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Improvement of QoS for 5G System using UTTCM coder over EPA channel

***Abstract**. The year 2020 was marked by an important scientific leap in communication systems, it is the 5G network that everyone has been waiting for, thus, it's time for the superfast speeds that 3G, 4G, and 4.5G (LTE Advanced) didn't deliver. The world become faster year by year, and need more of internet speed, need more of technologies that make our life easier. So here is 5G try to satisfy this need and try to achieve success in accessing communication at anytime, anywhere, and for anybody. So during this article, we will study 5G system based on the channel coder structure, and propose a substitute coder called "Unpunctured Turbo Trellis-coded Modulation" (UTTCM) in order of the iterative channel coding called "Turbo-Code" (TC) to improve the performance of (QoS) (in terms of BER) and through EPA channel model. The simulation results showed that the UTTCM coding has the most efficient and less complex channel coding in the 5G system.*

***Streszczenie.** Rok 2020 upłynął pod znakiem ważnego naukowego skoku w systemach komunikacyjnych, to sieć 5G, na którą wszyscy czekali, więc czas na superszybkie prędkości, których nie zapewniały 3G, 4G i 4,5G (LTE Advanced) . Świat z roku na rok staje się coraz szybszy i potrzebuje coraz większej prędkości internetu, coraz więcej technologii ułatwiających nam życie. Więc oto 5G próbuje zaspokoić tę potrzebę i spróbować osiągnąć sukces w dostępie do komunikacji w dowolnym czasie, miejscu i dla każdego. Dlatego w tym artykule przestudiujemy system 5G oparty na strukturze kodera kanałowego i zaproponujemy koder zastępczy o nazwie „Unpunctured Turbo Trellis-coded Modulation" (UTTCM) w kolejności iteracyjnego kodowania kanałów o nazwie „Turbo-Code" (TC) w celu poprawy wydajności (QoS) (pod względem BER) oraz poprzez model kanałów EPA. Wyniki symulacji wykazały, że kodowanie UTTCM charakteryzuje się najbardziej wydajnym i mniej skomplikowanym kodowaniem kanałów w systemie 5G. (**Poprawa QoS dla systemu 5G przy użyciu kodera UTTCM przez kanał EPA**)*

Keywords: 5G, UTTCM, channel coding, TC.
Słowa kluczowe: 5G, UTTCM, kodowanie kanałów, TC.

Introduction

The work presented in this article is in the field of mobile communication networks and more particularly on the 5th generation. 5G comes with new promises in terms of connectivity, performance, and geographical coverage. 5G should facilitate the emergence of a huge IoT ecosystem in which networks will be able to meet the communication needs of billions of connected objects, thanks to a balanced compromise between speed, latency, and cost. The main evolution from today's 4G and 4.5G (LTE Advanced) is that beyond the improvement in data transmission speed, new use cases for IoT and mission-critical communications will require new types of improved performance. The 5G gives the user data-rate greater than 1Gbps (data-rate of 4G is 100Mbps), also the number of connected devices is higher than the number of connected devices connected in 4G. The 5G aimed to give better services and connectivity in a crowded place, support a huge number of devices consuming low power (resolve the problem of a battery), aimed an intelligent handover with the least delay during the switching of the network, also intends to solve the issue of spectrum crisis in the maximum possible by the utilization of white spectrum and give data-rate and other services in indoor area equivalent to an outdoor area.

The most important factor that leads to the quality and durability of the mobile cellular network is related to the power and efficiency of the bloc "channel coding". That's why channel coding is one of the most important terms in today's communication systems. The challenge of coding digital information is to be able to recover the information well at the reception, as little as possible affected by the noise of the transmission channel. Over time, many researchers around the world have discovered a large number of powerful codes that detect and/or correct errors. The most famous of these codes we can be named is the (Turbo Code) presented by Berrou and al [1], which was the first error-correcting code too closely approach the channel capacity [2]. Coding is a digital function and modulation is an analog function [3]. These functions are done separately and independently in the most common modulation schemes. In Trellis Coded Modulation (TCM), however, the two are combined in one function by optimizing the Euclidean distance between code words. The Algorithm often used in decoding is the Viterbi or the Bahl–Jelinek (symbol-by-symbol MAP) algorithm.

In 1995 Robertson and Wörz [4] merge TCM and Turbo codes together in order to benefit from their both important structures properties and advantages, and proposed the "Turbo Trellis Coded Modulation" (TTCM) [2]. The encoder structure of the TTCM is made up of two identical TCM encoders in a parallel concatenation linked by a symbol interleaver. The Unpunctured Turbo Trellis Coded Modulation (UTTCM) [2, 5] is another more recent powerful coded modulation technique proposed [6] in 2007 and its design was improved in 2013 [7], the UTTCM transmits together: the input information bits and the 2 parity check bits from the two-component coders in the same codeword. In this paper two powerful codes are studied, the turbo code and the proposed substitute coder UTTCM, by comparing them to improve the QoS in the 5G system. The remaining part of the paper is organized as follows. Section II provides a brief overview of the evolution from the 2G to 5G on the coding used, then section III contain some notions of channel coding, in section IV we present the parameters of the two code used in our work (Turbo code and UTTCM) after we present and we discuss our result of simulation. Finally, we conclude our paper with a conclusion

Brief survey about evolution from the 1G to 5G

Over time the world has witnessed many huge great discovers in the cellular communication network, some of these most important discoveries we can name for example SAMUEL.F.B.MORSE who developed the telegraph and sent the first letter to his friend in 1848, whenever we think of wireless communications we can never start without paying tribute to the great Maxwell equations, in 1865 Maxwell demonstrated that electric and magnetic fields travel through space and this was the genesis of wireless communication, The next important stage as you all know was due to Hertz who demonstrated the existence of electromagnetic waves in 1880, And many hundreds and thousands of engineers and scientists all over the world who has gone together to produce the technologies which was the reason to the rapid evolution of cellular communication technologies from 2G GSM system to 5G. The evolution of wireless communication is primarily about the evolution of data rates as well as spectral efficiency which means more bandwidth and low latency. Bandwidth is the measurement of channel capacity or the maximum rate of information transfer possible over a noisy channel. The other important parameter latency is the time delay between the sender sending the message and the receiver decoding the same after receiving [8]. 5G is especially different compared to the other previous generation because he aims to provide a very high data rate also supports very high mobility, and we are going to see different technologies like millimetre range of spectrums, MIMO (they have been presented in the previous generation like massive MIMO and beam-forming), also we gone to see the heterogeneous network, IoT, Machine to Machine (M2M), Device to Device (D2D) and Space Division Multiple Access (SDMA).

We find that is necessary and very important to look back into the past at least to the basics and technologies used in the previous generation to help us for developing the system mobile communication, so, in the table 1 we summarize the different technologies from 1G to 5G. However, as we see that analog modulation slowly moved toward digital modulations. The access technique moved from time division to multiple access to code division multiple access; then there was wideband code division multiple access and when things move towards 5G there was orthogonal frequency division multiple access.

Table 1. Evolution of mobile communication systems from the 1G to 5G

	1G	2G/2.5G	3G	4G	5G
Evolution year	1970 /1980	1982 / 1992	1990/2000	2010	2020
Standards	NMT AMPS	GSM	UMTS CDMA-2000	LTE LTE- ADVENCED	IMT-2020
Data Rate	10 Kbps	10 -115 Kbps	0.114 -10Mbps	More than 100 Mbps	More than 1 Gbps
Technology	Analog voice switching Cellular concept FM modulation Hard handover	Digital Voice+data Higher data rate Error control Soft handover	Wireless internet High data rate High QoS support Wide area	Mobile Broadband multimedia Heterogeneous network Real broadband at wide area Radio cognitive	Wireless EDGE IoT, M2M D2D, SDMA Millimetre wave MIMO(beam forming/ massive) Small cellule
Multiplexing technique	FDMA	TDMA/ CDMA	WCDMA	OFDMA	OFDMA
Handoff	Horizontal	Horizontal	Horizontal	horizontal And vertical	horizontal And vertical

Channel CODING

Channel coding is often used to protect digital information from noise and interface and reduce the number of bits errors by introducing redundant bits which they allow the detection and correction of bits errors. We find basically two types of time encoding known as:

1) Block code: the block code is the division of the sequence of bits sent to a number of fixed bits called a code word that has well-defined mathematical properties where the information bits are followed by the parity check bits to detect and correct block of errors. Hence, we process and treat each block of information independently of each other. The block codes are generally divided like the Figure 1 shows.

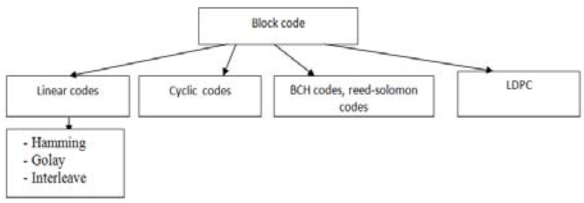

Fig. 1. Schema of block code

2) Convolution codes: They are the most widely used channel codes in particle communication systems; these codes are developed with a separate strong mathematical structure and are primarily used for real-time error correction, convolution codes, Unlike block codes, convert the entire data into one single code word, the encoder which depends not only on the current K input but also on the past input bits by using memory. Over time convolution codes have many wide advances researches to extend and improve the basic coding schema algorithm, now this advancement has resulted in two powerful coding schemas known as TCM and TC.

2-1 TURBO CODE: Turbo code is a class of parallel concatenated convolutional code, where concatenation means we take small codes (any type of code for example convolution, block….) and combine them in parallel or serial to create a more powerful code. The idea of concatenation is proposed for the first time by DAVID FORNEY. Turbo code structure usually consists of two or more recursive systematic convolutional encoders in a parallel concatenation schema, where the same information is sent in the two encoders but after getting interleaved. The concept is that the first encoder operates on the information sequence directly whereas the second encoder operates on the interleaved version of the information sequence [9]. The turbo decoder uses a MAX-Log-MAP algorithm as the constituent decoder component. The internal interleaver of the decoder is identical to the one the encoder uses [10].

2-2 TRELLIS CODE MODULATION: Trellis code is a version of convolution coding invented by Gottfried Ungerboeck of IBM in 1982[11] where he increases the data rate without increasing transmitted bandwidth by doubling the number of constellation points of the signal [12]. Thus, the function of TCM consists of trellis code and a constellation mapper, constructed from a constellation with M = 2n+1 points, the spectral efficiency of the transmission is n bits / s / Hz and the performances of the TCM are compared with those of modulation to 2n states; that is to say, having a 2-point constellation. The constellation of a TCM, therefore, has twice as many points as that of the uncoded modulation having the same spectral efficiency [13]. Trellis codes allow code design directly for the maximization of Euclidean distance where The Euclidean distance amongst constellation points is increased at every partition step.

Simulation results of the 5G system

Since the term 5G appeared researchers all around the world pay particular attention to improving the QoS in 5G systems by doing their research in all the block layers of the channel transmission as all [9,10,14,15,16]. Moreover, this leads us to find the most appropriate channel code that achieves the needs of the 5G system by proposing a substitute encoder called UTTCM and comparing it to TC using Matlab tools, focusing in particular on the channel coding block by varying the different parameters. Table 2 shows the different parameter values of TC and UTTCM used during our simulation.

Table 2 parameters of UTTCM and TC

Parameter	TC	UTTCM
modulation	256-QAM,1024-QAM,4096-QAM	32QAM,64QAM
coding rate	1/3	3/5 , 4/6
channel model	EPA	EPA
N° iteration	5	1, 2, and 3
Algorithm decoding	Log-MAP	Log-MAP

Three elements form, mainly, mobile communication systems: The transmitter, the receiver, and the transmission medium. One of the important transmission medium is the radio propagation. Knowing that there is a different channel model of radio classified by their characterized (path loss, shadow fading, multipath fading….), these environments are described in Recommendation ITU-R M.1034 which specified three different test environments: indoor office, pedestrian, and vehicular [17]. This section will describe and identify the propagation model recommended for 5G systems and used in our simulation. The terrestrial environments are Classified based on the size of their cellular, thus we identify Rural (or semi-rural) macro-cells their size is greater than several tens of KMS, and it has a low density of obstacles of human origin, moreover we have Urban (or semi-urban) micro/Pico-cells environment Their size ranges from a few tens to a few hundred meters to a few kilometres, depending on the density of habitation finely Indoor environment (Femto-cells): Femto-cells are small cells of around ten meters in radius, mainly intended to cover a dwelling or an office floor. Faced with ever-increasing demand, 5G systems have had to density their network: they increase the number of base stations and reduce the size of the cells to micro-cellular. ITU recommends that the pedestrian models, which are designed to model either indoor or outdoor pedestrian environments to be used to represent multipath conditions in micro-cells. These environments are characterized by low transmission powers, low antenna heights, and low mobility (3-4 km/h) [18]. The characteristics of the EPA channel model used in our simulation are given in Table 3, its characteristics are based on the number of taps that reach the receiver, the time delay relative to the first tap (LOS tap), and the maximum Doppler shifts for each tap.

Table 3. Tapped-delay line EPA channel

Tap n°	τ(ns)	SMR (dB)
1	0	0.0
2	30	-1.0
3	70	-2.0
4	90	-3.0
5	110	-8.0
6	190	-17.2
7	410	-20.8

Unpuntured Turbo Trellis Code Modulation:

The UTTCM code is created from the concatenation of two RS (recursive systematic) TCM encoders of rate m/(m+1) encodings the same information after using a random interleaver or pseudo-random. The two encoders are in fact strictly equivalent structures, having the same generator polynomials and the same trellis diagram is common. Figure 2 shows the structure of the UTTCM proposed.

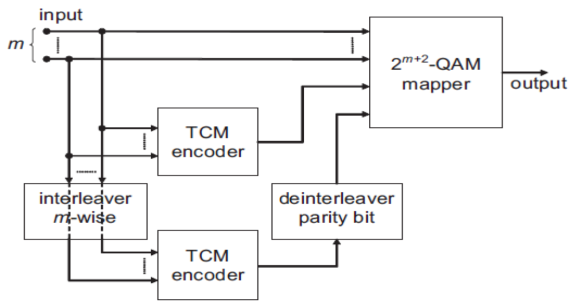

Fig. 2 encoding schema of UTTCM [7]

a)

b)

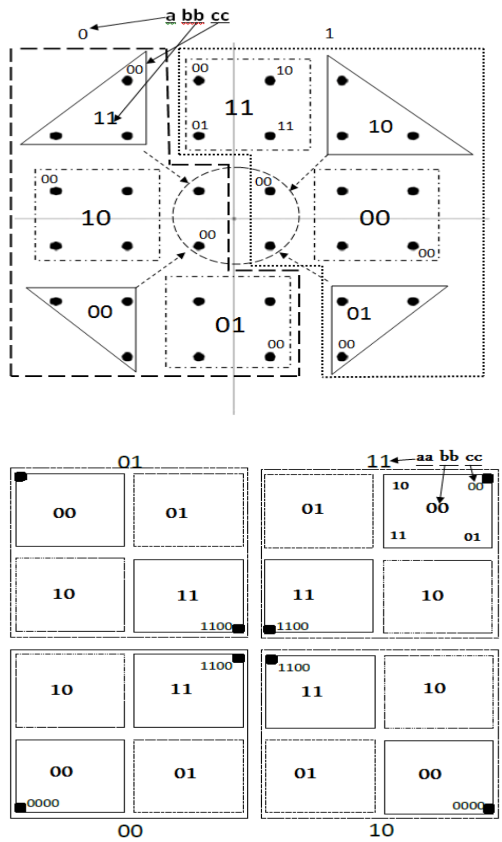

Fig. 3 consetallation of (a) 32-QAM (b) 64-QAM with Gray mapping

The UTTCM encoder used in this work is with m bits input and (m+2) bits output and the following table contains the generator polynomials of TCM encoders with 8-state for

Gray mapping in conjunction with a 32-QAM and 64-QAM modulation.

Table 4. Generator polynomials of 8-state for 32-QAM and 64-QAM

N° states	M	h0	h1	h2	h3	h4
	3	13	11	05	13	/
8	4	13	11	05	11	04

Figure 3 presented the constellation of the two modulation 32-QAM, and 64-QAM with the Gray mapping technique.

Interpretation of simulation results

In this section, we present and interpret the simulation results of UTTCM with modulation 32-QAM and 256-QAM for TC shown in Figure 4, later we compare the 64-QAM modulation for UTTCM, and 1024-QAM, 4096-QAM for TC in Figure 5 and Figure 6 using the Gray mapping for all the different modulation and experiment on 5G systems over the EPA channel.

From Figure 4 we can clearly see that for an efficiency spectral of 3 bps for UTTCM made up of two identical 8-state with rate 3/5, and 32-QAM modulation, on the other side TC has an efficiency spectral less than UTTCM equal to 2.66 bps with a rate 1/3 and 256-QAM modulation, the UTTCM coder has a good performance and low complexity compared to the TC with gain measured when BER=10-5 we found G=5.7dB.

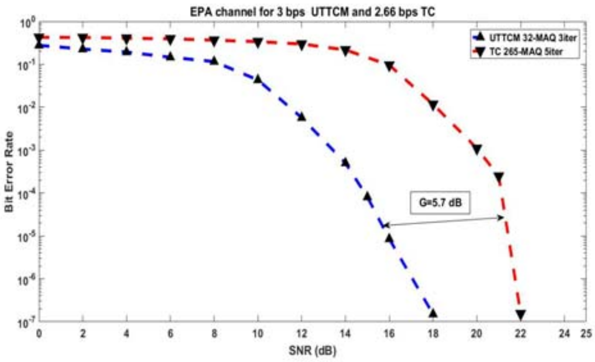

Fig. 4 performance comparison on the 5G system using UTTCM (32-MAQ) and TC(256-MAQ) over EPA channel

In this case (Fig 5), the UTTCM has a rate of 4/6 and 64-QAM while the TC has a rate of 1/3 and 1024-QAM, we observed that even when the UTCM has a spectral efficiency of 4 bps greater than the spectral efficiency of Turbo code 3.33 bps, the UTTCM always shows great performance and low complexity with gain=6.1 dB for BER=10-5.

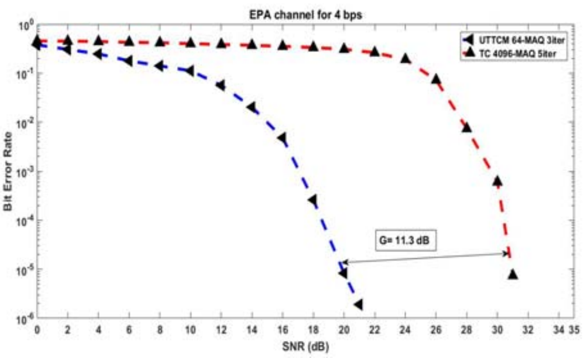

Fig. 5 performance comparison on the 5G system using UTTCM (64-MAQ) and TC (4096-MAQ) over EPA channel.

Finally, for the same efficiency spectral 4 bps and the same previous rate of the two encoders but with 64-QAM modulation for UTTCM and 4096-QAM modulation for TC, figure 6 shows that the Bit Error Rate (BER) of the proposed coded is lower than the BER of TC, which leads us to say that the UTTCM code is more efficient than the TC code with G=11.3dB for BER=10-5

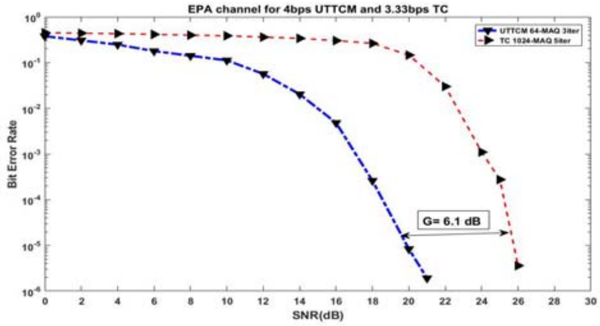

Fig. 6 performance comparison on the 5G system using UTTCM (64-MAQ) and TC (1024-MAQ) over EPA channel

The influence of iteration number with decoder complexity.

To confirm our results, we will show the iterative behavior of the UTTCM encoder, knowing that more the number of iterations increase, more the degree of complexity increases. The figures (07, 08, and 09) show the effect of the character iterative on the UTTCM encoder and compare them with the TC. These figures clearly show that the BER decreases as the number of augmented iterations. On the other hand, the curves show that the UTTCM code is a better BER than the turbo code.

These figures show that the UTTCM compared to turbo-code is better.

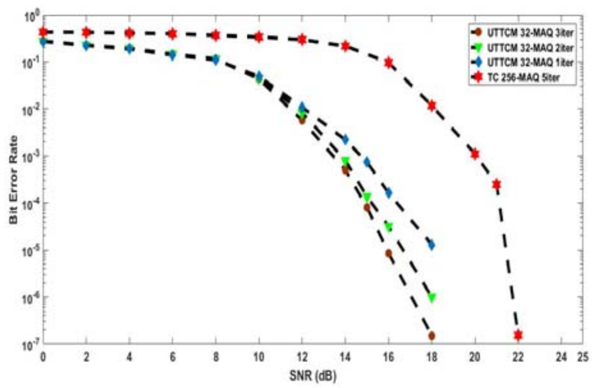

Fig. 7.The BER evaluation of the UTTCM code with 32-QAM at 1th, 2th, and 3th iterations, and the turbo-code with 256-QAM at the 5th iteration on the EPA channel

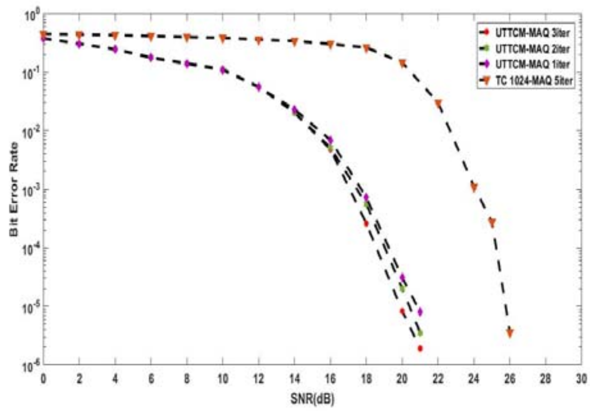

Fig. 8.The BER evaluation of the UTTCM code with 64-QAM at 1th, 2th, and 3th iterations, and the turbo-code with 1024-QAM at the 5th iteration on the EPA channel

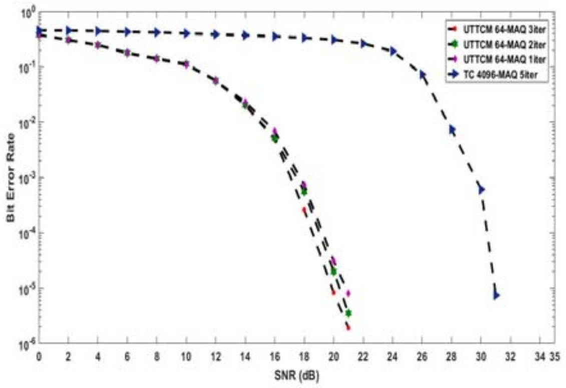

Fig. 9.The BER evaluation of the UTTCM code with 64-QAM at 1th, 2th, and 3th iterations, and the turbo-code with 4096-QAM at the 5th iteration on the EPA channel

Conclusion

Channel coding is a major factor in communication systems, over time many powerful codes appeared. So in this paper, we have introduced two noble error-correcting codes (channel coders), the TC and UTTCM.

Our simulation is performed for different modulations and at different code rates choosing the EPA channel. The results show that UTTCM performs better in 5G transmission systems than TC. Moreover, we showed the effect of iteration on both codes, the UTTCM is always better than TC. Finally for the 5G system the UTTCM encoder shows that it is a good candidate with high performance and low complexity even with a large number of decoding iterations.

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