

The Performances Bounds of Supper PHY Channel using Concatenated Codes to Transmit WBANs Medical Data via LTE

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Abstract: According to increase the demands of reliable medical networks infrastructure economically in developing countries, we have designed the proposed system that is a dependable wireless medical network using an existing mobile cellular networks with a sophisticated channel coding technology. This paper comes to calculate the error bounds of the new highly reliable communication channel depending on coding theory under Physical Layer (PHY) as a supper PHY channel. The proposed channel is serving transmission of medical data via Long Term Evolution (LTE) cellular network. This study is focusing on the concatenated error control coding for more channel robustness that required for the different medical data Quality of Service (QoS). The supper PHY channel has been designed for QoS of Wireless Body Area Network (WBANs) medical data through the ready existing cellular network LTE. In order to carry out the aim, we propose simple design of an external channel coding and decoding which can be considered as the concatenated techniques, by adding such external code with existing LTE standard code as inner code. The design of an extra channel codes depending on the remains errors from the LTE inner decoder and the medical QoS chasses. The accomplishment of the QoS constraints is investigated here as two chasses, highest QoS and lowest QoS levels and quantitative performance error results are provided under assumed Gaussian noise AWGN and Rayleigh fading and Burst noise channels.

Keywords: LTE, WBANS QoS, Concatenated Codes, Channels Environment, Error Performances Bounds.

I. INTRODUCTION

The WBANs technology has been verified-out in the latest standardization of IEEE 802.15.6 [1]. WBANs standard purposes to provide an international standard for extremely reliable wireless communication within the surrounding area of the human body, supporting huge range of data rates from 75.9 Kbps narrow-band up to 15.6 Mbps Ultra-Wide-Band (UWB); for wide-ranging applications [2-7]. However, in this work we are using the QoS medical data of this standard. LTE integrate a wide variety of wireless multimedia services, with high data transmission rates, capable of providing much more than basic voice calls [8]. The LTE specification provides uplink peak rates of 75 Mb/s and QoS facilities permitting a transfer latency of less than 5ms in the radio access network. LTE has the ability to manage fast moving mobiles, broadcast streams and supports multi-cast. LTE

supports accessible carrier bandwidths from 1.4 MHz to 20 MHz and support both Frequency Division Duplex (FDD) and Time Division Duplex (TDD). The data modulation of all uplink and downlink channels is Binary Phase Shift Keying (BPSK), Quadra phase shift keying (QPSK), Quadrature Amplitude Modulation (16QAM) and (64QAM). The LTE provides both error detection and error correction as channel coding scheme. Therefore the Universal Terrestrial Radio Access Network (UTRAN) employs two Forward Error Correction (FEC) schemes: convolution codes and turbo codes. Convolution coding can be used for low data rates, and turbo coding for higher rates [8]. However, our proposed system concentrating to use the low data rate channels for medical data. Therefore, we will use the convolution code in our proposed system.

The previous work had considered the GSM and UMTS technologies [9-10]. However, in this paper we are focusing more deeply on the reliability matters and designing phases of end-to-end transmission of WBAN medical data by introducing our proposed system, supper PHY channel based on the concatenated error controlling techniques using LTE cellular technology. The sophisticated error controlling coding techniques has been using here in these work [11-15]. The understanding of the different kinds of errors such as a contention based errors or physical channel errors are well done. However the work here fixing to overcome Gaussian noise AWGN and Rayleigh fading, and burst noise those may occurs during the transmission in unpredictable way, making the channel situation time-to-time is changing. The performances of proposed supper PHY channel has been derivation in this work under these three noisy channels, in order to demonstrate the feasibility of using highly reliable supper PHY channel over LTE technologies for transmitting WBANS medical data under different assumed environments.

The rest of this paper is organized as follows. In section II, the technical design of LTE low data rate channels and WBAN data PHY channel codes is addressed as a conventional system. In section III, the supper PHY channel designing structures are demonstrated here for two classes of QoS levels as a proposed system. The system performances optimizing of the theoretical and simulation results are shown in section IV as a performance analysis. Finally, conclusion and future work are given in section V.

II. CONVENTIONAL SYSTEM STRUCTURE

A. LTE Channels

The standard coding techniques for lower data rate in LTE are outlined in the “Table I”. The data rate of the channels is equal to 75 Mb/s. the input bits denoted by $C_0, C_1, C_3, \dots, C_{K-1}$ where K is the number of bit length that to be encoded. Then in output form the encoder is encoded bits that denoted by $d_0, d_1, d_2, \dots, d_{D-1}$ where D is the number of encoded bits. The relation between C_k and d_D is depending on the channel coding schemes, which is convolution or Turbo code [5]. The LTE standard code used convolution code for one Traffic Channel (TrCH) that is Broadcast Channel (BCH).

TABLE I
LTE ERROR CORRECTION TECHNIQUES

TRCH Type	Coding Type	R & K	# of Encoded Bits
BCH	Convolution Coding	R=1/3 & K =7	$Y_i=K_i$
PCH, MCH, DSCH	Turbo Coding	R=1/3 & K = 4	$Y_i=K_i+4$

TRCH =Traffic channel, BCH =Broadcast channel, PCH = Paging channel, MCH = Multi Cast Channel, DSCH = Downlink share channel, R = Code Rate, K = Constraint Length, Y = Encoded bits.

The technical parameters of encoding structures that using are appearing in “Fig.1.”[5]. the coding rate equal to 1/3 and constraint length equal to 7 with a generator polynomial as

$$G_0 = 1 + D^2 + D^3 + D^5 + D^6 \tag{1}$$

$$G_1 = 1 + D^1 + D^2 + D^3 + D^6 \tag{2}$$

$$G_2 = 1 + D^1 + D^2 + D^4 + D^6 \tag{3}$$

The generator polynomials that shown in “(1~3),” used in the convolution code to encode the incoming data. The decoding structure works by convolution decoded that use Soft Decision Viterbi Algorithm (SDVA) [11-15].

The inner code of the proposed system assumed to use Broadcast Channel for low data rates of LTE, therefore the standard techniques for the inner channel in our supper PHY proposed channel is considered as a convolution codes.

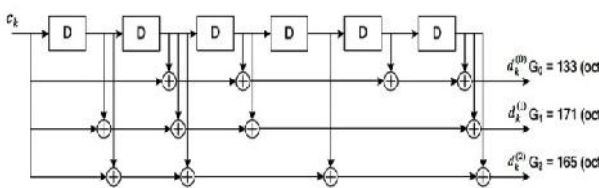


Fig. 1. LTE Cellular Networks Convolution Code Structure

B. WBANs Channels

Bose-Chaudhuri-Hochquenghem (BCH) Code plays a main role in WBANs IEEE 802.15.6 Standard [1]. BCH Code is one of the cyclic codes and underlies in class of linear block codes. It can be uses to correct errors by correction bound depending on the free distance of the code d_{free} [1]. The BCH Codes (63, 51, $t = 2$) and (126, 63, $t = 10$) Play an important role in the error detection and correction capabilities in WBANs Standard [1]. The biggest gain on BCH code is the existence of efficient decoding methods due to the special algebraic structure that introduced in the code (Berlekamp-Massey algorithm) with Chien search as in “Fig. 2.” [11-15].

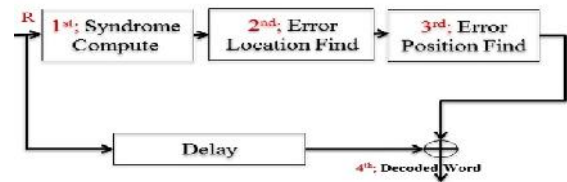


Fig. 2. WBAN BCH Decoding Structure

The generator polynomial for a systematic BCH (63, 51, $t = 2$) code that using in this paper work, where t is the number of bit errors that can be corrected, is given

$$g(x) = 1 + x^3 + x^4 + x^5 + x^8 + x^{10} + x^{12} \tag{4}$$

The parity bits are determined by computing the remainder polynomial $r(x)$ as

$$r(x) = \sum_{i=0}^{11} r_i x^i = x^{12} m(x) \text{ mod } g(x) \tag{5}$$

Where, $m(x)$ is the message polynomial as

$$m(x) = \sum_{i=0}^{50} m_i x^i \tag{6}$$

And $r_i, i = 0, \dots, 11$ and $m_i, i = 0, \dots, 50$ are elements of $GF(2)$. The message polynomial $m(x)$ is created as follows: m_{50} is the first bit of the message to be transmitted and m_0 is the last bit of the message, which may be a shortened bit. The order of the parity bits is as follows: r_{11} is the first parity bit transmitted, r_{10} is the second parity bit transmitted, and r_0 is the last parity bit transmitted.

Regarding to that detailed in this section, LTE capabilities’ for correcting whole low data rate channels errors is referred to the convolution code and WBANs capabilities’ for correcting whole channels errors is referred to the BCH code. However in some hard noisy channel condition adding by transmitting the WBAN medical data through LTE these techniques can’t perform good matching the higher QoS of medical data. The condition may change from time to time depending on the noisy channel. Therefore, the proposed system is come-out to use these techniques as it’s with adding additional channel code as a super physical channel via LTE

supporting by that the different QoS high and low of medical data under different noisy channel conditions.

C. WBANS QoS levels

The WBANS QoS eight levels have been verified-out in the latest standardization of WBANS [1]. The main paper objective is to achieve the two classes of medical QoS levels high and low for the proposed system. Therefore the goal that figured-out here by analyzing the WBANS medical data QoS needed as in “Table II”. It also notices the wide variation in data rate, Bit Error Rate (BER), delay tolerance, duty cycle, and lifetime, which requires scalable solutions with QoS provisions [16].

Regarding to the WBAN QoS that we study here from $[10^{-3} \sim 10^{-6}]$, our targeting is a technical parameters of the proposed supper PHY channel system has to give us the desired BER for each sets of priority level under fixed estimated transmission channel, achieving by that, the objective of proposed system in comparison to the conventional system (LTE) alone. For that will focus to achieve 10^{-6} for highest priority level and 10^{-3} for lowest priority level with higher E_b/N_0 less than 3dB for AWGN, less that 6dB for Rayleigh fading and less that 8dB for a burst noise. Therefore we classified WBANS user priority 0~4 as a lowest priority class and user priority 5~7 as a highest priority class for the designing phase of the proposed system.

TABLE II
QoS LEVELS MAPPING OF WBANS STANDARD

Priority Level Classes	User Priority	Traffic Designation
Lowest Priority Level [non-medical]	0	Background (BK)
	1	Best Effort (BE)
	2	Excellent Effort (EE)
	3	Video (VI)
Highest Priority Level [medical]	4	Voice (VO)
	5	Medical Data / Network Control
	6	High Priority Medical Data /Network Control
	7	Emergency / Medical Implant

III. PROPOSED SYSTEM STRUCTURE

The proposed system structure appeared in “Fig. 3.” as a concatenated supper PHY channel codes. The inner code assumed to use Broadcast Channel (BCH) code of LTE that is working by the convolution, code rate 1/3. The technical parameters for the extra channel detailed in this section by using extra outer encoder as convolution encoder and extra outer interleaver as block interleaver concatenated to the LTE inner code by adding WBAN standard code end to end, to this supper PHY channel. The block interleaver applied in the situation of Rayleigh fading and Burst Noise channel.

Two QoS classes has been considered, therefore to achieve this goal we are designing the technical parameters of the extra channel depend on the remaining errors from the inner LTE channel code. When the error as separated by at least the constraint length of the code, the error correcting capabilities

of the convolution code using “(7),” able to correct up to t errors. The free distance of LTE code is 15, therefore it’s able to correct up to 7 errors.

$$t = \frac{(d_{free} - 1)}{2} \tag{7}$$

Among all the Forward Error Correction (FEC) codes, the

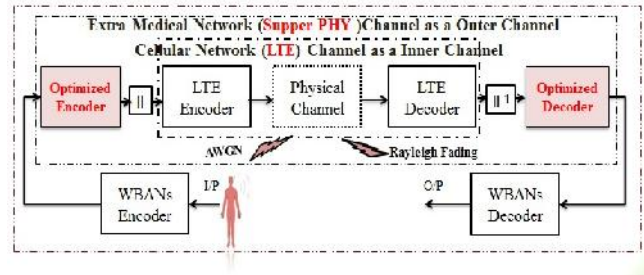


Fig. 3. The Proposed System Structure

convolution codes has great advantages by working use continuous streams of data and managing the performances by only two parameters (code rate R and constraint length K) and it has less complexity in compare to turbo codes. Therefore, a choice here is driving by convolution codes for the extra outer channel code.

The remains errors in the channel after an inner LTE decoder for fixed Signal to Noise Ratio (SNR), lets us considering the technical parameter for the extra channel to have free errors at the same SNR. Therefore the extra code parameters appeared in “Table III” is optimized regarding the two classes of QoS of medical data. The Lower class offers BER at least 10^{-3} and the higher class offer BER at least 10^{-6} within same SNR. The detail of the design performances analysis will be given in the next section.

TABLE III
INNER AND EXTRA CHANNEL CODES PARAMETERS DESIGN

	R	K	d_{free}	t	G	W_d	C_{2d-1}^d
LTE	1/3	7	15	7	133	7 8 22 44 22	77558760
					171	94 219	
					165	[416]	
L-QoS	1/2	8	10	5	247	2 22 60 148	92378
oS					371	340 1008 2642	
						6748	
						[10970]	
H-QoS	1/4	8	22	1	235	2 10 10 8 10	1.0520e+
oS				1	275	11 54 64	012
					313	[169]	
					357		

LTE =Long Term Evolution, L-QoS = Lower Quality of Service Code Class, H-QoS = Higher Quality of Service Code Class, R = Code Rate, K = Constraint Length, d_{free} = Free Distance, t = # of correcting error capabilities, G = Generator Polynomial, W_d = weight spectrum, C_{2d-1}^d = probability term in Rayleigh Fading.

IV. SYSTEM PERFORMANCE ANALYSIS

In the decoding parts the error bound probabilities can be calculated depending on the inner and outer and extra outer decoder’s separately; continuously, the code performance is

analyzed in terms of decoded BER. BER is normally calculated as a function of E_b/N_0 . Here E_b represents the average energy transmitted per information bit and N_0 represents the single-sided power spectral density of assumed AWGN channel.

The supper proposed PHY channel is testing under different estimated noisy channel. First, the performance bounds theoretically are driven under AWGN with adding WBANs end to end, only to demonstrate the feasibility of connecting WBANS Code. Second theoretically is driven under Rayleigh Fading without adding WBANs end to end. Then third, the simulation tests have been driven under all noisy channels AWGN, Rayleigh Fading and Burst noise.

A. Theoretical Out-Come via AWGN Channel

First of all, the LTE decoder calculate the first inner probability bit errors P_{bi} bound as in “(8-12),” .

$$P_{bi} \leq \frac{1}{bi} \sum_{di=0}^{\infty} w_{di} P_{ei}(di) \tag{8}$$

Where, $P_{ei}(di)$ is the probability of confusing two sequences differing in distances di positions of inner LTE code, and can be calculated as in “(9),” . w_{di} is weight spectrum that is the average number of bit errors associated with sequences of weigh di, and it’s calculated in “Table III”.

$$P_{ei}(di) = Q(\sqrt{2diRi E_b/N_0}) \tag{9}$$

Where, di is an inner LTE code free distance and Ri is an inner LTE Code Rate, the both Clearfield in “Table III”. Q function its clear in information theory and can be calculated using infinity integration as in “(10),”

$$Q(x) \cong \int_x^{\infty} \frac{1}{\sqrt{2f}} e^{-t^2/2} dt \tag{10}$$

$$P_{bi} \leq \frac{1}{bi} \sum_{di=0}^{\infty} w_{di} \cdot Q(\sqrt{2diRi E_b/N_0}) \tag{11}$$

$$P_{bi} \leq 416Q(\sqrt{(2 \times 15) / 3 \cdot E_b/N_0}) \tag{12}$$

Then, the inner LTE code performance, that using in this paper can be calculated by “(11),” and the code performance results appear in “Table IV”.

Generally speaking, the data stream coming from LTE inner code feed the extra code. The code performance of the outer code is a function of the inner LTE code.

Second, the outer decoder calculate the second outer probability bit errors P_{bo} bound separately as in “(13-17),” by the outer code parameter introduced in “Table III”.

$$P_{bo} \leq \frac{1}{bo} \sum_{do=0}^{\infty} w_{do} \cdot Q(\sqrt{2doRo E_b/N_0}) \tag{13}$$

$$P_{bo} \leq 10970 Q(\sqrt{(2 \times 10) / 2 \cdot E_b/N_0}) \tag{14}$$

$$P_{b1} \leq 416Q(\sqrt{10 \cdot E_b/N_0}) \cdot 10970Q(\sqrt{10 \cdot E_b/N_0}) \tag{15}$$

$$P_{bo} \leq 169 Q(\sqrt{(2 \times 22) / 4 \cdot E_b/N_0}) \tag{16}$$

$$P_{b2} \leq 416Q(\sqrt{10 \cdot E_b/N_0}) \cdot 169Q(\sqrt{11 \cdot E_b/N_0}) \tag{17}$$

Then, the outer codes performance of Supper PHY channel, that using in this paper can be calculated by “(15),” P_{b1} for Lower QoS class of medical data and “(17),” P_{b2} for higher QoS class of medical data and whole codes performance results appear in “Table IV”.

The last step here is introduced in the following step by calculating the final code performance of the proposed system. The WBANs decoder (63,51,2) calculate the last probability bit errors P bound using “(18),” as in “(21-24),” which is a function of the optimized outer code.

$$P_b \leq \sum_{i=x+1}^n \binom{n}{i} P_x^i (1-P_x)^{n-i} \text{ where } \binom{n}{i} = \frac{n!}{(n-i)! \cdot i!} \tag{18}$$

For WBAN code the error bound can be calculated as in “(19),” and the WBANs code performance results appear in “Table IV”.

$$P_b \leq \sum_{i=2+1}^{63} \binom{63}{i} P_x^i (1-P_x)^{63-i} \tag{19}$$

$$P_x = Q(\sqrt{2R E_b/N_0}) = Q(\sqrt{2 \times 51 / 63 \cdot E_b/N_0}) \tag{20}$$

By using “(20),” as a function of “(15),” and “(17),” to calculate the final bound, we can have

$$P_{x1} = P_{b1} \cdot Q(\sqrt{2 \times 51 / 63 \cdot E_b/N_0}) \tag{21}$$

$$P_{x2} = P_{b2} \cdot Q(\sqrt{2 \times 51 / 63 \cdot E_b/N_0}) \tag{22}$$

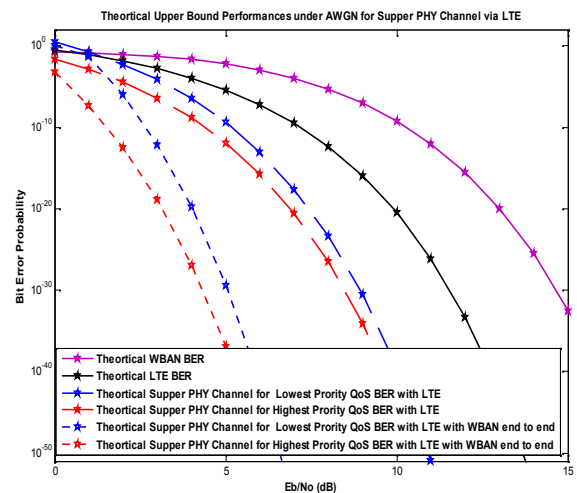


Fig. 4. Theoretical Results via AWGN channel

Then, by apply “(21),” in “(19),” will have “(23),” and apply “(22),” in “(19),” will have “(24),” . “(23),” Is a final Supper PHY proposed channel when adding WBANs code end to

end for low QoS and “(24),” for High QoS, and the proposed system code performance bounds results appear in “Table IV”.

$$P_1 \leq \sum_{i=2+1}^{63} \binom{63}{i} P_{x1}^i (1 - P_{x1})^{63-i} \quad (23)$$

$$P_2 \leq \sum_{i=2+1}^{63} \binom{63}{i} P_{x2}^i (1 - P_{x2})^{63-i} \quad (24)$$

TABLE IV
THEORETICAL ERROR PROBABILITIES VIA AWGN CHANNEL

E_b/N_0	0	1	2	3	4	5
WBANs	0.1763	0.1379	0.0933	0.0515	0.0215	0.0062
LTE	0.3256	0.0807	0.0143	0.0017	0.0001	0.0000
L-QoS	2.7957	0.1717	0.0054	0.0001	0.0000	0.0000
H-QoS	0.0251	0.0014	0.0000	0.0000	0.0000	0.0000
L-QoS-WBANs	1.0000	0.0506	0.0000	0.0000	0.0000	0.0000
H-QoS-WBANs	0.5854	0.0000	0.0000	0.0000	0.0000	0.0000

LTE = The BER for LTE only, L-QoS = The BER for Supper PHY proposed channel for Low-QoS, H-QoS = The BER for Supper PHY proposed channel for High-QoS, L-QoS-WBANs = The BER for Supper PHY proposed channel for Low-QoS with end to end connection of WBANs, H-QoS-WBANs = The BER for Supper PHY proposed channel for high-QoS with end to end connection of WBANs,

B. Theoretical Out-Come via Rayleigh Channel

For this part, the $P_{j,i}$ attenuations are random independent Rayleigh variables of probability density as in “(25),”

$$P_{(\dots_{j,i})} \cong \frac{1}{\dagger^2 \dots_{j,i}} \exp(-\dots_{j,i} / (2\dagger^2)) \prod_{\dots_{j,i}} \geq 0 \quad (25)$$

Where $E(\dots_{j,i}^2) = 2\dagger^2$ and $\prod_{\dots_{j,i}} \geq 0$ is the indicator of the set $\{\dots_{j,i} \geq 0\}$, which equals 1 if $\dots_{j,i} \geq 0$, and 0 if not. In all theoretical and simulation work for our proposed system will be estimate this Rayleigh variable as 0.55 which is greater than 0 to evaluate the supper PHY channel.

First of all, the LTE decoder calculate the first inner probability bit errors P_{bi} bound as a function of the performance of the BFSK modulation as in “(8-12),”

$$P_{bfsk} \cong \frac{1}{2} \left[1 - \sqrt{\frac{E_b/N_0}{1 + E_b/N_0}} \right] \quad (26)$$

$$P_b \leq \frac{w(df)}{b} C_{2df-1}^{df} \left(\frac{1}{4RE_b/N_0} \right)^{df} \quad (27)$$

Where, C can be calculated using the free distance d_{freei} of the inner LTE code by “(28),” and appeared in “Table III”. E_b is represents the average energy received per symbol of transmitted information, and it’s calculated as in “(25),” and given here by “(27),”

$$C_{2d-1}^d = \frac{(2d-1)!}{d!(d-1)!} \quad (28)$$

$$\overline{E_b} = E(\dots_{j,i}^2) E_b = 2\dagger^2 E_b = 0.55 E_b \text{ assumed} \quad (30)$$

Then, the inner LTE code performance, that using in this paper can be calculated by “(31-32),” and the code performance results appear in “Fig. 5”.

$$P_{bi} \leq P_{bfsk} \cdot \frac{w(dfreei)}{b} C_{2dfreei-1}^{dfreei} \left(\frac{1}{4RiE_b/N_0} \right)^{dfreei} \quad (31)$$

$$P_{bi} \leq 416 \times 77558760 P_{bfsk} \cdot \left(\frac{1}{4 \times 0.55 \cdot E_b/N_0} \right)^{15} \quad (32)$$

Generally speaking, the data stream coming from LTE inner code feed the extra code. The code performance of the outer code is a function of the inner LTE code.

Second, the outer decoder calculate the second outer probability bit errors P_{bo} bound separately as in “(33),” by the outer code parameters introduced in “Table III”.

$$P_{bo} \leq P_{bfsk} \cdot \frac{w(dfreeo)}{bo} C_{2dfreeo-1}^{dfreeo} \left(\frac{1}{4RoE_b/N_0} \right)^{dfreeo} \quad (33)$$

$$P_{bo} \leq 10970 \times 92378 \times P_{bi} \cdot \left(\frac{1}{4 \times 0.55 \cdot E_b/N_0} \right)^{10} \quad (34)$$

$$\therefore P_b \leq 10970 \times 92378 \times P_{bi} \cdot \left(\frac{1}{1.1 \cdot E_b/N_0} \right)^{10} \quad (35)$$

$$P_{bo} \leq 10970 \times 1.0520 \times 0.12 \times P_{bi} \cdot \left(\frac{1}{4 \times 0.55 \cdot E_b/N_0} \right)^{10} \quad (36)$$

$$\therefore P_b \leq 169 \times 1.0520 \times 0.12 \times P_{bi} \cdot \left(\frac{1}{0.55 \cdot E_b/N_0} \right)^{22} \quad (37)$$

Then, the outer codes performances of supper PHY channel, that using in this paper under Rayleigh fading can be calculated by “(35),” P_{b1} for Lower QoS class of medical data and “(37),” P_{b2} for higher QoS class of medical data and whole codes performance results appear in “Fig. 5”.

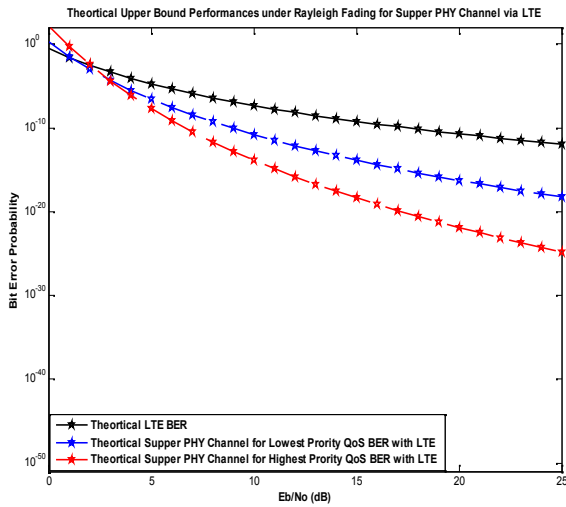


Fig. 5. Theoretical Results via Rayleigh channel

C. Simulation Out-Come via Noisy Channels

The performance of the Supper PHY Proposed Channel is evaluated using computer simulation by calculating the BER. The parameters that used in the simulations are given in “Table V” and the results via AWGN, Rayleigh fading and burst noise is proven clearly in “Table VI” and “Fig. 6-8,” The simulation tests carried by MATLAB programing under

TRCH Type	Via 4G-LTE
Channels	AWGN and Rayleigh Fading and Burst Noise
Modulation	BFSK via LTE
Receive E_b/N_o	-5 – 25 [dB]
Outer Encoder	As in Table III
Inner Encoder	LTE Standard Encoder use Convolution Code R1/3 and K=7
Interleaver	Block Interleaver
Inner Decoder	LTE Standard Decoder use SDVA[Soft]
De-Interleaver	Block De-Interleaver
Outer Decoder	Convolution Decoder with a SDVA[hard]
Data Bits	10Mb/s

AWGN and Rayleigh fading as has [formula that returns a matrix of random numbers chosen from the Rayleigh distribution with parameter 0.55, where scalars 1 and encoded data are the row and column dimensions of noisy corrupted data] and Burst Noise as [to happen every 50 bits interval for 5 bits length burst noise]. The use of internal block interval helped to improve the performance under Rayleigh fading burst noise condition. The extra outer interleaver in encoding side, deals with a two-dimensional

(encoded data/10)*(10) array. The encoded data sequence from extra outer encoder feed here as, first written into the interleaver in the x (encoded data/10) direction and then read out in the y (10) direction. The outer de-interleaver in the decoding side returns the bits as the normal position.

Analyzing system simulation results as:

- 1) The Gaussian noise channel is a main channel that has been used in this paper work to optimize the supper PHY proposed channel codes. The performances bound theoretically have been proven in this paper, in this section, the supper PHY proposal channel simulation results shown in “Fig.6” under AWGN. In the designing phase of the proposed channel we assumed to give BER 10^{-3} for lower QoS and 10^{-6} for higher QoS within at least E_b/N_o equal 2~3 dB or higher. The conventional LTE channel gives 10^{-3} at 2.4 dB where the supper PHY channel gives 10^{-3} at 1.8 dB. The improvement gain that the proposed system achieved for transmitting Lower QoS medical data through supper PHY channel is about 0.6 dB. From the other hand, the conventional LTE channel gives 10^{-6} at 4.8 dB where the Supper PHY Channel gives 10^{-6} at 2.9 dB. The improvement gain that the proposed system achieved for transmitting Lower QoS medical data is about 1.9 dB.

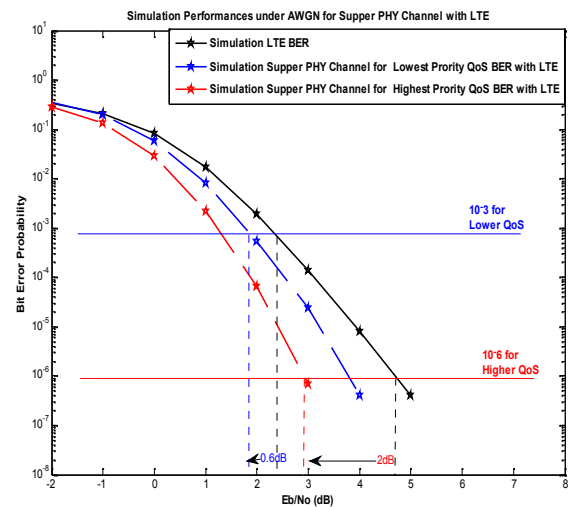


Fig. 6. Simulation Results via AWGN channel

- 2) The use of internal block interleaver helped to improve the performance under Rayleigh fading condition as we can see in “Fig. 7”.
- By all mean, the black curve shows the LTE system with no external channel added, therefore, it’s applied for non-medical data. The blue curve shows the supper PHY proposed channel and the dotted blue curve show it with using block interleaver. Therefore is applied for lower priority QoS class of medical data. The conventional LTE channel gives 10^{-3} at 7 dB where the Supper PHY Channel with interleaver gives 10^{-3} at 5

dB. The improvement gain that the proposed system achieved for transmitting Lower QoS medical data through supper PHY channel is about 2 dB. The red curve shows the supper PHY proposed channel and the dotted red curve show it with using block interleaver. Therefore is applied for higher priority QoS class of medical data.

The conventional LTE channel gives 10^{-6} at 10 dB where the supper PHY channel with interleaver gives 10^{-6} at 5.8 dB. The improvement gain that the proposed system achieved for transmitting Lower QoS medical data through supper PHY channel is about 5.2 dB.

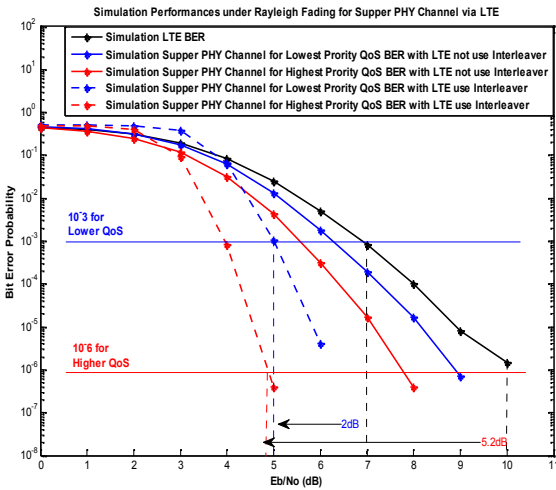


Fig. 7. Simulation Results via Rayleigh channel

- 3) The use of internal block interleaver helped to improve the performance under burst noise condition by converting the burst error to random error, as we can see in “Fig. 8”.

By all mean, the black curve shows the LTE system with no external channel added, therefore, it’s applied for non-medical data. The blue curve shows the supper PHY proposed channel and the dotted blue curve show it with using block interleaver. Therefore is applied for lower priority QoS class of medical data.

The conventional LTE channel is not given 10^{-3} , where the supper PHY channel with interleaver gives 10^{-3} at 6.5 dB. The improvement that the proposed system achieved for transmitting Lower QoS medical data through supper PHY channel is clearly appeared under this hard noisy condition. The red curve shows the supper PHY proposed channel and the dotted red curve show it with using block interleaver. Therefore is applied for higher priority QoS class of medical data.

The conventional LTE channel is not given 10^{-6} , where the supper PHY channel with interleaver gives 10^{-6} at 4.9 dB. The improvement that the proposed system achieved for transmitting Lower QoS medical data through supper PHY channel is clearly appeared under this hard noisy condition such as burst noise.

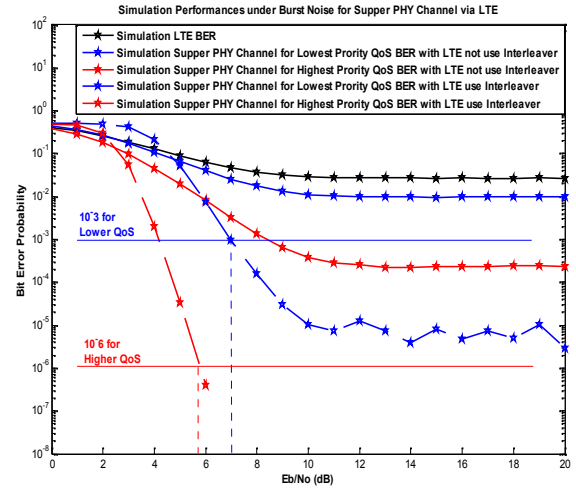


Fig. 8. Simulation Results via Burst channel

V. CONCLUSION

The paper comes by strengths is that; Cellular network LTE can transmit the medical data through the Supper PHY proposed Channel that is designed for different QoS via different noisy environmental conditions. The optimization of the Supper PHY channel came by optimizing the extra channel only, since the inner channel has been fixed regarding to the international standard LTE. End-to-end connection of WBANs is analyzing out via AWGN channel solitary.

The understanding of the eight levels of the QoS medical data has well done, however, the optimizations here have classified two classes (lower and higher) for all QoS. The medical data has been transmitted robustly by the supper PHY proposed channel, since the enhancement E_b/N_0 gap under all the environments condition has been achieved. However delaying and complexity outcome in highest QoS level made the proposed system somehow carry weakness from this point of view. Therefore, a constraint length is fixed in designing face when optimizing the extra channel code of this proposed system. Regarding to the achieving two classes of QoS requirements, the results figures above cleared carefully. However, the future works following this paper is to derive the Supper PHY proposed channel performance under multi user interference condition.

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References

- [1] “IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks,” *IEEE Std 802156-2012*, pp. 1–271, Feb. 2012.
- [2] S. Movassaghi, M. Abolhasan, J. Lipman, D. Smith, and A. Jamalipour, “Wireless Body Area Networks: A Survey,” *IEEE Commun. Surv. Tutor.*, vol. 16, no. 3, pp. 1658–1686, Third 2014.
- [3] L. Wang, N. An, A. H. Sodhro, D. Qiao, Y. Zhou, and Y. Li, “Power-Aware Wireless Communication System Design for Body Area Networks,” *E-Health Telecommun. Syst. Netw.*, vol. 02, no. 02, pp. 23–28, 2013.
- [4] I.-H. Kim, G.-M. Jeong, E.-C. Park, and K.-D. Chung, “A WPAN Platform Design in Mobile Phone Considering Application Development and Usability,” *Int. J. Comput. Commun. Control*, vol. 7, no. 1, pp. 73–89, Mar. 2012.

- [5] R. Mc Sweeney, C. Spagnol, E. Popovici, and L. Giancardi, "The Impact of Source and Channel Coding in the Communication Efficiency of Wireless Body Area Networks," *Int. J. Adv. Softw.*, vol. 2, no. 4, pp. 337–348, Mar. 2010.
- [6] H. Cao, V. Leung, C. Chow, and H. Chan, "Enabling technologies for wireless body area networks: A survey and outlook," *IEEE Commun. Mag.*, vol. 47, no. 12, pp. 84–93, Dec. 2009.
- [7] Shah Murtaza, "QoS Taxonomy towards Wireless Body Area Network Solutions," *Int. J. Appl. Innov. Eng. Manag. IJAEM*, vol. 2, no. 4, Apr. 2013.
- [8] European Telecommunications Standards Institute, "LTE; Evolved Universal Terrestrial Radio Access (E- UTRA); Multiplexing and channel coding." ETSI TS 136 212 V10.1.0(2011-04).
- [9] E. Ahmed and R. Kohno, "Dependable medical network based on 2G and 3G cellular mobile standards with external channel code in concatenated code structure," in *International Journal of Communication and Computer Engineering (JICCE)*, 2014. ISSN:2010-3743.
- [10] European Telecommunications Standards Institute, *TS 125 222 - V9.1.0 - Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (TDD) (3GPP TS 25.222 version 9.1.0 Release 9)*. 2010.
- [11] S. Lin and D. J. Costello, *Error control coding: fundamentals and applications*. Upper Saddle River, N.J.: Pearson-Prentice Hall, 2004.
- [12] R. H. Morelos-Zaragoza, *The Art of Error Correcting Coding*. John Wiley & Sons, 2006.
- [13] S. Semenov and E. Krouk, *Modulation and Coding Techniques in Wireless Communications*. John Wiley & Sons, 2011.
- [14] C. Schlegel and L. Perez, *Trellis coding*. IEEE Press, 1997.
- [15] Alain Glavieux, *Channel Coding in Communication Networks: From Theory to TurboCodes -*. 2007.
- [16] Shah Murtaza, "QoS Taxonomy towards Wireless Body Area Network Solutions," *Int. J. Appl. Innov. Eng. Manag. IJAEM*, vol. 2, no. 4, Apr. 2013



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