Indonesian Journal of Electrical Engineering and Computer Science
Vol. 27, No. 1, July 2022, pp. 318~327
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v27.i1.pp318-327

Transmission performance in compressed medical images using turbo code

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Article Info

Article history:

Received Nov 4, 2021
Revised Apr 20, 2022
Accepted May 27, 2022

Keywords:

Channel decoder
Fourth generation
Long term evolution
Orthogonal frequency-division multiplexing
Set partitioning hierarchical trees

ABSTRACT

Medical imaging is now an essential support for screening, diagnosis, treatment protocols implementation, patient monitoring, operative preparation and post-operative control. In addition, scientific and technological advances make it possible to set up new imaging methods, often complementary to the existing ones, but also to gradually improve their accuracy. The result is an increase, in the acquisitions number made for the same patient and for information produced for each examination. Since these images must be kept for a certain period, the storage space required for archiving all this data is constantly evolving and images are often viewed locally, and it can be viewed remotely through networks with limited bandwidth such as the long term evolution (LTE) mobile network. The use of compression quickly proves to be essential, whether to facilitate storage or for these data mass browsing remotely. The results of the work carried out in this article are mainly focused on the medical images compression by the set partitioning hierarchical trees (SPIHT) method, which, in fact, allow a significant reduction for data. We are also interested in the transmission of these images on an LTE mobile radio channel in a way that can provide a high bitrate with good transmission quality, by exploiting the channel coding technique, which is effective in combating the noise introduced during the transmission of these images.

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1. INTRODUCTION

Medical imaging is part of biological imaging, which was developed from the nineteenth century onwards. Biomedical applications such as tissue of quantification, localization of pathology, diagnosis, a study of anatomical structure, partial volume correction of functional imaging data, treatment planning, and computer-integrated surgery [1]-[4]. Medical images play a vital role in helping health care suppliers reach patients for diagnosis and remediation. Recently, the use of medical imaging for the detection by chest X-ray of COVID-19 viruses in the lungs [5]. The survey of medical images depends fundamentally on the visual interpretation of radiologists. However, this is time exhaustion and commonly subjective, depending on the experience of the radiologist [6]-[8].

Medical image compression is best to have digital signature and watermark included previously because we are trying online to move data with our image because the internet is a very crowded network, and we have to apply bandwidth effectively [7], so only pressure is entered. Medical imaging provides a set of image information patterns for clinical diagnoses, such as computerized tomography (CT), X-rays, and magnetic resonance imaging (MRI), among others [8]-[12]. Today, image and video storage, file sharing, television services, and listening to the radio are just a few examples of multimedia services used in everyday life [9]. The main information digitalization and the constant evolution of communication technologies resulted in an increase in multimedia content consumption in recent years [13].

Compared to the analogue voice-only systems 25 years ago, the difference is dramatic. Although long term evolution (LTE) is still at a relatively early stage of deployment, the industry is already well on the road toward the next generation of mobile communication, commonly referred to as the fifth generation or 5G [13], [14]. LTE has become the most successful mobile wireless broadband technology, serving over one billion users as of the beginning of 2016 and handling a wide range of applications [14]-[17]. Mobile broadband is an important part of future cellular communication, but future wireless networks are largely also about a significantly wider range of use cases and a correspondingly wider range of requirements [18].

Nevertheless, the high-resolution images can provide a good guarantee for the performance of other image processing work, so the high resolution of images has always been a hot topic of research. Image super-resolution based on sparse representation and dictionary learning is a very popular technology, usually this method uses first and second-order derivatives to extract features from the image [19]-[21] but this extraction method cannot efficiently extract high-frequency features such as textures [21]. However, the increase in production needs is hampered by the spectral resources availability for electromagnetic radiation, and by the nature of the channels themselves. Indeed, communications are made on more and more frequency bands limited by a large number of standards [22].

In addition, wireless communication is achieved by the propagation of an electromagnetic wave in space, and the channel is generally of the multi-path type, due to several obstacles (buildings, trees, and cars). On reception, the signal received from a set of signals consists of different directions, which make the channel frequency selective and increase its effect with the transmission rate [23]. To solve these problems, two promising technologies have emerged, the first is the image compression technique SPIHT, which has made it possible to gain a very high speed and improve the storage capacity for the transmission of on a radio mobile channel [24], [25]. The second is channel coding, which provides good quality and robust transmission. In addition, historical speeds have been reached with the appearance of the two previous technologies combination to give a new system, which is the main basis for the radio-mobile communication system LTE and which allows better exploitation of the higher spectral efficiency with less transmission error [26]-[29].

In the first step, we will devote ourselves to optimize the data storage capacity by using of the image compression technique optimization [19], [20]. Much research has been done to enrich the SPIHT algorithm, some researchers have proposed a new zero tree structure which not only includes insignificant coefficients but also adjusts the sorting pass in the classified operation, others have used the feature of the "spatial correlation" of the significant coefficients in each sub-band, introduce the general-purpose set partition strategy in an adaptive way. on this principle, set partitioning and sorting by importance is the key to excellent coding performance with very low computational complexity [30], [31]. This recognition spawned more algorithms in this category, including amplitude and group partitioning (AGP), SWEET, NQS, and set partitioning embedded block (SPECK) [32]. The evaluation of the BER transmission performance as a PSNR function will be done using MATLAB [33].

Via the SPIHT algorithm, we will present the principle techniques. After that, we will approach a more mathematical aspect, related to the fundamental theorems used for compression. Just before the explanation of the decompression method of these images. In the second step, we are interesting in the transmission chain modeling and simulation of the LTE radio-mobile network physical layer by the use of two techniques image compression SPIHT and channel coding (turbo-coded).

LTE system structure: the physical layer of LTE technology is an efficient way to send data and control signals between the base station and the mobile user. LTE uses many advanced technologies, including orthogonal frequency division multiplexing (OFDM) [34]-[37]. Besides these technologies on the uplink (Uplink), it uses single carrier frequency division multiple access (SC-FDMA), while on the downlink (Downlink) [38]-[40], it uses orthogonal frequency division multiple access (OFDMA) [13], [18], [24]-[29]. In this section, we will model the different blocks of the physical layer in the downlink (link between an e-NodeB and a UE) case through examples of the downlink transport channels (DLSCH) [41]-[44]. For this, we will consider the three involved entities: the transmitter, the propagation channel and the receiver. In the transmitting part, the digitized data coming from the upper layers are encapsulated in the frames form [45], called "transport block" before their passage in the radio link and their transmission whose duration is characterized by transmission time interval (TTI). The transport block size (TBS) depends on the number of physical resource blocks (PRB) and on the modulation and coding scheme adopted [46]. The transmitter starts with the resource data which is grouped in the transport blocks form [47]. In each TTI, a transport block will first be transferred to the channel coding part, which is made up of two CRC and Turbo coder coders [48]. Knowing that the most used CRC calculations are designed in order to always be able to detect errors of certain types, such as those due for example, to interference during transmission. CRC is used at the start of channel coding [49]. Next, the bit rate adaptation block combined with the hybrid automatic repeat request (ARQ) retransmission technique is a kind of coordinator between channel coding and the blocks of the downlink shared physical channel [50]. The design of the simulated transmitter for the LTE system using compression of image is shown in the Figure 1.

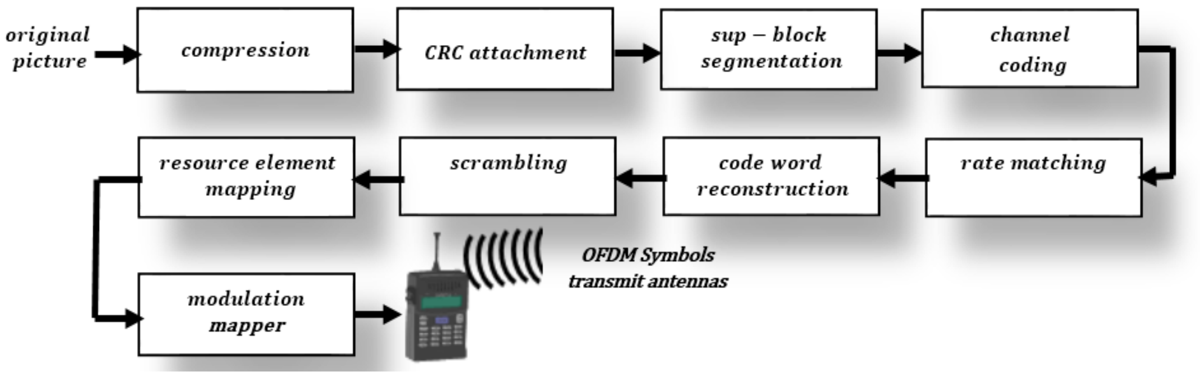

Figure 1. Block diagram of transmitter LTE system using compression of image

Then the code word transmitted to the physical channel in a sub frame must be scrambled before modulation to deal with the interference by performing the exclusive or (XOR) operation of the bits entered with a scrambling code [16]. At the last of the transmitter chain, we use so-called modulation, which allows bits to be associated with modulation symbols, such as for each code word must be modulated with one of (QPSK, 16-QAM, 64-QAM) modulations. Then we send the modulation result via the OFDM technique [34], [35], through radio channels, to reach the receiver, which does the reverse processing [36].

LTE channel coding: among the LTE system advantages, there is the benefit that no recommendations or limitations apply to the digital algorithms used when coding the channel. This gives a certain degree of freedom to choose the algorithms with the best compromise between good performance and least complexity [29]. The (turbo-code) algorithms principle [50], like any error correcting code, is to introduce redundancy in the message in order to make it less sensitive to the noises and disturbances undergone during transmission. Coding consists in using two simple coders, the inputs of which have been interleaved; thus, each coder sees a different series of information at its input.

The channel coding for the PDSCH link of the LTE system carried essentially on the classic Turbo-code coder, which is a kind of robust channel coding. When using an AWGN channel, the Turbo code performance may be close to the theoretical limits of Shannon's capacity [37]. The turbo encoder used is a parallel convolutional code concatenated with two recursive convolutional encoders and a quadratic polynomial permutation (QPP) interleaver, as a permuted version of the input sequence [14], with its generator matrix $G = \begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \end{bmatrix}$, and the coding smoothing $= 1/3$.

Typical channel models: The 3GPP standard in [38], [39] was limited to the use of three main channel models, represented in pedestrian A and vehicular A channels in [11]-[13]. Table 1 shows the typical urban (TU) channel in [13], [18], which correspond exactly and respectively to environments characterized by a small, medium and large delay difference, knowing that these channels operated a bandwidth that arrives at 5 MHz or higher [13]. As described in TS 36.101 [18], [27] and TS 36.104 [39]-[42] and thanks to the 3GPP and ITU standard, the LTE system is adopted on three models of the essential propagation channels for simulation and tests, these models are defined as follows, the extended pedestrian A (EPA), extended vehicular A (EVA) and extended typical urban (ETU) channel models. The following table shows the maximum Doppler shifts for each model to represent the low, medium and high moving conditions [42]-[45].

Table 1. LTE Tapped-delay line channel models parameters

Tap no.	EPA channel		EVA channel		ETU channel	
	τ (ns)	SMR (dB)	τ (ns)	SMR (dB)	τ (ns)	SMR (dB)
1	0	0.0	0	0.0	0	-1.0
2	30	-1.0	30	-1.5	50	-1.0
3	70	-2.0	150	-1.4	120	-1.0
4	90	-3.0	310	-3.6	200	0.0
5	110	-8.0	370	-0.6	230	0.0
6	190	-17.2	710	-9.1	500	0.0
7	410	-20.8	1090	-7.0	1600	-3.0
8			1730	-12.0	2300	-5.0
9			2510	-16.9	5000	-7.0

2. MATERIALS AND METHODS

Generally, there are three aspects about the statistical experiments: firstly, it showed that there is certain redundancy in the adjacent pixel in input image, in other words, adjacent pixel is very similar, and the correlation between adjacent pixels is very high. Secondly, some disposal could be done, such as removing redundancy of input image in the encoder. Thirdly, there is certain redundancy among the coefficients in wavelet region at each sub band, differential coding can be taken into count in wavelet region, especially in the low-pass filter bank.

Our work is focused on studying the impact of transmission of image COVID-19 compressed by SPIHT technic over the 4th generation mobile network (LTE). And this is through a simulation of the physical layer of the LTE in downlink with the MATLAB tool by varying the different parameters, which will allow us to highlight the contribution of this new performance technology such as bit rate, and bit error rate (BER). The parameters used during the simulation are given as follows in Table 2. In this paper, the focus is mainly on the downlink LTE in Rayleigh fading environments for the two different multipath models EVA and EPA, using the modulation scheme 16-QAM with the installation of the equalizer zero-forcing at the receiver to avoid interference between the transmitted signals presented in Table 3 and 4. So for the transmission of the data, a better understanding of the LTE PHY radio interface is important for transport block sizes and rate code words.

Table 2. The parameters of our simulation

Parameter	Values
Duplexing mode:	FDD
Transmission mode	TM1
Transmission scheme	Port 0
Number of downlink resource blocks	110
Number of allocated resource blocks	110
Cell-specific reference signal ports	1
Number of transmit antennas	1
Transmission layers	1
Number of code words	1
Modulation code word 1	16-QAM
Number of frame transmis	2 Frame (s)
Channel model and doppler shift	$(EPA\ , f_d = 5Hz\ )/\ (EVA, f_d = 5Hz\ )$
Equalization mode	Zero-forcing

Table 3. Transport block sizes of the code word

Transport block sizes code word									
25456	28336	28336	28336	28336	0	28336	28336	28336	28336

Table 4. Code rate of the code word

Code rate code word									
0.4762	0.5137	0.5137	0.5137	0.5137	0	0.5137	0.5137	0.5137	0.5137

3. SIMULATION AND RESULTS ON THE LTE SYSTEM

From the simulation results, the BER, peak signal-to-noise ratio (PSNR), mean structural similarity (MSSIM) are used to measure their quality and the throughput of a digital communication system is an important quantity used to quantify the data integrity transmitted by the system. The following figures present the transmission performance on the LTE system, using the SPIHT image compression technique in the EPA, EVA channels with a channel coding of turbo code type in which it's coding rate equal to 1/3. While, decoding is done using the Max Log-MAP algorithm with an iteration number equal to five.

3.1. Simulation of image transmission on the EPA channel

In this section, we will use the medical images (COVID-9, Figure 2), to test the performance of our transmitter LTE communication system. The image used is in grayscale, 128×128 dimensions, coded on 8 bits per pixel (bpp). Figure 2 indicate examples of medical images transmitted over EPA channel for SNR varying between 0 and 3.75 dB. Table 5 shows the variations in PSNR, MSSIM, and rate values relative to SNRs in an EPA channel. It is clearly noted that the flow rate reaches a maximum value for SNR = 3.75 dB.

Figure 3 give the transmission performance of a medical image compressed by SPIHT technique in an EPA channel, with the TC encoding channel and five iteration decoding. We can see that the turbo code reduces the effect of noise on the proposed system performance for an SNR = 3 dB, we get a BER ≈ 10^{-6}. Where Figure 4 presents the throughput (%) of image transmission (COVID-19) compressed by the SPIHT on the EPA channel.

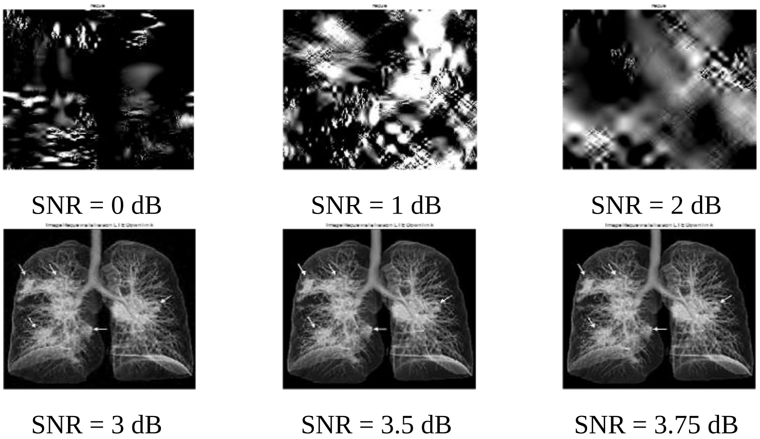

Figure 2. Transmission of image (COVID_19) compressed by SPIHT over EPA channel model

Table 5. BER, PSNR, MSSIM and throughput versus SNR for fifth iterations of channel decoding over EPA channel model

SNR (dB)	0	1	2	3	3.5	3.75
PSNR (dB)	3.5822	1.6128	8.0274	27.7830	44.3032	44.5234
MSSIM	-0.0306	0.0093	0.0987	0.7050	0.9884	0.9890
Thr (Mbps)	0.0000	0.0000	0.0000	8.2128	18.1304	25.2144
Thr (%)	0.0000	0.0000	0.0000	32.5719	71.9049	100.0000
BER	0.2383	0.2024	0.1267	0.0017	1.865 e-06	0

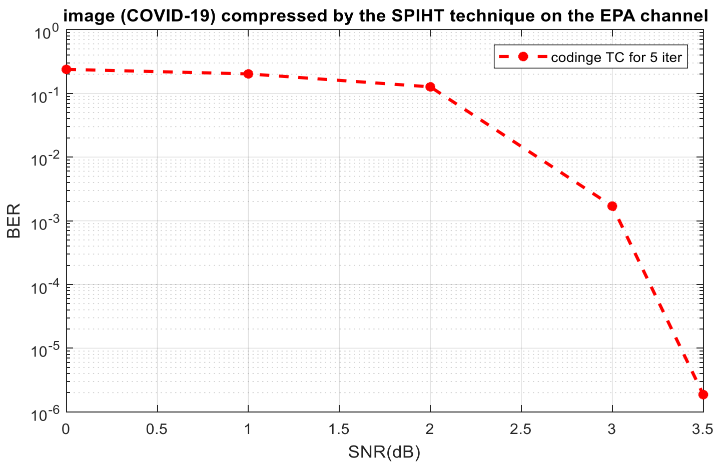

Figure 3. Image transmission performance compressed by the SPIHT technique and coded by the TC coder for 5th iterations on the EPA channel

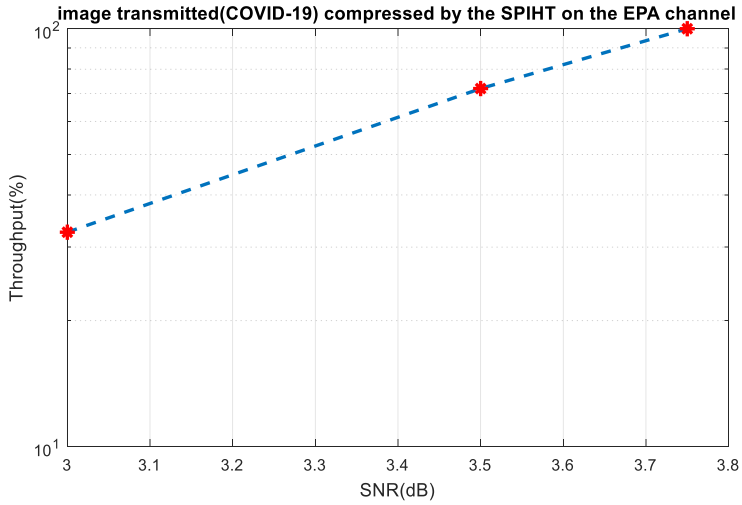

Figure 4. Throughput (%) of image transmission compressed by the SPIHT technique and coded by the TC coder for the 5th iterations on the EPA channel

3.2. Simulation of image transmission on the EVA channel

Figure 5 shows examples of receiving medical images transmitted over EVA channel for an SNR that varies between 0 and 6.25 dB. The image used is in grayscale, 128×128 dimensions, coded on 8 bits per pixel (bpp). In the case of medical images (Figure 5), we need an SNR = 6 dB to transmit our data perfectly (with 5 iterations of the TC decoding). Figure 6 shows the performance (BER Vs SNR) of a medical image transmission compressed by SPIHT technique on EVA channel, with the TC encoding channel (with five decoding iteration). We can see that the turbo code reduces the effect of noise on the performance of the system such as for SNR = 3 dB, with a BER 10-6. BER, PSNR, Mssim and Throughput versus SNR for fifth iterations of channel decoding over EVA channel model as shown in Table 6.

Figure 6 shows the performance of the transmission (rate Vs SNR) of a medical image compressed by SPIHT technique on EVA channel, with TC encoding channel (with five decoding iteration). Note that the flow rate reaches a maximum value just for an SNR = 6.25 dB. Figure 7 shows that the image compression can be used with very different constraints and expectations depending on its uses, the desire for the reduction of the number of bits in image results in a constraint on the storage capacity, the compressed image quality, the transmission speed, the access time from a storage medium, the processing time, complexity, compatibility, and behaviour towards errors.

It has been recognized that the compression methods are the most effective in terms of compression ratio. Among these, the wavelet transform method is a global method that works the overall image without cutting and brings out a fuzzy for high compression rates. For the application implementation, we have chosen to implement a multi-resolution analysis by the coding method in the sub-bands SPIHT technique.

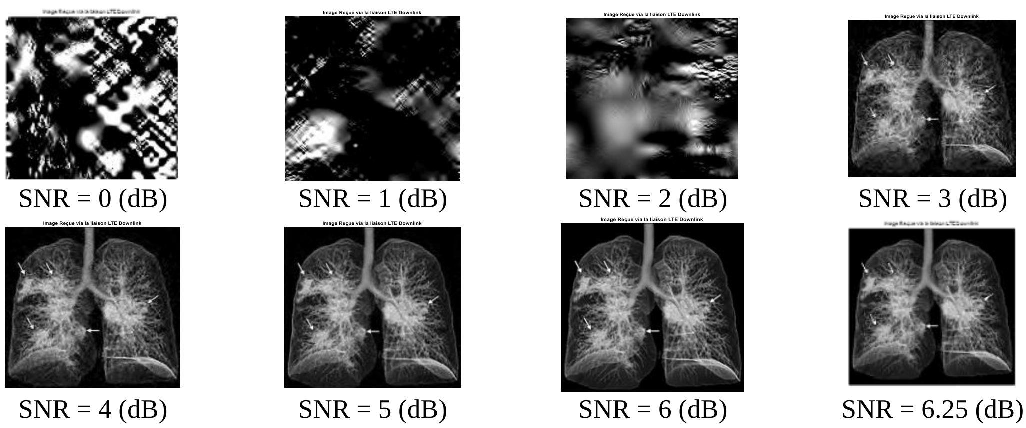

Figure 5. Transmission of Image (COVID-19) compressed by SPIHT over EVA channel model

Table 6. BER, PSNR, Mssim and throughput versus SNR for fifth iterations of channel decoding over EVA channel model

SNR (dB)	0	1	2	3	4	5	6	6.25
PSNR (dB)	-1.9140	0.0454	0.7226	20.5756	23.2840	26.9746	34.6578	42.1774
MSSIM	-0.0017	0.0228	0.0173	0.3383	0.4961	0.6741	0.9344	0.9842
Thr (Mbps)	0.0000	0.2024	5.7762	10.6804	17.8120	22.2675	24.8460	25.1861
Thr (%)	0.0000	0.8029	22.9083	42.3581	70.6420	88.3125	98.5391	99.8876
BER	0.2527	0.2213	0.1800	0.0940	0.0463	0.0066	6.05e-05	1.14e-07

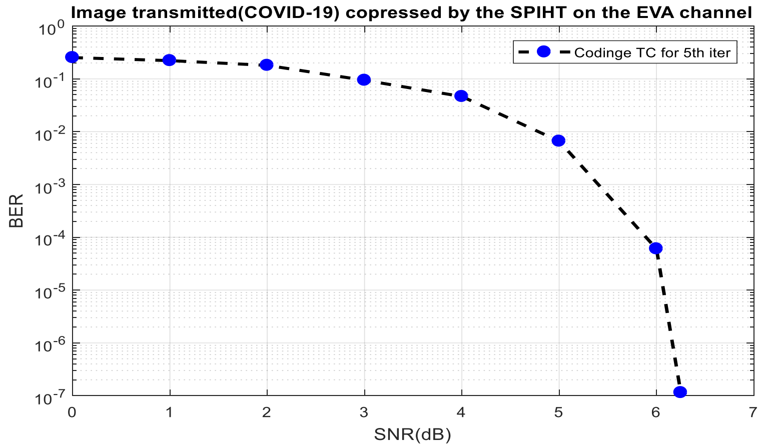

Figure 6. Image transmission performance compressed by the SPIHT technique and coded by the TC coder for 5th iterations on the EVA channel

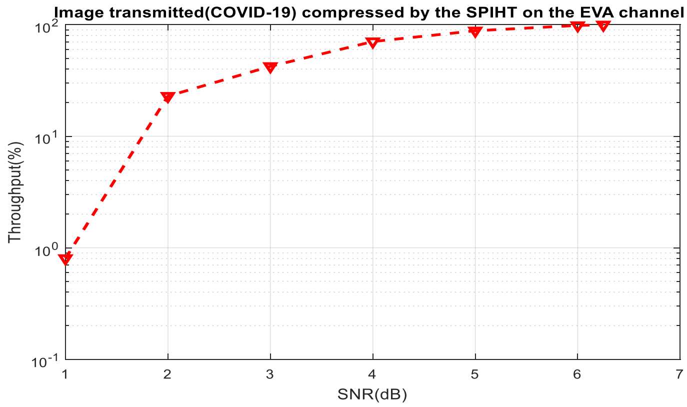

Figure 7. Throughput (%) of image transmission compressed by the SPIHT technique and coded by the TC coder for the 5th iterations on the EVA channel

4. CONCLUSION

This work has allowed the development of an efficient method of medical images compression based on the SPIHT algorithm. The irreversible nature of this method today represents a major drawback insofar as it does not offer the ethical and legal guarantees of exact reconstruction of the initial image. However, lossy compression methods are the only ones to allow high compression rates. Ultimately, they are a response to the growing importance of problems linked to the desire to develop telemedicine applications, where availability and speed of transfer are critical parameters. This application is sure to be improved in its performance in terms of compression, throughput, and security, and finally lead to a remote diagnostic tool claimed by practitioners, doctors, and many others. According to the simulation results. It has shown that the SPIHT technique with the turbo-code channel coding technique application makes it possible to estimate a significant bit rate and necessary for the images transmission compressed with a better transmission performance in terms of BER on the three radio channels EPA, EVA and UTE of the LTE network.

ACKNOWLEDGEMENTS

We want to thank very much the members and the directors of LTIT Laboratory-Bechar University (Algeria) for their great availability, their encouragement, and their precious advice.

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