconet. A master of any piconet may be a slave in other one. Up to 10 piconets can exist within Bluetooth range [1, 2].

Bluetooth operates in the unlicensed 2.4 GHz ISM (Industrial Scientific Medical) frequency band, which is also utilized by various wireless and radio technologies, such as IEEE 802.11b/g standard [4], IEEE 802.15.4 standard [5], 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 (PANs) [6], 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 [7]. These EDR packets support gross air rates of 2 Mbps and 3 Mbps through $\pi/4-DQPSK$ and 8DPSK modulation respectively.

The paper is organized as follows. In section II, Related work is discussed. Section III highlights the issue of the Bluetooth packet format. In IV section the proposed modifications are presented. In section V the simulation assumptions are given. The simulation results are introduced in section VI. Finally, the paper is concluded in section VII.

II- RELATED WORK

Several authors have analyzed the performance of classic Bluetooth packets with the expurgated Hamming (15, 10) code used in the Bluetooth standard [7]. The most appreciable work in the coding of the payload field and EDR was introduced by Galli et al and Ling et al [7, 9]. In [8] proposes uses other error control codes for improving Bluetooth performance such as convolutional codes. It improves the performance but reduce the PL field length. The propositions of FEC bearing data medium (DM) packets for EDR were proposed in Chen [9]. Also, in [9] investigates the improving EDR packets through Forward Error Control (FEC) and interleaved FEC. In the same manner, all proposed cases improve the performance but reduce the throughput.

It is known that Bluetooth employs variable-size packets. In this paper, we try to enforce these capabilities through proposition new packet format. These proposed formats choosing according to CQDDR rules. This paper gives more flexibility in packet type choosing.

It investigates the performance of classic and EDR Bluetooth packets with standard and proposed packets. Also, the paper activates the RSSI role for improving the throughput. Basic Bluetooth packets (DM_1, DH_1) and EDR Bluetooth packets ($2DM_1$, $2DH_1$) are employed in our simulation and the results can be generalized. The simulations are carried out over an AWGN and fading channels [10].

III - BLUETOOTH PACKET FORMAT

The standard packet format for old versions of Bluetooth is shown in Fig. (1), while the format of EDR Bluetooth packets is given in Fig. (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 its master [10]. 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).

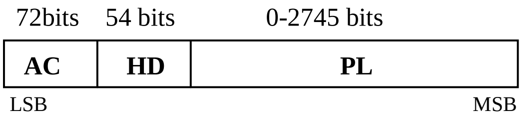

Fig. (1): Bluetooth classic packets format

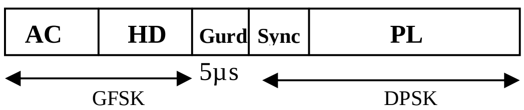

Fig. (2): Bluetooth EDR packet format

The last field of the Bluetooth packet is the payload. The functions of AC and HD are not changed in EDR packets. Bluetooth has several types of packets. We focus in our study on a certain type called ACL packets which refers to Asynchronous connectionless. Packets of the ACL payload may be one of two types; DM_x and DH_x. 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 [11]. It takes value 1, 3, and 5 referring to 1,3, or 5 time slots between consecutive frequency hops. Always DM_x packets are coded packets and DH_x packets are uncoded packets [12].

IV – THE PROPOSED MODIFICATIONS

In this paper, we study throughput enhancing over Bluetooth system with different cases such as EDR packets, classic packets and proposed packets format over AWGN and Rayleigh-flat fading channels. This section proposes the usage of different packet size. Our proposition depends on the truth of Bluetooth packet performance which depends on the three fields AC, HD, and PL. over Bluetooth link a packet is discarded if there is an error in the AC, HD, or PL (after decoding), which was not corrected using the error correction scheme. This is the real Bluetooth systems operation. From this truth we try to proposing new packets. AC and HD fields are encoded by BCH (30, 64) code and repetition (1, 3) code, respectively. These two fields are very important for establishing a Bluetooth link. So they must be protected by FEC. The length of redundant bits in AC and HD is more than 8 byte. In a good channel this redundant bits can be extended PL to enhance throughput. These proposed packets can exceed the length of PL field to enhance throughput. The paper tries to increasing number of CQDDR choice by adding new packets. In Bluetooth system, the packet size is determined in CQDDR through RSSI which sense the wireless link and channel condition. Our proposed packets are efficient in good channel. Fig.(3) shows the proposed adaptive Bluetooth classic packet format.

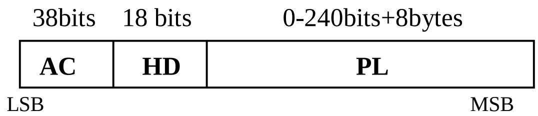

Fig. (3): Adaptive Bluetooth classic packets format (DH_1)

In proposed EDR packets we take the three main fields AC, HD, and PL only in our consideration. The proposed adaptive Bluetooth EDR packet format is shown in Fig. (4).

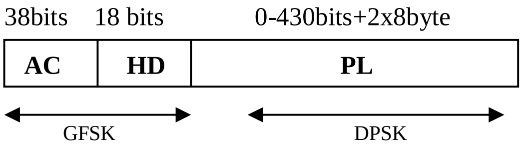

Fig. (4): Adaptive Bluetooth EDR packets format ($2DH_1$)

Our proposition is built on two real factors. First, DH packets are chosen by RSSI in the case of good channel. The second factor is the most discarded packets due two uncoded PL [14]. From this result, if RSSI selects DH packets why not select our proposed packet.

V – SIMULATION ASSUMPTION

In this section, the simulation environment is described. The Monte Carlo simulation method is used in the simulation experiments to compare between the traditional expurgated Hamming (15, 10) code used in the standard Bluetooth packet, EDR packets, and the proposed schemes. This method ensures obtaining correct statistical results.

An important assumption used in the simulation is that a packet is discarded if there is an error in the AC, HD, or PL (after decoding), which was not corrected using the error correction scheme. This is a realistic assumption to simulate the real Bluetooth systems operation.

In this simulation, hard decision is assumed at the receiver in the decoding process for all channel codes. In the simulation, the interference effects are neglected. In case of EDR simulation, we use AC, HD, and PL fields. The modulation in our simulation is Binary Phase Shift Keying (BPSK).

In some 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

We will concentrate in our experiments on DH1, DM1 (classic Bluetooth packets), 2DH1, and 2DM1 (EDR Bluetooth packets) only, and the results can be generalized. MATLAB was used for carrying our simulation experiments of different cases. All simulations results have been gotten by transmission of 10000 trails (packets) over different SNR values.

VI – SIMULATION RESULTS

In this section, several experiments are carried out for the purpose of showing the effects of FEC schemes of AC and HD fields in the performance of Bluetooth to ensure the capability of our proposed packets. Also, our experiments give comparison between the standard classic Bluetooth packets, proposed packets, AC and HD fields in standard form, AC and HD in proposed form, EDR packets, and proposed EDR packets.

A- AWGN channel

In this section, many of experiments are carried for studying the effectiveness of our proposition. These experiments are carried to confirm this proposition can enhance throughput with keeping system stability or not.

First experiment: AC and HD fields only without PL are transmitted in standard case and without FEC. The result is shown in Fig. (5), this figure shows the effect of FEC is very clear. Statistics of No. of Loss Packets (NLP) is given in Table (1)

Second experiment [EDR packets]: Transmission encoded EDR (2DM1), $2DH_1$, proposed (PR0) $2DH_1$ with AC and HD are without FEC, and proposed (PR_1) extended $2DH_1$ ($2DH_1$+8byte) with AC and HD are without FEC. The results are shown in Fig. (6), this figure shows the effectiveness of our proposed packet.

SNR	**No. Loss Packets** **AWGN CHANNEL (EDR BT)**					
	AC& HD	**AC& HD NO FEC**	**2DM 1 EDR**	**2DH1 EDR**	**2DH1 PR0**	**2DH PR1**
0 dB	4317	9810	ALL	ALL	ALL	ALL
2 dB	816	8389	9504	ALL	ALL	ALL
4 dB	85	4530	3381	9959	9979	9989
6 dB	2	1106	151	6383	6844	7261
8 dB	0	97	2	790	840	955
10dB	0	1	0	16	23	27

Table (1) Number of Packet Loss (EDR packets in AWGN channel (Packets losses statistics)

Third experiment [Classic Packets]: Transmission standard DM1, proposed (PR0) DM1, DH1, proposed (PR0) DH1 with AC and HD are without FEC, and proposed (PR1) DH1 with AC and HD are without FEC. The results are given in Fig. (7), this figure indicates effectiveness of AC and HD FEC in the case of DM1 encoded packets but this effect is decreased in the uncoded packets DH1. That means proposed packets may be efficient in case of uncoded packets and good channel as a basic condition. Table (2) gives statistics of No, of Loss Packets.

The results of these experiments reveal that at high SNR proposed packets are very efficient. It enhances the throughput by adding 8 byte to PL field in classic Bluetooth packets case. But in the case of EDR packets (2DH1) proposed packet adds 16 byte to PL field. So it will enhance the throughput if we ignore the difference in Number of loss packets.

SNR	No. Loss Packets AWGN CHANNEL (Classic BT)				
	DM1	**DM1 PR0**	**DH1**	**DH1 PR0**	**DH1 PR1**
0 dB	9974	ALL	ALL	ALL	ALL
2 dB	8087	9683	ALL	ALL	ALL
4 dB	1995	5659	9507	9723	9864
6 dB	80	1190	4365	4901	5093
8 dB	0	92	439	559	667
10dB	0	2	10	12	15

Table (2) Number of Packet Loss (Basic packets in AWGN channel (Packets losses statistics)

PR0: means proposed case 1. In this case the three fields of Bluetooth packet are transmitted without FEC.

PR1: means proposed case 2. In the case the redundant bit which is reserved in the PR0 is added to uncoded PL it is 8 byte for classic packets and 16 byte in case of $2DH_1$ EDR packets.

SNR dB	No. Loss Packets Fading channel (EDR BT)					
	AC& HD	**AC&HD NO FEC**	**2DM1 EDR**	**2DH1 EDR**	**2DH1 PR0**	**2DH1 PR1**
5 dB	3672	6952	6879	8718	8781	8834
15dB	423	1056	923	1715	1778	1803
25dB	37	109	98	202	201	214
35dB	4	14	12	22	24	26

Table (3) Number of Packet Loss (EDR packets in fading channel (Packets losses statistics)

***B**- Fading channel*

The same previous experiments are repeated over Rayliegh fading channel. The results of first, second, and third experiments are shown in Figs. (8, 9, 10), respectively, Also, the NLP statistics are given in Tables (3, 4).

SNR	No. Loss Packets Fading channel (classic BT)				
	DM1	**DM1 PR0**	**DH1**	**DH1 PR0**	**DH1 PR1**
5dB	6461	7432	8424	8567	8659
15dB	814	1099	1567	1621	1678
25dB	79	115	162	162	171
35dB	11	12	16	19	18

Table (4) Number of Packet Loss (Basic packets in fading channel (Packets losses statistics)

The result means, there is an increasing in PL in the case of PR1 in DH1 packets. Also, this proposition is applied on DM1 packets but with PL standard length to ensure the effects of AC and HD in uncoded and encoded BT packets in two types EDR and classic packets. Those give us chance to increase the throughput by 16 byte in case of 2DH1 packets in good channel (basic condition) by CQDDR. PR0 means, in this case AC and HD field are transmitted without FEC (the whole BT packet is uncoded packet). PR1 means plus uncoded AC and HD also the PL length is increased with the 8 byte. That is means the length of standard Bluetooth packet is the same in our simulation experiments.

VII – Conclusion

CQDDR select BT packet size by RSSI according to the channel condition. In this paper we have proposed a new adaptive BT packet for classic and EDR packets to enhance throughput over BT link. Our results reveal that the most of discarded packets over BT link due to PL which is longest field in the case of uncoded PL. this paper use this truth to employing new packets. At high SNR CQDDR selects DH packets. So we propose new packets, if CQDDR uses proposed packet we will get big throughput enhancement. Proposed packets can be used at high SNR and stable link will give loss of transmitted packets nearly equal standard DH packets. The experimental results reveal that a proposed packet is employed by CQDDR with DH1 and 2DH1 only where, it improve the throughput by increasing PL field length, 8 bytes, 16 bytes, and 24 bytes in the case of classic DH1, 2DH1, and 3DH1 respectively. On other hand, the proposed packets is inefficient for longer classic (DH3, DH5) and EDR BT packets, 2DH3 and 2DH5. Finally proposed packet performs better than DH3 and DH5.

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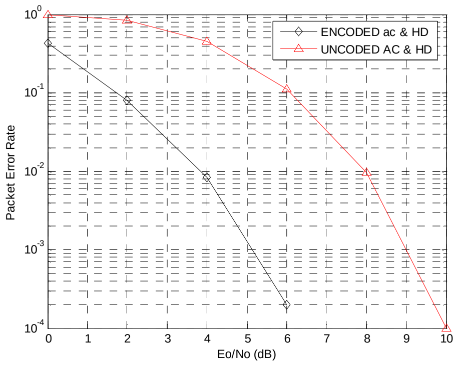

Fig.(5): PER vs. SNR over AWGN channel (AC&HD with and without FEC)

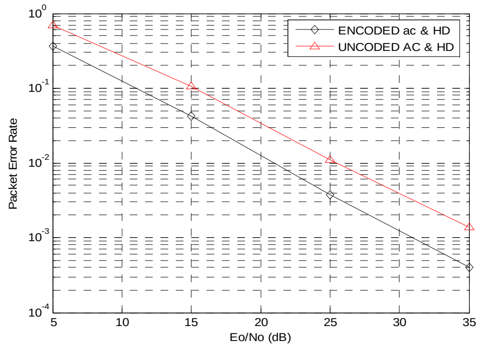

Fig .(8): PER vs. SNR over fading channel (AC&HD with and without FEC)

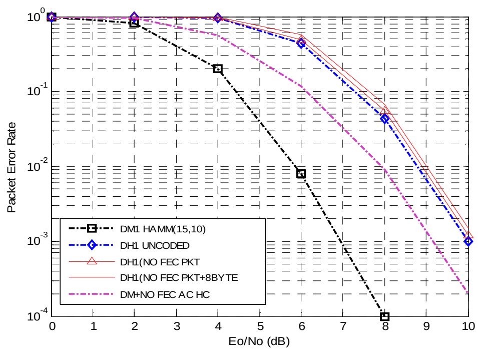

Fig .(6): PER vs. SNR over AWGN channel (EDR and proposed cases)

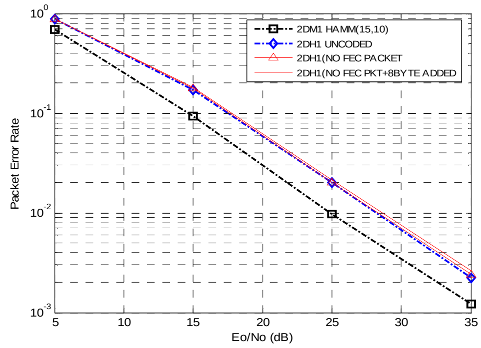

Fig .(9): PER vs. SNR over fading channel (EDR& Proposed cases)

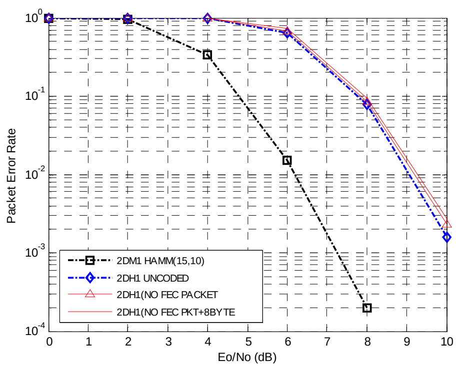

Fig.(7): PER vs. SNR over AWGN channel (Classic &Proposed cases)

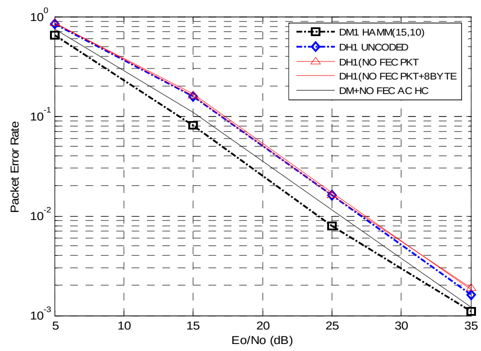

Fig .(10): PER vs. SNR over fading channel (classic and proposed case)