Performance Analysis of LDPC Channel Coding in 4G Systems

Othman O. Khalifa, Noralya Fatin Bt. Muzamil

Abstract*: *Due to the degradation in wireless communication system by the burst errors in of fades under multipath environment, the efficient and the quality of received signals are questionable. Therefore, the error corrections are crucial part needed to satisfy the users. This paper focuses on performance analysis of channel coding in 4G systems. There are many codes, but this paper highlights on Viterbi Algorithm and LDPC codes with BPSK modulation and Additive white Gaussian noise(AWGN). The comparative performance of Viterbi algorithm and LDPC is explored in this paper. This comparison will be beneficial for next mobile communication system generations.

Index Terms*: *Channel Coding, Bit Error Rate, Error Correction Codes, Viterbi algorithm, LDPC codes.

I. INTRODUCTION

Channel coding correction playing an important role to make the transmission sturdy enough against these channel impairments by adding redundancy to the transmitted signal. However, the wireless channels are often affected by atmospheric conditions such as scattering and reflections from surroundings. These multiple signals with different amplitudes and phases reaches the receiver, thus causes either constructive or destructive fading. Error detection and correction or error control are the methods that implement stable delivery of digital information over unstable communication channels. However, the development of mobile networks has not stopped growing, several generations have emerged (1G, 2G, 3G, 4G and soon the 5G) and known a remarkable evolution, providing an exceptional flow and which does not steadily increasing, bandwidth becoming larger and one of the advantages of such bandwidth is the number of users which can be assisted. Channel coding correction is categorized into many types. There are several channel coding correction that have been proposed for 4G such as Turbo codes, convolution codes, low density parity check (LPDC) codes. The later, have recently drawn much attention due to their near capacity error correction performance, and are currently in the focus of many standardization activities, e.g., IEEE 802.11n, IEEE 802.16e, and ETSI DVB-S [1][2].

II. 4G AND BEYOND

The challenge of developing new coding solutions is to provide performance gains closer to the channel capacity while not limiting throughput or adding latency. Claude Shannon showed that it is possible to optimize the energy and time transmitting data across a communications channel if you have the right coding scheme. LDPC codes first proposed by Robert Gallager in 1960 [3] and then Robert Tanner, in 1981 generalized LDPC codes and developed a graphical method of representing these codes, now called Tanner graphs or bipartite graphs [4]. 4G is the fourth generation of standards. It is a system that expected to provide a comprehensive and secure all- based solution to laptop computer and other mobile devices; such as Internet access, gaming services, and streamed multimedia may be provided to users. However, many communication standards have been introduced in the past three decades. Starts form 2G system that replaced the first generation (1G) analog cellular phone technology based on frequency modulation, such as the Advance Mobile Phone System (AMPS) in 1990s, that was used BCH block codes to perform error correction. Then development of 3G wireless system during the late 1990s which uses modern error correction code known as Turbo codes. These codes have higher coding gain. The 3G wireless systems do not provide a full range of multi-rate services and is not a fully integrated System. Currently, 4G supporting high quality multimedia for mobile nodes and security measures were incorporated. It addresses mobility, security, and QoS issues at the design stage of mobile communication network. In near future, the 5G wireless cellular networks will provide highest bandwidth and data rates with mobility. Table1 describes the various generations of cellular communication networks and their key characteristics [2].

Table 1 Mobile Communication Evolution from 1G to 5G.

	1G	2G	3G	4G	5G
Freq. band	Analog 30 KHz	digital 1.8GHz	1.6 – 2.0 GHz	2-8 GHz	3-300 GHz
Band Width	30 Kbps	1.25 Kbps	5 MHz	20 MHz	100 MHz
Data Rate	2 Kbps	64 Kbps	Up to 2 Mbps	Up to 1 Gbps	Higher than 1Gbps
Access	FDMA	CDMA TDMA	WCDM A	OFDM	OFDM MIMO
Error Correcti ng Codes		RS, BCH Codes	Turbo Codes	LDPC Codes	--
BER		Poor 10^-3	Moderate 10^-6	Good 10^-8	-
Decodin g Comple xity		Moderate	Highere	Lower	-

Revised Manuscript Received on May 22, 2019.
Othman O. Khalifa, Department of Electrical and Computer Engineering, International Islamic University Malaysia, Malaysia.
Noralya Fatin Bt. Muzamil, Department of Electrical and Computer Engineering, International Islamic University Malaysia, Malaysia..

Services	Analog (Voice)	Digital Voice, SMS, higher capacity	Audi, video, higher quality	IP access, Wearable devices	IP access, Weara ble devices , AI
Latency	>1000ms	300–1000 m	Up to 120ms	<100ms	≤1ms
Limitati ons	Poor spectral efficiency , major security issues	Data rate limitation, does not support internet	Fail of WAP of internet	Battery useis more, require complicat ed hardware	unkno wn

A various error correcting code for error correction were used in the wireless communications networks, i.e. 2G onwards. However in 3G and beyond, the Turbo codes and LDPC codes were used. LDPC shows the best choice of parameters such as code gain, code rate, BER, maximum block length and decoding complexity. However, it shown that the LDPC codes with large information length perform better than Turbo codes at high code rates.

III. LOWER DENSITY PARITY CHECK (LDPC)

LDPC code is a linear error correcting code, that transmitting a message over a noisy transmission channel. It is also known as Gallager codes as they are invented by Gallager in 1962 [3]. In 1996 [5], Mackay and Neal reinvented LDPC codes which have near Shannon limit performance. They have Better performance as compared with Turbo code when the block length is too large and Lower computational complexity for decoding. In addition parallization capability facilitates hardware implementation of LDPC codes. LDPC codes [6][7] are used in number of applications such as 4G mobile communication, optical communication, satellite communication, and DSL (Digital Subscriber Loop), DVB-S2 (Digital Video Broadcasting), and WiMAX (Worldwide Interoperability for Microwave Access). According to [8] linear codes acquired from sparse bipartite graphs are called LDPC codes. Assuming G is a graph with message nod (n left nodes) and also check nodes (r right nodes). The graph increases to a linear code of block length n and dimension at least n − r in the subsequent method. The n coordinates of the codewords are correlated with the n message nodes. The codewords are equal to the sum of all check nodes among the message nodes in neighboring positions is zero. Fig.1 illustrate the example of LDPC codes representation using Tanner graph where the Parity Check Equations and matrix shown below:

$$\begin{aligned}
&c1: && X1 \oplus X3 \oplus X5 \oplus X7 = 0 \quad \text{mod-2}\\
&c2: && X1 \oplus X4 \oplus X6 \oplus X8 = 0 \quad \text{mod-2}\\
&c3: && X2 \oplus X3 \oplus X6 \oplus X7 = 0 \quad \text{mod-2}\\
&c4: && X2 \oplus X4 \oplus X5 \oplus X8 = 0 \quad \text{mod-2}
\end{aligned}$$

$$\mathbf{H}=\begin{bmatrix}1&0&1&0&1&0&1&0\\1&0&0&1&0&1&0&1\\0&1&1&0&0&1&1&0\\0&1&0&1&1&0&0&1\end{bmatrix}$$

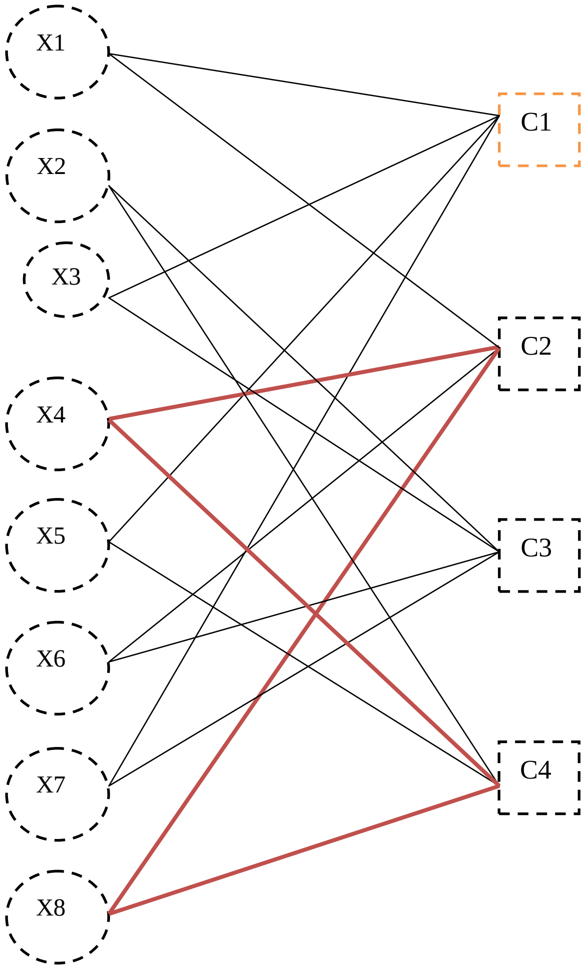


Fig. 1: LDPC Tanner graph matrix. **H**

By considering at the adjacency matrix of the graph, the graph representation is analogous to a matrix representation. If the ith check node is connected to the jth message node in the graph, let H be a binary r × n-matrix in which the entry (i, j) is 1. Then, the graph of the set of vectors c = (c1, . . . , cn) such that H • c > = 0 will defined the LDPC code. The matrix H is called a parity check matrix. Contrarily, any binary r × n-matrix that boosts a bipartite graph in the midst of n message and r check nodes, and the code determined as the null space of H is exactly the code related to this graph. Hence, any linear code has a representation as a code related to a bipartite graph (note that this graph is not uniquely defined by the code). However, only one out of every binary linear code has an image by a sparse bipartite graph. However, it is reveals that LDPC codes can approach the Shannon limit as closely as the turbo codes do. Moreover, recent studies show that performance of the LDPC codes matches or even outperforms that of turbo codes while requiring lower complexity [9]

IV. VITERBI ALGORITHM

One of the two types of decoding algorithms is Viterbi algorithm [10] for convolutional encoding and the other type is sequential decoding.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The advantage of Viterbi decoding is that it has a fixed decoding time [11][12][13]. Hence, suitable to hardware decoder completion. At each time instant, a new value of the state metrics has to be calculated. In the same words, every clock cycle, the state metrics have to be updated. Hence, normal approach to escalate the throughput of the system, is not relevant. The component that dominates the most power and area is the Add-Compare-Select (ACS) unit

V. SIMULATION PARAMETERS

In this work, Table 2 shows the parameters used to depict the simulation result of LDPC codes and Table 3 shows the parameters for Viterbi decoder. The data generated to be either 1 or -1 as shown in Fig,1 as a sample. The Additive white Gaussian noise (AWGN) is added as shown in fig.2.

Table 2 LDPC Code Parameters

Type	***Parameters***
Modulation:	BPSK
Channel:	AWGN
Parity Check:	15 x 12
Maximum iteration number :	100

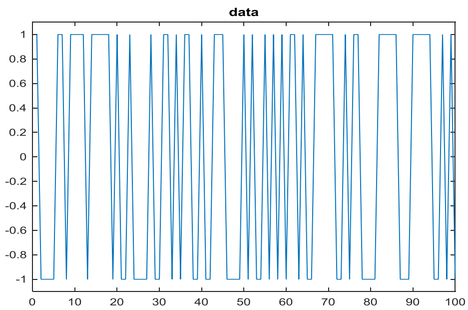
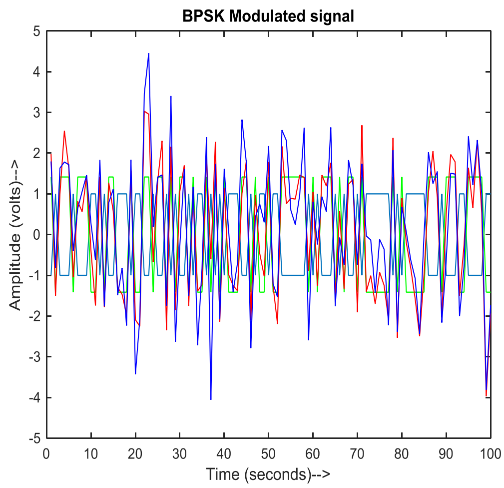


Fig. 1 Generated Data

Table 3 Viterbi decoder parameters

Type	***Parameters***
Modulation:	BPSK
Channel:	AWGN
Encoder:	G(D)=[1+D^2, 1+D+D^2]



Fig,2 Modulated signal with AWGN

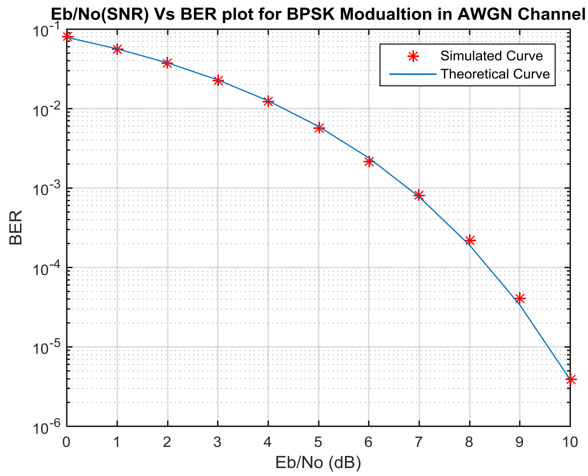


Fig. Error Probability Curve of BPSK in AWAN channel

VI. SIMULATION RESULTS

The simulation of LDPC used the low density matrix created by Gallager. Encode, modulate, and transmit frames of binary data through an AWGN channel. Then, demodulate, decode, and estimate the bit error rate.

The bit-error rate statistics were collected for BPSK modulation with and without LDPC codes under different SNRs. The average bit-error rates were plot as a function of SNR

It is observed that BER reduces significantly when using of LDPC codes. This enhancement is achieved at the cost of a higher encoding and decoding complexity. In addition, it decreased the information rate. The LDPC code has the following advantages. First of all, LDPC can accomplish performance close to the Shannon limit contributed that the codeword length is long. Next, LDPC has simpler complexity than the Turbo code. The normally used decoding algorithm for LDPC is “belief propagation”, which is complemented and can be accomplished at certainly higher speeds than the decoding of Turbo codes.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Third, the decoding algorithm is provable in the sight that decoding to a accurate codeword is a measurable event .

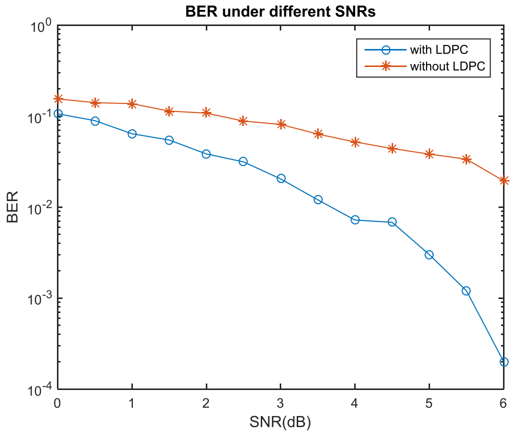


Fig.3 BER under different SNR for BPSK

Fig.4 shows the simulation use binary phase shift keying (BPSK) modulation over an additive white gaussian noise (AWGN) channel for Viterbi algorithm. The BER achievement for the constant length increases.

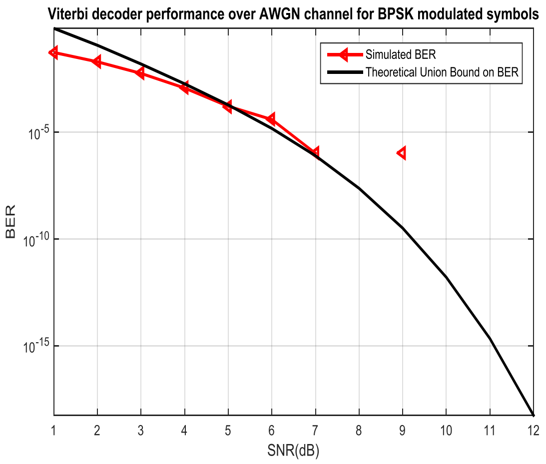


Fig.4 :Viterbi Performance

VII. CONCLUSION

Wireless Communications systems are playing an important role in people's lives especially in activities such as mobile communications and internet access. However, the transmission of information via communication channel has a major problem; it is very sensitive to disruptions such as noises, distortions, interferences, and multipath fading. In this paper, the simulation results show that in LDPC coding the BER suddenly drops as the number of iterations increase with a small increase in Eb/No. Which is not possible in other coding. Also BER was achieved using less number of iterations and hence the latency and receiver complexity has decreased for LDPC coding. As a conclusion, LDPC codes reduce the noise closest to Shannon limit.

REFERENCES

1. 4G?, W. (2018). What is 4G?. [online] 4g.co.uk. Available at: https://www.4g.co.uk/what-is-4g/ [Accessed 17 Dec. 2018].
2. Pradeep, M., Prakash, D., & Anjana, J., Modern error correcting codes for 4G and beyond: Turbo codes and LDPC codes. 2015 Radio And Antenna Days Of The Indian Ocean (RADIO), 2015,pp. 1-2,
3. Gallager, R.G. Low density parity check codes, IRE Trans Information Theory, 1962, IT-8, pp 21-28
4. Robert M. Tanner, "A recursive approach to low complexity codes," IEEE Trans. Inf. Theory, pp. 533-547, Sept. 1981.
5. MacKay D. J. C. and Neal R.M. Near Shannons limit performance of the low density parity check codes, Electron. Lett., vol. 32 18 Aug.1996, pp.1645-1646.
6. Muhammad Salman, K., & Muhammad Masood, Error Detection and Correction. Retrieved from https://fypethernetlancard.wordpress.com/2011/07/30/error-detection-and-correction, 2011.
7. Yu, Y., Jia, Z., Tao, W., & Dong, S.. LDPC Codes Optimization for Differential Encoded LDPC Coded Systems with Multiple Symbol Differential Detection. 2016 IEEE 5Th Global Conference On Consumer Electronics,2016, pp.1-2.
   Shokrollahi, a.. LDPC Codes: An Introduction, 2013
8. Richardson and R. Urbanke, "The renaissance of Gallager's low-density parity-check codes," IEEE Commun. Magazine, vol. 41, issue 8, pp. 126-131, Aug. 2003.
9. Viraktamath, S., Talasadar, D., V. Attimarad, G., & Radder, G. , Performance Analysis of Viterbi Decoder using different Digital Modulation Techniques in AWGN Channel, 2014,vol.9, pp. 01-06, F Electronics And Communication Engineering (IOSR-JECE)
10. J. He, Z. Wang, and H. Liu, "An efficient 4-D 8PSKTCM decoder architecture," IEEE Trans. Very Large Scale Integr. (VLSI) Syst., vol.18, no. 5, pp. 808–817, May 2010.
11. J. Jin and C.-Y. Tsui, "Low-power limited-search parallel state viterbi decoder implementation based onscarece state transition," IEEE Trans.Very Large Scale Integr. (VLSI) Syst., vol. 15, no. 11, pp. 1172–1176,Oct. 2007.
12. M. Boo, F. Arguello, J. D. Bruguera, R. Doallo, and E. L. Zapata., ―High-performance VLSI architecture for the Viterbi algorithm,‖ IEEE Trans. on communications, vol. 45, no. 2, pp.168–176, 1997

AUTHORS PROFILE

Othman O. Khalifa received his Bachelor's degree in Electronic Engineering from Garyounis University, Libya in 1986. He obtained his Master degree in Electronics Science Engineering and PhD from Newcastle University, UK in 1996 and 2000 respectively. He worked in industry for eight years and he is currently a Professor and at the department of Electrical and Computer Engineering, International Islamic University Malaysia. His area of research interest is Communication Systems, Digital image / video processing, coding and Compression, Wavelets, Fractal and Pattern Recognition. Prof. Khalifa is a Charter Engineer (CEng) and Senior member of IEEE, USA and a member IET, UK. and a member of the Council of Professors of Malaysia. Prof. khalifa was the chairman of the International Conference on Computer and Communication Engineering (ICCCE), 2006, 2010, 2012, 2014. Prof. Khalifa has extensively contributed through his writings in international journals, conferences and book. He published more than 450 publications including 10 books. He is a member of many international advisory boards for many international conferences a member of many editorial boards of many international.

Noralya Fatin Bt. Muzamil is postgraduate student at Electrical and Computer Engineering, International Islamic University Malaysia.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication