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# Medical Reliable Network Using Concatenated Channel Codes through GSM Network

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*Abstract*— **Although the 4th generation (4G) of global mobile communication network, i.e. Long Term Evolution (LTE) coexisting with the 3rd generation (3G) has successfully started; the 2nd generation (2G), i.e. Global System for Mobile communication (GSM) still playing an important role in many developing countries. Without any other reliable network infrastructure, GSM can be applied for tele-monitoring applications, where high mobility and low cost are necessary. A core objective of this paper is to introduce the design of a more reliable and dependable Medical Network Channel Code system (MNCC) through GSM Network. MNCC design based on simple concatenated channel code, which is cascade of an inner code (GSM) and an extra outer code (Convolution Code) in order to protect medical data more robust against channel errors than other data using the existing GSM network. In this paper, the MNCC system will provide Bit Error Rate (BER) equivalent to the BER for medical tele monitoring of physiological signals, which is $10^{-5}$ or less [1]. The performance of the MNCC has been proven and investigated using computer simulations under different channels condition such as, Additive White Gaussian Noise (AWGN), Rayleigh noise and burst noise. Generally the MNCC system has been providing better performance as compared to GSM.**

## I. INTRODUCTION

The use of telecommunications in health care has developed exponentially in recent decades, and has enhanced opportunities for patients especially in remote areas. The mobile telemedicine system design based on GSM was addressed recently in [2-3]. Tele-monitoring is one of the telecommunication techniques that access delivery to healthcare services for people in remote areas. Tele-monitoring is the transmission of physiological signals, such as, electrocardiogram (ECG) and blood oxygen saturation (SpO2). Tele-monitoring is especially useful for patients at home and in ill-equipped healthcare facilities that require monitoring of their physiological signals [4-6]. The structure of digital communication systems consists of a transmitter, transmission channel and a receiver. In the receiver, error detection and correction techniques can be applied to provide better reception quality. The essential part of communication is to ensure that the receiver can correctly interpret the transmitted symbols. Through Error detection and correction techniques; the digital signals become more reliable in a noisy communications environment, because these techniques usually can detect and correct the errors. On the other hand errors control coding techniques play an important role. However it lets the digital data to be encoded in such a way that it introduces dependency among large number of symbols, thus enabling the receiver to create a more accurate detection of the symbols [7]. Bit Error Rate (BER) is defined as the ratio of Erroneous bits received to the total number of bits received. In digital communication systems, BER is used instead of Signal to Noise Ratio (SNR) to determine the received signal quality. BER is particularly useful in measuring the error probability *(Pe)* of different error control coding techniques with respect to the ratio of information bit energy to noise power spectral density *(Eb/No)* values [7]. Reliable transmission of tele-monitoring physiological signals, which are critical to the diagnosis, and treatment of diseases are essential. Reliability in tele-monitoring system defines as the probability of the system to operate successfully under environment conditions; successfully mean that transmitted messages are reach their destination completely uncorrupted. Reliable transmission procedures must guarantee detection and correction of erroneous transmissions. However, the transmission channel is often subject to various disturbances and interferences from the external environment (noise) [8]. Any type of noise can corrupt the physiological signals during transmission. In spite of the GSM standard including significant amounts of error correction, some errors may still be present in the received data. These transmission errors can have fatal outcomes [9]. A high level of reliability can be obtained by introducing redundancy bits in the signal transmission (encoding). The paper focuses on implementing a system (MNCC) based on channel coding for transmitting medical data using concatenated channel code which adds extra channel code with the GSM standard channel code. This protects the physiological signals against errors and undesirable signals that may occur during transmission. GSM channel is standard, which is fixed by European Telecommunication Standard Institute (ETSI) [9-11]; the technical parameter can't be change in order to provide good system performance. The only one way is to design good extra outer channel code with strong decoding capabilities resulting in better performance compared to GSM alone.

The rest of this paper is organized as follows. In section II, the technical design of GSM data channel TCH/F9.6 is addressed. In section III, the effectiveness of the concatenated channel to design a simple MNCC is demonstrated. The system performance and simulation results are shown in section IV. Finally, a conclusion is given in section V and future work in section VI.

## II. GSM DATA CHANNEL TCH/F9.6

In GSM the traffic channel (TCH) is used to transmit voice and data [9-11]. In this paper we studied error control performance of GSM channel coding scheme for Traffic Channel of Full rate (TCH/F9.6) as a base to design MNCC.

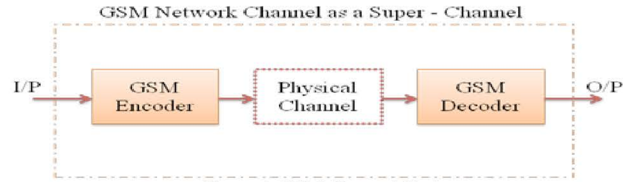


Figure.1.GSM Channel Code

### A. GSM Encoder

The GSM Encoder shown in “figure.1” is used to encode the data. It consists of a tail bits inserter, a convolutional codes encoder, a puncturer, and an interleaver. It is briefly explained as; first the user unit delivers to the encoder a bit stream organized in blocks of 240 bits every 20ms $\{c_o(0),\ldots c_o(239)\}$. And then in the second stage, the block of 240 bits is not encoded but only increased with 4 tail bits equal to 0 at the end of the block as.

$d(c_o) = d(c_o)$ for $c_o= 0,1,2,\ldots. 239$ (1)

$d(c_o)=0$ for $d(240), d(241), d(242), d(234)$ “tail bit” (2)

After that, the block of 244 bits $\{d(0),\ldots d(243)\}$ is encoded with the 1/2 rate convolution code defined by the following polynomials

$$G_0 = 1+D^3+D^4 \qquad (3)$$

$$G_1 = 1 + D +D^3+D^4 \qquad (4)$$

The result of that is 488 coded bits $\{c_i(0), c_i(1),\ldots c_i(487)\}$ with

$$C_i(2c_o) = d(c_o) + d(c_o-3) + d(c_o-4) \qquad (5)$$

$$C_i(2c_o+1) = d(c_o) + d(c_o-1) + d(c_o-3) + d(c_o-4) \qquad (6)$$

for $c_o = 0,1,\ldots,243$ ; $d(c_o) = 0$ for $c_o < 0$

Then, the code is punctured in such a way that the following 32 coded bits are not transmitted as

$\{C_i(11+15i)$ where $i=0,1,\ldots,31\}$ (7)

The result is a block of 456 coded bits, $\{c_i(0),\ldots c_i(455)\}$. After encoded stage there is interleaving stage. The 456 bits are interleaved according to

$i(B,j) = x(n,c_i)$ (8)

Where $c_i = 0,\ldots.455$ and $n= 0,1,\ldots.,N,N+1,\ldots\ldots$and $B=B0 +4v+ c_i \bmod (19) + c_i \operatorname{div} 114$ and $j= c_i$ mode $(19) +19\ [c_i \bmod (6)]$

The result of interleaving is a distribution of the reordered 114 bit of a given data block, n = N, over 19 blocks, in each block 6 bits equally distributed, in a diagonal way over consecutive blocks.

### B. GSM Decoder

The GSM decoder shown in "figure.1" is used to decode the coming encoded data. It consists of a stealing flag cutter, a de-interleaver, a delayer, a de-puncturer, a convolutional codes decoder, and a tail bits cutter. Two stealing flag bits are cut from each 116-bit block; the remaining 114-bit block is de-interleaved in a diagonal manner. A delay of 228 bits is inserted to keep the bit index consistent. Four 114-bit de-interleaved blocks are combined, de-punctured and convolutionally decoded by soft decision viterbi algorithm. Four tail bits are cut from every 244 bits. So the length of output bits from GSM decoder is 240bits same as the input length.

## III. DEPENDABLE MEDICAL NETWORK CHANNEL CODE SYSTEM (MNCC) THROUGH GSM NETWORK

The MNCC base on Concatenated channel code as shown in “figure.2”. It consists of the cascade of an inner code (GSM) and outer convolution code. The proposal uses concatenating two convolution codes [12]. Since GSM decoder standard is inner soft Viterbi decoder, the soft decoder provides soft-input decisions to the outer Viterbi decoder. Block interleaver proposed between the two encoders when the channel affected by seriously noise such as Rayleigh or burst noise to separate bursts of error produced by the inner decoder as shown in “figure.3”.

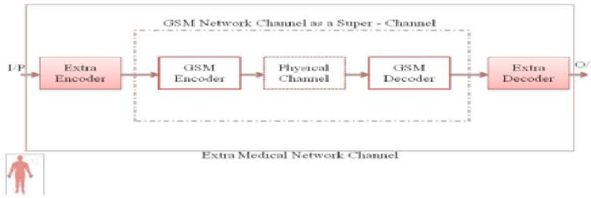


Figure.2.Concatenated Channel Code

More detail about MNCC structure in the “figure.3” below. The two main parts in MNCC parts are extra encoder and extra decoder.

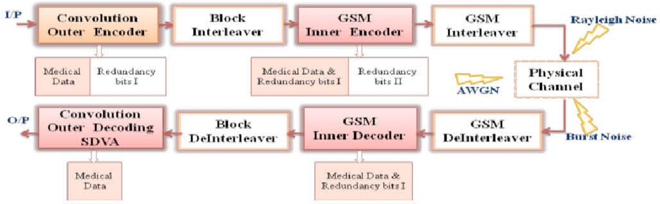


Figure.3.MNCC System

### A. Extra Encoder

The Extra Encoder consists of three parts; outer encoder, outer interleaver, inner encoder. We propose the outer encoder as a convolution encoder. The block of10000 bits with a frame length 60 bit/20ms $\{d(0),\ldots d(59)\}$ is encoded with the 1/4 rate convolution code defined by the following polynomials:

$$G_0 = D^2 + D^3 + D^4 \qquad (9)$$

$$G_1 = 1 + D + D^2 + D^3 + D^4 \qquad (10)$$

$$G_2 = 1 + D + D^2 + D^3 + D^4 \qquad (11)$$

$$G3 = 1 + D + D^4 \qquad (12)$$

The result is 240 coded bits {c(0), c(1),…c(239)}with

$$C_o(4k) = d(k-2) + d(k-3) + d(k-4) \tag{13}$$

$$C_o(4k+1) = d(k) + d(k-1) + d(k-2) + d(k-3) + d(k-4) \tag{14}$$

$$C_o(4k+2) = d(k) + d(k-1) + d(k-2) + d(k-3) + d(k-4) \tag{15}$$

$$C_o(4k+3) = d(k) + d(k-1) + d(k-4) \tag{16}$$

for k = 0,1,...,60 ; d(k) = 0 for k < 0

The outer interleaver we proposed as block interleaver, which deals with a two-dimensional (encoded data/24)*(24) array. The encoded data sequence from outer encoder first written into the interleaver in the x direction and then read out in the y direction. As described in “figure.4”. The inner encoder is GSM encoder which we detailed in section II part A

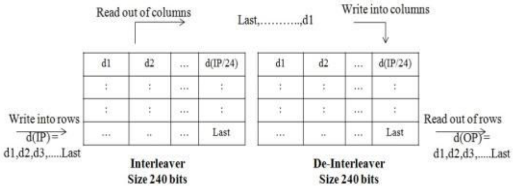


Figure.4.Outer Interleaver and De-interleaver

### B. *Extra Decoder*

The Extra Decoder consists of three parts; inner decoder, outer de-interleaver and outer decoder. A natural concept about a decoding algorithm for concatenated codes is to first decode the inner code and then the outer code. The inner decoder is GSM decoder which we detailed in section II part B. As in “figure.4”; the outer de-interleaver returns the bits as the normal position. The outer decoder that we propose works SDVA; In Soft decision decoding, the received codeword is compared with all the possible code words by calculating the Euclidean distance and then the codeword that gives minimum Euclidean distance is selected. As mentioned above, the structure of whole system in “figure.5” below.

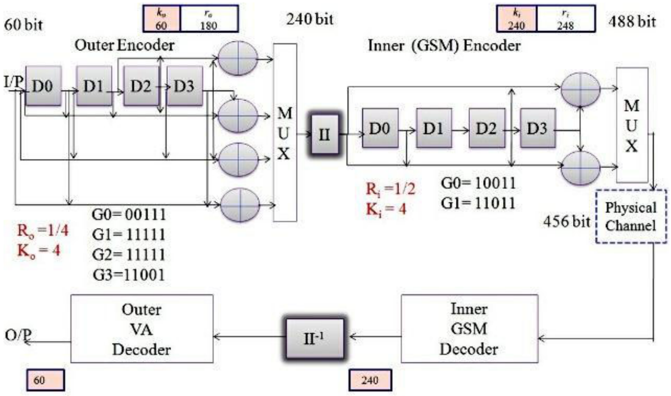


Figure.5.The MNCC System Structure

## IV. MNCC SYSTEM PERFORMANCE

### A. *Simulation Parameters*

In this part, the performance of the MNCC is evaluated using computer simulation. The parameters that used in the simulations are given in the following “Table.1”.

Table I. Simulation parameters of MNCC

| | |
|---|---|
| Channel | AWGN or Rayleigh Noise (0.55) or Burst Noise (Interval =70 & lengths 7) |
| Modulation | Gaussian Minimum Shift Keying (GMSK) |
| Receive $E_b/N_o$ | -2 – 20 [dB] |
| Outer Encoder | Before fix the rate R:1/2,1/3,1/4 or 1/5<br>After fix Rate = 1/4for desired $E_b/N_o$ =2.6 (GN)<br>Constrain Length = 3,4,5,7 or 9 and fixed 4<br>Generator module:<br>G0 = 00111,G1 =11111,G2 = 11111,G3=11001 |
| Inner Encoder | GSM Standard Encoder |
| Interleaver | Block Interleaver size 240 bits/20ms |
| Inner Decoder | GSM Standard Decoder |
| Outer Decoder | Convolution Decoder with a Viterbi Algorithm |
| Information Bits | 600,000 bits: 10000 blocks with 60 frame length |

### B. *Selection of the outer code parameters*

In MNCC, the convolution code is used as an outer code as explained in Part III. In convolution code, the main two parameters that can play an important role in the BER performance are the code rate (R) and constrain length (K), here we detailed under AWGN. The change of K with fix R=1/4; illustrated in “figure.6”. Even though the BER performance is improved significantly by increase K, that adds complexity in the trellis structure and delay to find the survivor path; for that we fixed the K=4 for MNCC. On the other hand, the change of the R with fix K=4; illustrated in “figure.7”. Even though the BER performance is improved significantly by reduce R the input data frame is decreasing, which mean decrease the data rate. Decreasing an input data frame lets the redundancy increase to keep the output fixed 240 bit as a frame length to be input for GSM encoder. The selection of the outer code rate is base on the received signal to noise ratio power. The desired BER is $10^{-5}$, for example if the desired $E_b/N_o$ is 2.6 dB the outer code rate should be 1/4 as shown in “figure.7”.

### C. *Simulation Results*

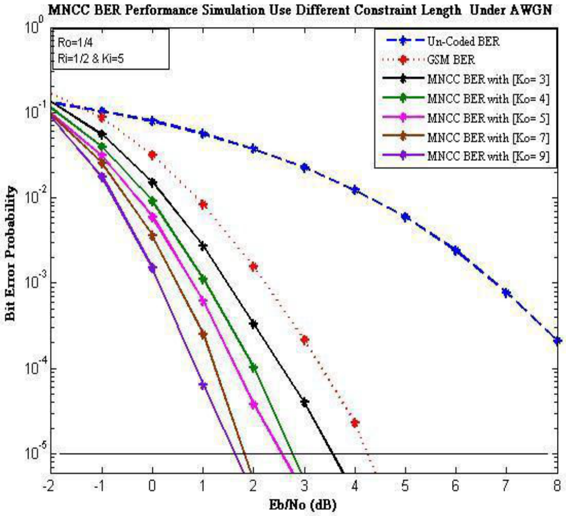


Figure.6. MNCC under AWGN for Ro 1/4 with Different K

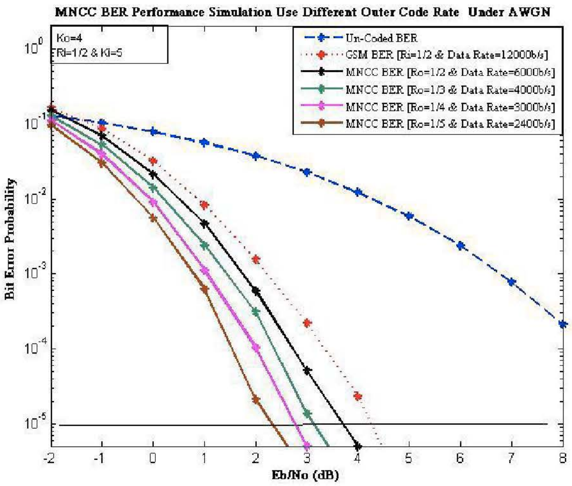


Figure.7. MNCC under AWGN for Different R

The BER performances of GSM and MNCC are illustrated in "figures.8" below. The error probability $10^{-5}$ for MNCC system under AWGN channel; achieved in $E_b/N_o$ 2.6 dB; it shows improved result of BER in compare to GSM which is 4.4dB, the gain about 1.8 dB. The error probability $10^{-5}$ for MNCC system under Rayleigh Noise; achieved in $E_b/N_o$ 12.2dB without interleaver and with interleaver is 6.7dB; it shows improved result of BER in compare to GSM which is 16.3 dB with it interleaver. Finally under Burst Noise channel, the error probability $10^{-5}$ is achieved with using the interleaver. However the BER performance of the MNCC system has improved significantly by increase $E_b/N_o$ under these types of noise channels.

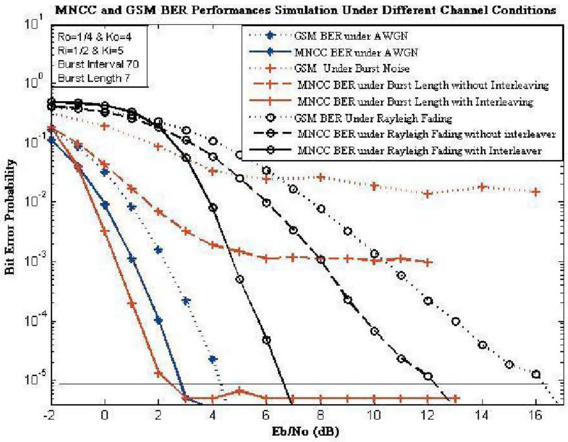


Figure.8. MNCC under Different Noise Conditions

## V. CONCLUSION

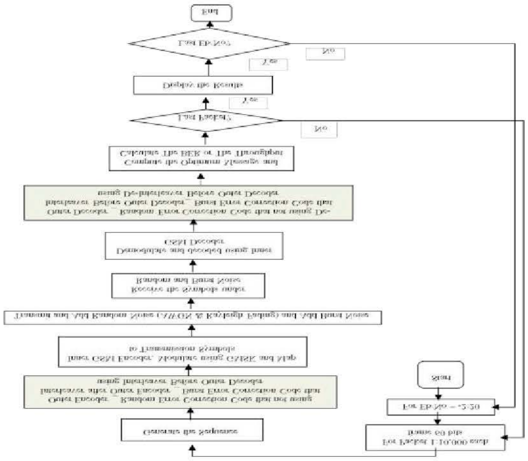
In this paper, we introduce simple design for medical channel code through GSM Data Channel; using Concatenated codes as in the Algorithm in Appendix. That is in order to have a system more reliable and dependable for send more critical signals such as physiological signals. From the simulation results we found better performance for MNCC as compared to GSM performance and we achieved the desired BER $10^{-5}$ under the different noise that assumed such as AWGN, Rayleigh noise and burst noise channels.

## VI. FUTURE WORKS

- Applying the proposal on the 3G, and test it by send medical data more practically,

## APPENDIX

MNCC ALGORITHM USED IN SIMULATION



## ACKNOWLEDGMENT

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