SIMULATION MODELLING AND ANALYSIS OF PHYSICAL LAYER CODING SCHEMES FOR V2X APPLICATIONS

George Kiokes[1], Panagiotis Gkonis[2], Nikolaos Uzunoglu[3]

[1] Hellenic Air-Force Academy, Dekeleia, Attica GR-1010, Greece
[2,3.] National Technical University of Athens, Iroon Politechniou 9, Athens, Greece
[1.] Tel. +306937027669; e-mail. gkiokes@iccs.gr
[2,3.] Tel. +302107722289; e-mail. [2]pgkonis@esd.ntua.gr, [3]nuzu@cc.ece.ntua.gr

Abstract

This paper provides a comprehensive investigation of the performance and practical implementation issues of two coding schemes, employing Turbo Codes and low-density parity-check (***LDPC***) codes, over vehicular ad-hoc networks based on IEEE 802.11p specifications. Using simulation authors present the results of an evaluation of system performance for the two different coding schemes. We concentrate our evaluation on two different environments Rayleigh Fading and Weibull Fading. BER (Bit Error Rate) and SNR (Signal to Noise Ratio) values for BPSK modulation are examined and tested.

1. INTRODUCTION

Effective use of an Intelligent Transportation System (ITS) cannot only improve vehicular safety but also enhance the efficiency of current transport systems and driving comfort. Dedicated short-range communications (DSRC) system is a critical component of ITS for the future transport telematic services. This demand leads to wireless access for vehicular environments (WAVE), which is also regulated by the IEEE 802.11p standard [1]. In **American Society for Testing and Materials** (ASTM) 2213-03 standard, IEEE 802.11 and 802.11a are modified as a medium access control (MAC) and physical layer (PHY) specifications, respectively, for the DSRC system. In 1949, Claude Shannon developed a result that has become one of the fundamental theorems of coding theory. In his analysis he quantified the maximum theoretical capacity for a communications channel, the Shannon limit, and indicated that error-correcting channel codes must exist that allowed this maximum capacity to be achieved. In [2] Irving Reed and Gus Solomon published a paper which describes a new class of error-correcting codes that are now called Reed-Solomon (RS) codes. RS codes are the most popular class of block codes. In today's systems, convolutional codes are the most widely used channel codes. They owe their popularity to good performance and flexibility to achieve different coding rates. Block codes are different from convolutional codes in the sense that the code has a definite code word length *n,* instead of a variable code word length. In 1993 Berrou, Glavieux and Thitimajshima [3] proposed “a new class of convolution codes called turbo codes whose performance in terms of Bit Error Rate (BER) are close to the Shannon limit”. IEEE 802.11p Physical Layer (PHY) standard intends to support road transport, traffic applications and public safety over roadside and high-speed mobile units, or between high-speed vehicles. Researches have shown that multiple propagation paths or multipaths have both slow and fast aspects. The received signal for narrowband excitation is found to exhibit three scales of spatial variation such as Fast Fading, Slow Fading and Range Dependence. Moreover temporal variation and polarization mixing can be present.

This paper provides a comprehensive investigation of the performance for two different coding schemes (LDPC codes and Turbo codes), over vehicular ad-hoc networks for Rayleigh and Weibull fading channels.

2. LDPC CODES VS TURBO CODES

In information theory, Low-Density Parity-check codes [4] are a sub-class of linear error correcting coding schemes, which are methods of transmitting messages over noisy transmission channels. LDPC codes can be described as the null space of a sparse $\{0,1\}$ check matrix as well as by a bipartite graph, Tanner graph, which represents the rows and columns of the parity-check matrix. A generic LDPC decoder architecture is shown in Figure 1. It comprises K_u shared variable nodes units (VNUs),

K_c shared check variable nodes units (VNUs), K_c shared check nodes units (CNUs) and a shared memory fabric used to communicate messages between VNUs and CNUs. The computing operations taking place in each iteration are part of the min-sum decoding algorithm, while is a type of iterative message-passing decoding, also proposed as an approximation to the belief propagation (BP) algorithm. It is also referred to as the BP-based algorithm. The min-sum algorithm is a soft-decision, iterative algorithm for decoding binary-LDPC codes and is commonly used due to its simplicity and good BER performance. During the process, each decoding iteration consists of updating and transferring extrinsic messages between neighboring variable nodes and check nodes.

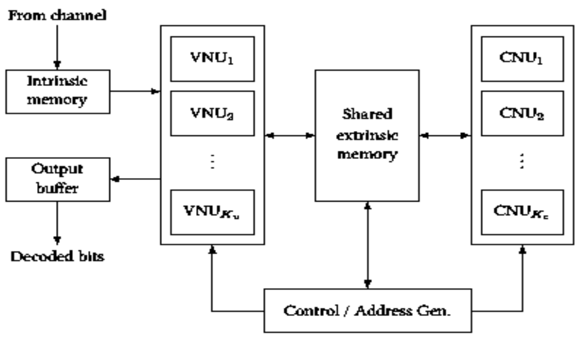

Figure 1. Generic LDPC decoder

A Turbo encoder [5] consists of two (or more) systematic block codes (Fig. 2). In a simplified Turbo encoder, there are two convolutional encoders in parallel. The interleaver is a key component of a Turbo encoder that guarantees excellent bit error rate and frame error rate performances.

A key development in Turbo codes is the iterative decoding algorithm. In the iterative decoding algorithm, decoders for each constituent encoder take turns operating on the received data. Each decoder produces an estimate of the probabilities of the transmitted symbols. The decoders are thus soft output decoders. Probabilities of the symbols from one decoder, known as extrinsic probabilities, are passed to the other decoder (in the symbol order appropriate for the decoder), where they are used as prior probabilities. The decoding algorithm thus passes probabilities back and forth between the two decoders, with each one combining the evidence it receives from the incoming prior probabilities with the parity information provided by the code. After a number of iterations, the decoding process converges to an estimate of the transmitted codeword.

The algorithm most commonly used for soft-decision decoding is the maximum a-posteriori probability (MAP) algorithm, also commonly known as the BCJR algorithm

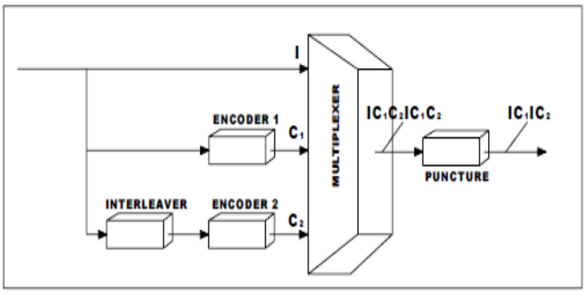

Figure 2. Block diagram of Turbo encoder

3. FADING TYPES FOR V2X COMMUNICATIONS

One of the most important problems that appears in vehicular communications is the multipath fading. This effect is causing a fluctuation in the received signal. To reduce or solve this problem we need to be able to predict this fading effect. There are two channel models for V2X communications that can be found in the literature in order to describe the multipath fading. The first propagation model [6] is proposed in the IEEE draft standard [7] and the distribution functions which can be used for modelling and designing it are either Rice or Rayleigh, with Doppler influence. The second model, presented in [8], takes into account two particularities of the mobile-to-mobile propagation channel : the inter-tap correlation and the nonstationarity modeled by a first order two-state Markov chain. In addition, the tap amplitudes are Weibull distributed. In the next paragraphs we introduce Rayleigh and Weibull distribution functions which can be used for describing the multipath fading.

3.1. Weibull distribution

The primary advantage of Weibull analysis is the ability to provide reasonably accurate failure analysis and failure forecasts with extremely small samples. Another advantage of Weibull analysis is that it provides a simple and useful graphical plot of the failure data. The Weibull distribution is often used to model the time until failure of many different physicals systems. The Probability Density Function (PDF) and the Cumulative Distribution Function (CDF) of Weibull is:

$$PDF(x) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k}, \quad CDF(x) = 1 - e^{-(x/\lambda)^k}$$

where k > 0 is the shape parameter and λ > 0 is the scale parameter of the distribution. The Weibull shape parameter can take values between 0 and ∞. For k=1 the Weibull distribution is identical to the exponential distribution, while for k=2 the Weibull distribution is identical to the Rayleigh distribution.

3.2. Rayleigh distribution

The Rayleigh distribution is a special case of the Weibull distribution and is often observed when the overall magnitude of a vector is related to its directional components. This distribution represents the worst fading case because we do not consider to have Line-of-Sight (LOS). The power is exponentially distributed. The phase is uniformly distributed and independent from the amplitude. The PDF and the CDF for the Rayleigh distribution is:

$$PDF(x) = \frac{x}{\sigma^2} exp - \frac{x^2}{2\sigma^2}, \quad CDF(x) = 1 - e^{-\frac{x^2}{2\sigma^2}}$$

where: x is the received signal envelope voltage, σ is the rms value of received voltage before envelope detection, σ^2 is the time average power of received signal before envelope detection.

4. SIMULATION RESULTS

In order to evaluate the coding options presented in the previous sections a full system model of 802.11p PHY was implemented in Matlab – Simulink, employing LDPC code and Turbo code. We have estimated Bit Error Rate (BER) versus Signal-to-Noise Ratio (E_b/N_o). For the performance evaluation of the Turbo codes we use a recursive systematic convolutional code with constraint length K=3 and specific frame size. The model generates Turbo code, and decodes the code iteratively (10 iterations) using MAP detectors.

Log-Domain [9] technique was used for the decoding of LDPC codes. The comparison was performed for BSPK modulation and the relative vehicular velocity was 50 km/h. The distance which the measurements took place was 200m for the path between transmitter and receiver. For the Weibull fading according authors at [8] the shape factor was found 3.95 for small cities. We assumed 400 ns RMS delay spread. The Doppler spread was found 268 Hz. The rate of both codes is R = 1/2. Figure 3 shows the performance of Turbo codes and the LDPC codes for Rayleigh fading channel with iterations one and ten respectively. Figure 4 shows the performance in Weibull path. Our simulation results for Rayleigh environment have shown that with LDPC scheme the performance was slightly better than the Turbo coding chain especially in the range between 0.5 to 3 dB. After that the two coding schemes performs equal. Regarding the second case over Weibull fading channel, our results have shown that performance obtained by LDPC coding is better than the Turbo coding by 0.5 dB in the 1st and the same in the 10th iteration.

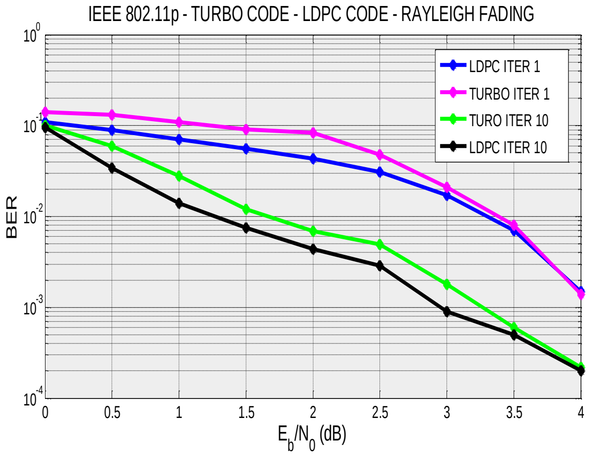

Figure 3. Simulation results for Rayleigh fading

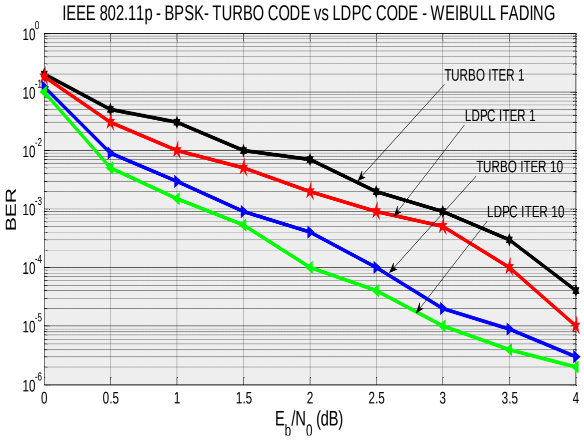

Figure 4. Simulation results for Weibull fading

5. CONCLUSION

This article presents the performance evaluation results of a comparative study for IEEE 802.11p PHY employing two different coding schemes, LDPC coding and Turbo coding. From the obtained simulation results, the BER vs SNR for BPSK modulation scheme in Rayleigh fading channel and in Weibull fading channel is calculated. In our evaluation, we have explored Turbo codes and LDPC codes and we came to the conclusion that LDPC codes tend to outperform the other coding scheme especially in low and middle E_b/N_o values. The results presented in this paper show that in difficult environmental cases both codes achieved significant improvement in our propagation conditions.

References

[1] Weidong Xiang, Yue Huang, Sudhan Majhi 'The Design of a Wireless Access for Vehicular Environment (WAVE) Prototype for Intelligent Transportation System (ITS) and Vehicular Infrastructure Integration (VII)', Department of ECE, Michigan University, Vehicular Technology Conference, 2008. VTC-2008 Fall. 2008

[2] Reed, I. S. and Solomon, G., "Polynomial Codes Over Certain Finite Fields," SIAM Journal of Applied Math., vol. 8, 1960, pp. 300-304.

[3] Berrou, A. Glavieux, and P. Thitimajshima, Near Shannon limit error-correcting coding and decoding, in Proc. of ICC, Geneva, Switzerland, May 1993, pp. 1064–1070.

[4] R. G. Gallager, "Low density parity check codes" IREY Transaction Information Theory, vol IT-8, pp. 21-28, Jan. 1962

[5] W. Stallings, "Coding and Error-Control," Chapter 8 of Wireless Communications and Networks, Prentice Hall, Inc. New Jersey 2002

[6] G. Acosta and M. A. Ingram, "Six time- and frequency-selective empirical channel models for vehicular wireless LANs," 1st IEEE International Symposium on Wireless Vehicular Comm., 2007

[7] IEEE P802.11p/D0.26, Jan. 2006, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 3: Wireless Access in Vehicular Environments

[8] I. Sen and D. W. Matolak, "Vehicle-vehicle channel models for the 5-GHz band,"IEEE Trans Intelligent Transportation Systems vol. 9, 2008,pp.235–245

[9] Wymeersch, H.; Steendam, H.; Moeneclaey, M.; Log-domain decoding of LDPC codes over GF(q) IEEE ICC 2004 Volume: 2 Publication Year: 2004 , Page(s): 772 - 776 Vol.2