Proceedings of the Pakistan Academy of Sciences:
A: Physical and Computational Sciences 58(4): 27-34 (2021)

ISSN (Print): 2518-4245; ISSN (Online): 2518-4253
https://doi.org/10.53560/PPASA(58-4)767

Pakistan Academy of Sciences

Research Article

Design of Robust Video Transmission System by Using Efficient Forward Error Correction Scheme

Amaad Khalil[1], Nasruminallah[1], Irfan Ahmed[2*], Salman Ilahi Siddiqui[2]

[1]Department of Computer Systems Engineering, University of Engineering & Technology, Peshawar, Pakistan
[2]Department of Electrical Engineering, University of Engineering & Technology, Peshawar, Pakistan

Abstract: The advent of modern digital technologies has made multimedia communication systems one of the most demanding technologies of the time. The use of available bandwidth for efficient and errorless multimedia communication is the key challenge for the wireless communication research community. However, a wireless network has the disadvantage of being prone to random channel noise and data contamination. This paper proposes a robust video transmission framework by using an efficient forward error correction technique. In this work, the experimental performance of widely used forward error correction codes i.e., Convolution codes, LDPC codes, Turbo codes, and Concatenated codes, are compared based on their capability to compensate the channel noise and distortion. An efficient encoding scheme is devised for the transmission of YUV encoded frames by using the selected FEC codes in a noisy channel environment. The retrieved video is analysed by using the Peak Signal-to-Noise ratio and bit error rate as performance metrics. The results and cross comparison shows that concatenated codes have a handsome improvement in avoiding channel contamination and distortion.

Keywords: YUV, Error Correction Codes, Convolution Codes, Low Density Parity Check Codes, Concatenated Code, Turbo Code, BER, PSNR.

1. INTRODUCTION

The digital multimedia communication system is the emerging field of research due to the growing demands in system mobility, accessibility, and high data rates requirements [1]. Researchers have been working to develop efficient encoding techniques to reduce error rates while deploying limited bandwidth for the transmission of high-quality data samples [2]. Multimedia transmission over wireless channels is a significant task due to the high date rate demand and unpredictable behaviour of wireless channels [3]. The random behaviour of wireless channel is one of the major factors of error induction during the transmission of information samples. Therefore, an efficient and robust error correction coding technique is required to avoid random transmission errors.

Error control mechanism comprises error detection and correction in received data samples. In the wireless communication research community, error correction strategies can be classified according to the following cases:

- Error correction by resending the overall data, called automatic repeat request (ARQ).
- Rectifying errors and reconstructing original data instead of resending, called forward error correction (FEC).

FEC adds redundant bits in data which are further used to detect and rectify errors at the receiver's side. Thus avoid retransmission of data, which in turn reduces transmission cost and time [4,5]. Some well-known FEC codes are low density parity check (LDPC), turbo codes, concatenated codes, and convolutional codes.

Received: August 2021; Accepted: December 2021
*Corresponding Author: Irfan Ahmad <irfanahmad@uetpeshawar.edu.pk>

Convolutional codes, introduced in 1955, are one of the simplest error correction codes which convert any length message to a single codeword. It consists of a finite state machine, at the encoder side, for serial processing of available bits. Viterbi decoder is used to decode the encoded bits by deploying trellis diagram; which works on the principle of finding the most likely path by means of a suitable distant matrix [5]. S. Dhaliwal et al. analysed the performance of convolutional codes using Viterbi algorithm with different code rates and constraint length. It was observed through MATLAB simulation graphs that increased encoding rate has a proportional effect at BER, while an increased number of constraints helps in reduced BER, respectively [6]. LDPC is basically linear block codes. The encoder of LDPC codes uses bipartite graphs and works on checking variable nodes. For the decoder it uses message passing or belief propagation algorithm [7]. The performance of LDPC achieves Shannon capacity, while having less complexity level at smaller values of Eb/No. As the performance of FEC mainly depends on code rate and sizes of check and parity nodes, therefore, the application of LDPC codes is demonstrated with respect to these parameters in [8].

Turbo codes are also one of the prevailing error correction codes. In turbo codes, soft output Viterbi algorithm (SOVA) is used to achieve the Shannon capacity. This algorithm consists of two main steps, in the first step, it finds the maximum likelihood path by using Viterbi algorithm's trellis graph. In the next step, log likelihood ratio (LLR) is calculated by using back tracking operation. This algorithm is computationally complex but still widely used in modern mobile communication systems due to its performance in error correction [9]. Concatenated code is a type of serial iterative codes called serial concatenated correction codes (SCCC). SCCC consist of an inner code, an outer code and a linking inter-leaver. In 1998, Benedetto et al. further studied the design of serially concatenated codes and introduced inter-leaver in it [10]. This design gives superior performance when it is compared with turbo codes. The recent proposed articles in [11-16] show that researchers are interested in multimedia transmission employing concatenated codes to obtain better performance. This new concept provided better results with maximum inter-leaver gain. There are many standard models available in the literature for video coding and transmission i.e. RGB, YUV and HIS [17]. Therefore, each model suits a specific situation and is adopted for certain scenarios and applications [18]. All these methods involve the separation of colour images in three distinct colours: red, green and blue; and altering each into grey-level images. Due to many conversion steps, this approach has a disadvantage of computational complexity. As proposed in [19], Vector image restoration is another technique developed specifically for multichannel color images. A YUV video transmission system encodes all frames on the basis of two information components: brightness (luma) and color (Chroma) [17], which are then sent separately. Moreover, YUV is preferred over RGB due to the limited bandwidth utilisation [19].

2. OUR CONTRIBUTIONS

The prime objective of this research work is to design a robust video transmission system with an efficient error correction scheme by comparing different FEC codes. Recent use of FEC has shown better performance due to their ability to avoid the need for data retransmission. Therefore, we applied widely used FEC codes over YUV coded video for performance comparison purposes. YUV coded video is preferred because it encodes brightness information separately from the colour information. In this paper, we aim to devise a better-quality video transmission system that can provide faithful error correction at lower values of Eb/No in the presence of an impaired wireless channel, despite the lack of an encoding mechanism. The proposed approach will enable better performance in video-based multimedia applications such as video streaming, military activities, and data transmission in satellite communications.

3. PROPOSED SETUP

TThe work done in this paper aims to devise high performance video transmission system. Therefore, experiments are designed to analyse the performances of widely used error correction codes and modulation schemes, while AWGN channel is used to model a channel's behaviour. The proposed transmission system model is depicted in Fig. 1. The experimental system is tested by sending a digital video stream through AWGN channel, after being passed through different processing blocks of the developed system shown in Fig. 1. The channel coding techniques, used for error correction and detection, are convolutional, concatenated, turbo and LDPC codes with BPSK modulation technique.

3.1 Pre-Processing

The first step followed in the devised system is the conversion of video bit stream into the standard YUV format. The YUV video format is preferred over the RGB video format because of the fact that compact bits are easier to store in YUV video format rather than the RGB format. In the next step, the generated subsequent video bits are forwarded to the channel encoder block.

3.2 Channel Encoder

The channel encoder block is responsible for converting video bits into the encoded stream. This block portrays the main theme of this research work, which uses the encoding schemes i.e., convolutional, LDPC, turbo and concatenated encoders for forward error correction. The encoders and their parameters used in this research work are listed below:

1. The convolutional encoder has three basic parameters: n, k and m, where k, n, and m are input bits, output bits of convolutional codes, and the number of memory registers, respectively. The encoder takes the input message 'k' and encodes it into the output message 'n' of twice the size input message after being processed by the memory bits 'm'.
2. The LDPC encoder adds parity bits to the applied data, keeping track of the channel-induced errors. It consists of a code generator and a parity generator matrix block.
3. The turbo encoder block is a combination of two parallel recursive systematic code encoders separated by the inter-leaver. The inter-leaver produces a weighted code word by introducing randomness in the bits.
4. Concatenated encoder has two serial convolutional encoders, separated by the inter-leaver. The technique is used in this research work due to its performance in error correction.

3.3 Modulation

Modulation is the process of transforming the digital information into the analog signal for transmission channel compatibility. During this process, some parameters of the carrier signal, i.e., amplitude, frequency and phase, are altered with respect to the magnitude of the message signal. The process is mandatory to transmit digital information into the analog channel. Many modulation techniques are available in the literature that efficiently transmit digital data. Phase Shift Keying (PSK) is a mostly used modulation scheme for digital data transmission. PSK works on the principle of changing the phase of a carrier signal for different information bits.

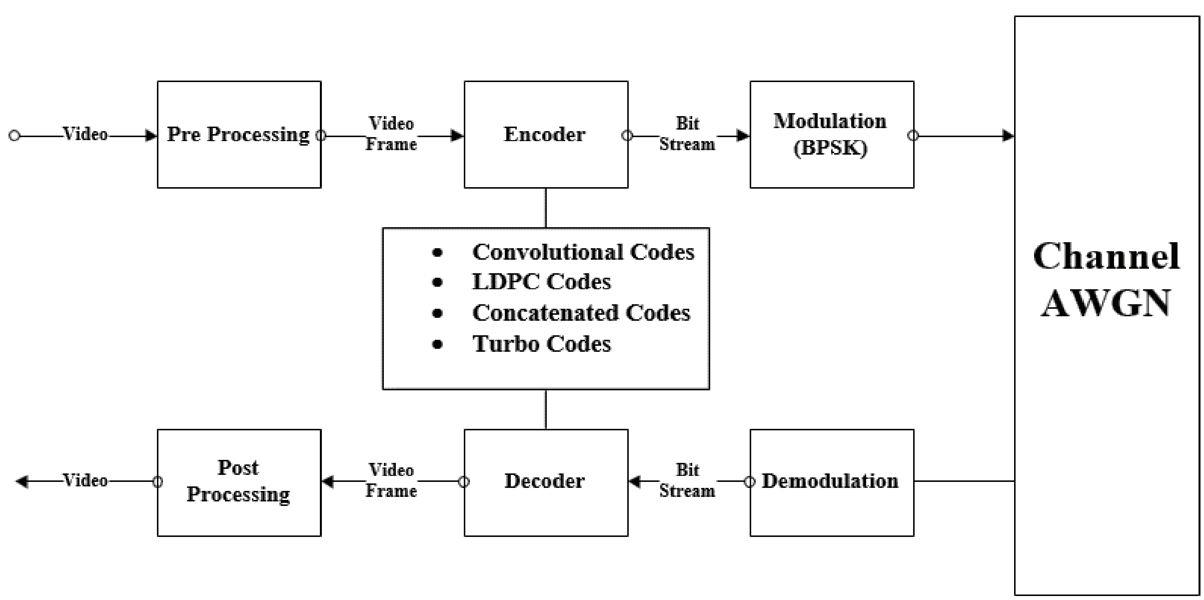

Fig. 1. Video Transmission Model

All other parameters of the carrier signal will remain constant, but only phase shift will carry the information. The phase value depends upon values of M, which has discrete values. M represents the total number of phase shifts used to represent discrete symbols. These discrete values can either be in binary or quadruple form. PSK can be described mathematically as:

$$s_i(t) = \sqrt{\frac{2E}{T}}\cos\left(\omega_o t + \emptyset_i(t)\right) ; 0 \leq t \leq T ; i = 1,2 \ldots M \quad (1)$$

where ω_o is the carrier frequency, E is the amplitude and

$$\emptyset_i(t) = \frac{2\pi i}{M}$$

Some types of PSK which are mostly used are listed below:

3.3.1 Binary Phase Shift Keying (BPSK)

In BPSK, carrier signal's phase is shifted 180 degrees from that of the original signal. As in binary communication, we have two states (M=2), therefore, the phase shift is either 0 or π. It can be written mathematically as:

$$s_1(t) = \sqrt{\frac{2E}{T}} cos(\omega_o t + 0) \quad (2)$$

$$s_2(t) = \sqrt{\frac{2E}{T}} cos(\omega_o t + \pi) \quad (3)$$

3.3.2 Quadruple Phase Shift Keying (QPSK)

In QPSK, the carrier wave phase is shifted from the original phase to four possible phase shifts. This type of modulation has four discrete values for M. The carrier wave shifts are 0, π/2, π or 3π/2. The equation is:

$$s_i(t) = \sqrt{\frac{2E}{T}} cos\left(\omega_o t + i\frac{\pi}{2}\right) \quad (4)$$

The modulation procedure used in our proposed system is the BPSK modulation. The carrier wave's phase is modified from one state to another in BPSK modulation having two possible phase shift values 0 or π.

3.4 Channel Decoder

At the receiver's end, the incoming data is demodulated using a similar technique used at the modulation end. The decoder module at the receiver end reverses the processing carried out at the transmitter end. The decoder module detects bit errors due to the channel and then removes the error as per the specific encoding principles being used.

3.4.1 Convolutional Decoder

The decoder is implemented using the Viterbi algorithm for the convolutional code's module. The Viterbi algorithm uses maximum likelihood estimation for decoding and it is considered a computationally expensive algorithm. Therefore, the Viterbi algorithm is used for a constraint length of less than 10.

3.4.2 LDPC Decoder

LDPC encoded YUV video stream is decoded through belief propagation algorithm. The belief propagation algorithm is usually deployed in a noisy transmission channel for better residual error rate reduction performance.

3.4.3 Turbo Decoder

Soft-Input-Soft-Output (SISO) algorithm is used in the turbo codes as a decoder. It uses Max-Log-MAP algorithm for decoding the incoming information.

3.4.4 Concatenated Decoder

The concatenated Trellis algorithm is widely used to decode the FEC coded transmitted signals and efficiently recover the corrupted data. Trellis algorithm uses the maximum likelihood estimates and BCJR. After decoding, we compare the transmitted and received frames by using BER and PSNR as performance metrics across different Eb/No. The obtained results are then plotted for performance comparison of the encoded techniques.

4. EXPERIMENTS AND RESULTS

4.1 Experimental Setup

The designed system is tested by comparing the performances of different error correction codes obtained through computer simulation. The system is modeled by using the computer program (IT++

library in C programming language) which applies channel codes over a video bit stream. The video sequence 'foreman.yuv' is used as test sample to analyse the performance of the proposed setup. In this experimental setup, coded bit stream, from a single frame, is generated from standard 4:2:0 YUV video, which contains 300 frames in it. The size of each frame is 176×144×8 bits and a single frame out of 300 wass chosen as a test sample for result evaluation. The test data, which is in the form of a digital video stream, is transmitted through the AWGN channel. The video was transmitted through the system by varying Eb/No values from 0 onwards. The value is gradually increased until an errorless frame is obtained.

4.2 Performance Metrics

For a proposed system, the performance is assessed through subjective quality evaluation metrics. The performance metrics used in this work are Bit Error Rate (BER) and Peak-SNR (PSNR), which were obtained by applying different values of Eb/No as channel characteristics. The following mathematical equations are used for the purpose:

$$BER = P_b = Q\left(\sqrt{\frac{2E_b}{N_o}}\right) \quad (5)$$

$$PSNR = 10\ log_{10}\left(\frac{255^2}{MSE}\right) \quad (6)$$

while Mean Squared Error (MSE) for a video frame can be calculated as:

$$MSE = \frac{1}{MxN}\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j) - \tilde{x}(i,j)]^2 \quad (7)$$

4.3 Results

The results are obtained from different encoding schemes by varying the value of Eb/No as channel characteristics. It is observed that concatenated coded frames were received error free at small values of Eb/No, which shows the superior performance of concatenated codes and can be used to decode video streams at lower values of Eb/No. The experimental procedure is shown in Figure 2, 3, 4 and 5.

The obtained results are more thoroughly observed and evaluated by using the performance metrics selected for his work. The following discussion is the analysis of obtained results.

4.4 Peak Signal to Noise Ratio (PSNR)

The selected video was coded with FEC codes, and the performance of each code is evaluated by transmitting the coded video through the developed system. The varying Eb/No values yielded PSNR table for each encoding scheme for comparative performance analysis. PSNR values for each encoding scheme was plotted for different values of Eb/No, as shown in Figure 6. The graph shows that concatenated codes outperformed other error correction codes. Furthermore, the LDPC performance stood second with turbo codes at third and convolutional codes with the least performance efficiency.

4.5 Bit Error Rate (BER)

The obtained results are already analysed on the basis of PSNR values for the performance comparison of encoding schemes. In this work, Bit Error Rate (BER) values are also analytically observed as another metric for the detailed comparative study in different scenarios. The plotted graph of Figure 7. further backs the earlier observations, where BER findings are in line with the PSNR results of Figure 6. The concatenated codes outperformed while the performance of convolutional codes is less efficient.

5. KEY FINDINGS

The following points are observed through experimental analysis:

- Convolutional codes worked, but performance degradation has been observed as the values of Eb/No are increased. Hence it shows better performance at smaller values of Eb/No.
- LDPC codes showed comparatively better performance by inducing small error rate. This work proposes this coding scheme due to less complexity in its deployment.
- Turbo codes have shown better performance in diverse range of scenarios. The turbo codes experiments have shown low bit error rate while execution time is relatively high. It is observed that the rise in execution time of turbo codes is due to its complex decoding structure.
- Concatenated codes outperformed in the

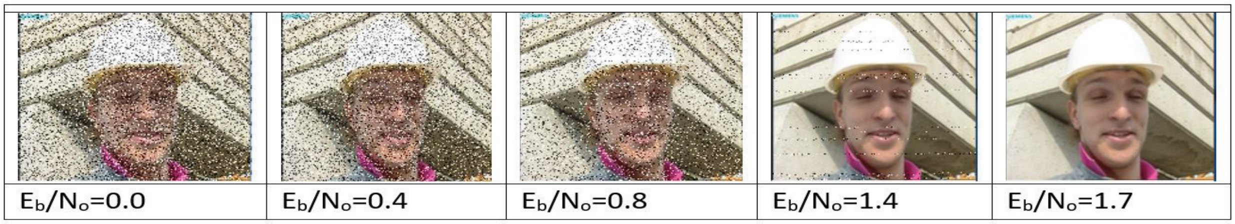

Fig. 2. Convolutional Coded Video Frame for Different Values of Eb/No

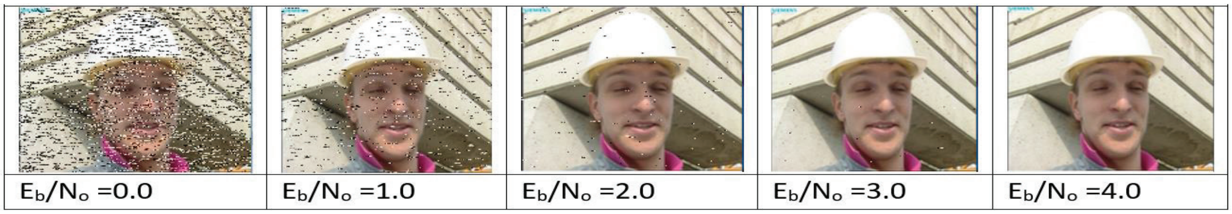

Fig. 3. LDPC Coded Video Frame for Different Values of Eb/No

Fig. 4. Turbo Coded Video Frame for Different Values of Eb/No

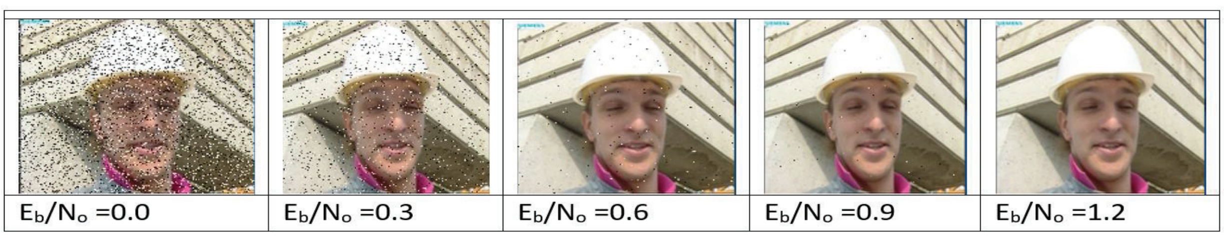

Fig. 5. Concatenated Coded Video Frame for Different Values of Eb/No

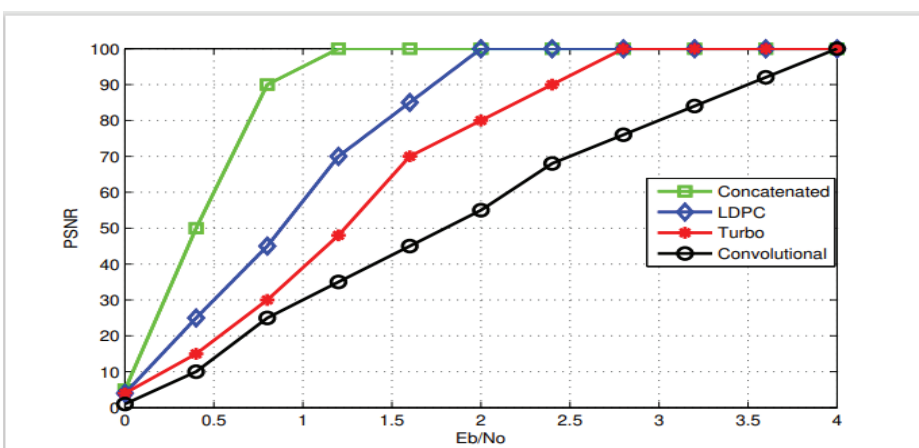

Fig. 6. *Comparison Graph of Encoding Schemes Based on PSNR vs Eb/No*

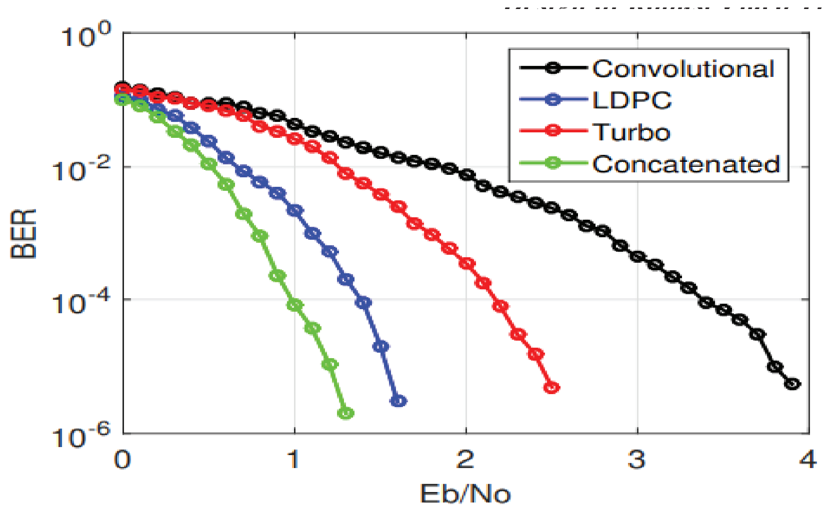

Fig. 6. Comparison Graph of Encoding Schemes Based on BER vs Eb/No

current study by showing the promising result. The encoding scheme possesses reasonable complexity and execution time with respect to the other error correcting codes.

6. CONCLUSION

Video transmission through the wireless channel is a challenging task. The recent work done in efficient video transmission through noisy channels embeds signal overhead with extra bit encodings for error corrections. So, in this scenario, FEC codes are better to be utilised for least overhead embedding which in turn consumes less transmission bandwidth and power. The work done in this paper shows the comparative analysis of well-known FEC coding schemes i.e., convolutional, LDPC, concatenated and turbo codes. In this experimental study, an efficient video transmission setup is devised to compare the encoding schemes' analytical performances via different Eb/No values. The devised setup contains channel which is modelled by Additive White Gaussian Noise (AWGN) for contaminating the transmitted bit stream. Subjective quality assessment across different Eb/No values enlightened the better performance of concatenated code. The conclusion is obtained by graphical comparison of PSNR and BER values. The evidence observed through the performance assessment tools back up the argument that concatenated codes gives a better result at lower values Eb/No. These two reasons are the major motives responsible for the performance degradation of the system.

7. CONFLICT OF INTEREST

The authors declare no conflict of interest.

8. REFERENCES

1. M. C. Davey, and D. MacKay. Low-density parity check codes over gf (q). *IEEE Communications Letters,* 2(6):165 167, (1998).
2. E. Khan, A. A. Moinuddin, and Mohammed Ghanbari. Cross-layer approach for reliable transmission of wavelet coded images over portable multimedia devices. *Recent Advances in Multimedia Signal Processing and Communications,* pages 271 294. Springer, (2009).
3. H. Seferoglu, and A. Markopoulou. *Opportunistic network coding for video streaming over wireless. In Packet Video 2007*, pages 191 200. IEEE, (2007).
4. M. Zorzi. Performance of FEC and ARQ error control in bursty channels under delay constraints. *Vehicular Technology Conference, 1998. VTC 98. 48th IEEE,* volume 2, pages 1390 1394. IEEE, (1998).
5. J. G. Proakis. *Digital signal processing: principles algorithms and applications. Pearson Education India,* (2001).
6. S. Dhaliwal, N. Singh, and G. Kaur. Performance analysis of convolutional code over di erent code rates and constraint length in wireless communication. *I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), 2017 International Conference* on, pages 464 468. IEEE, (2017).
7. R. Gallager. Low-density parity-check codes. *IRE Transactions on information theory,* 8(1):21 28,

(1962).

8. A. Gupta, M. E. Scholar, A. Jain, and P. D. Vyavahare. Analysis of error correcting capability of ldpc code over fading and non-fading channel under various parameters. *Computing, Communication and Networking Technologies (ICCCNT), 2017 8th International Conference on,* pages 1 5. IEEE, (2017).
9. K. Manolakis, M. A. Gutierrez, and V. J. Nickel. Adaptive modulation and turbo coding for 3gpp lte systems with limited feedback. *Vehicular Technology Conference (VTC Spring), 2014 IEEE 79th,* pages 1 5. IEEE, (2014).
10. N. K. Sharanya, and S. Jayashree. Performance analysis of concatenated codes for di erent channels. *Recent Trends in Electronics, Information & Communication Technology (RTEICT), IEEE International Conference* on, pages 715 719. IEEE, (2016).
11. A. Khalil, N. Minallah, M.A. Awan, H.U. Khan and A.S. On the performance of wireless video communication using iterative joint source channel decoding and transmitter diversity gain technique. Wireless Communications and Mobile Computing, 2020.
12. A. Khalil, N. Minallah, I. Ahmed, K. Ullah, J. Frnda, and N Jan. Robust mobile video transmission using DSTS-SP via three-stage iterative joint source-channel decoding. Humancentric Computing and Information Sciences, 11. 2021
13. H.U Khan, N. Minallah, A. Masood, A. Khalil, J. Frnda, and Nedoma. Performance Analysis of Sphere Packed Aided Differential Space-Time Spreading with Iterative Source-Channel Detection. Sensors, 21(16), p.5461. (2021)
14. N. Minallah, K. Ullah, J. Frnda, K Cengiz and A. Javed. Transmitter Diversity Gain Technique Aided Irregular Channel Coding for Mobile Video Transmission. Entropy. 2021 Feb;23(2):235.
15. N. Minallah, K. Ullah, J. Frnda, L. Hasan, J. Nedoma . On the Performance of Video Resolution, Motion and Dynamism in Transmission Using Near-Capacity Transceiver for Wireless Communication. Entropy. 2021 May;23(5):562.
16. N. Minallah, I. Ahmed, M. Ijaz, A. Khan, L. Hasan, A. Rehman. On the Performance of Self-Concatenated Coding for Wireless Mobile Video Transmission Using DSTS-SP-Assisted Smart Antenna System. Wireless Communications and Mobile Computing.;2021.
17. H. C. Andrews, and B. R. Hunt. *Digital Image Restauration.* (1977).
18. D. Tschumperle, and R. Deriche. Constrained and unconstrained codes for vector image restoration. *Proceedings of the Scandinavian Conference on Image Analysis*, pages 153 160, (2001).
19. L. Shi, Y. Feng, B. Zhang, and H. Sun. Combination restoration for motion-blurred color videos under limited transmission bandwidth. *Inter- national Journal of Image, Graphics and Signal Processing,* 1(1):41, (2009).