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RESEARCH ARTICLE

FINITE–PRECISION ANALYSIS OF DEMAPPERS AND DECODERS FOR LDPC-CODED M-QAM SYSTEMS

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Abstract:- The performance of LPDC is strongly affected by finite-precision issues in the representation of inner variables. Great attention has been paid, to the topic of quantization for LDPC decoders, but mostly focusing on binary modulations and analyzing finite precision effects in a disaggregated manner, i.e., considering separately each block of the receiver. Modern telecommunication standards, instead, often adopt high order modulation schemes, e.g. M-QAM, with the aim to achieve large spectral efficiency. This puts additional quantization problems that have been poorly debated. The choice of suitable quantization characteristics for both the decoder messages and the received samples in LDPC-coded systems using M-QAM schemes is being understood. The analysis involves also the demapper block that provides initial likelihood values for the decoder, by relating its quantization strategy with that of the decoder. A new demapper version, based on approximate expressions, is also presented, that introduces a slight deviation from the ideal case but yields a low complexity hardware implementation. A relevant issue concerns comparison between the error rate performance that is achievable by using LDPC codes and that ensured by other schemes employing SISO decoding. Moreover, modern broadcast communications are characterized by increasing throughput requirements. For example, for the DVB-T2 standard, that must support High Definition Television (HDTV) services.. Another issue in broadcast transmissions concerns complexity of the decoder implementation that can be somehow reduced by introducing suitable approximations. The current scenario of error correcting codes is dominated by schemes using Soft-Input Soft-Output (SISO) decoding. Among them, an important role is played by Low-Density Parity-Check (LDPC) codes that permit to approach the theoretical Shannon limit, while ensuring reduced complexity

Index Terms—Integer wavelet transform, k-means clustering, masking, robust reversible watermarking (RRW).

1. INTRODUCTION

Low Density Parity Check (LDPC) codes are state-of-art error correcting codes, included in several standards for broadcast transmissions. Iterative soft decision decoding algorithms for LDPC codes reach excellent error correction capability; their performance, however, is strongly affected by finite-precision issues in the representation of inner variables. Great attention has been paid to the topic of quantization for LDPC decoders, but mostly focusing on binary modulations and analyzing finite precision effects in a disaggregated manner, i.e., considering separately each block of the receiver. Modern telecommunication standards, instead, often adopt high order modulation schemes, e.g. M-QAM, with the aim to achieve large spectral efficiency. This puts additional quantization problems that have been poorly debated and the choice of suitable quantization characteristics for both the decoder messages and the received samples in LDPC-coded systems using M-QAM schemes. The analysis involves also the demapper block that provides initial likelihood values for the decoder, by relating its quantization strategy with that of the decoder. A signal label for a signal in a 2*m*-ary modulation scheme is simply the m-bit pattern assigned to the signal. A mapping strategy refers to the grouping of bits within a codeword, where each *m* bit group is used to select a 2*m*-ary signal in accordance with the signal labels. The most obvious mapping strategy is to use each group of *m* consecutive bits to select a signal. We will call this the consecutive-bit (CB) mapping strategy. An alternative strategy is the bit-reliability (BR) mapping strategy which will be described below. A new demapper version, based on approximate expressions, is also presented, that introduces a slight deviation from the ideal case but yields a low complexity hardware implementation.The current scenario of error correcting codes is dominated by schemes using Soft-Input Soft-Output (SISO) decoding. Among them, an important role is played by Low Density Parity-Check (LDPC) codes that permit to approach the theoretical Shannon limit while ensuring reduced complexity. For such reason, these codes have been included in some recent telecommunication standards. The second generation of Digital Video Broadcasting (DVB) standards, in particular, considers LDPC codes in place of more conventional concatenated schemes formed by Reed-Solomon and convolution codes that in this projection adopted in first generation DVB standards. Similarly, the second version of the satellite DVB (DVB-S2) standard includes LDPC codes in conjunction with BCH codes. LDPC codes will be probably adopted also in the upcoming second generation of the terrestrial DVB (DVB-T2) standard that will replace soon its present version. Possible technologies to be included in such new standard are currently under evaluation. Based on the above considerations, a relevant issue concerns comparison between this projection, i.e. the error rate performance that is achievable by using LDPC codes and that ensured by other schemes employing SISO decoding. An example of such comparison will be given in Section II for the important case of the Digital Video Broadcasting – Return Channel Satellite (DVB-RCS) standard. Moreover, modern broadcast communications are characterized by increasing throughput requirements; this is true, for example, for the DVB-T2 standard that must support High Definition Television (HDTV) services. So, there is the need of large spectral efficiencies, which is usually satisfied by employing high order modulation schemes. The DVB-T standard adopts QPSK, 16-QAM and 64-QAM schemes in conjunction with OFDM, and probably the same will be for DVB-T2.Another issue in broadcast transmissions concerns complexity of the decoder implementation that can be somehow reduced by introducing suitable approximations. In particular, in SISO decoders, complexity is strongly affected by the finite-precision representation of the inner variables. The objective is to analyze "Finite-precision effects on an LDPC coded M-QAM system" of the type depicted it employs binary LDPC codes in conjunction with high order modulation schemes. The meaning of the various blocks and quantities involved will be explained in this , but most of previous works in this projection is limited to consider binary modulation. Higher order modulation schemes, like -QAM, whose adoption is justified by the need to increase the spectral efficiency, put a number of additional problems. In particular, they require modeling the effect of the demapper block (i.e., the symbol-to-metric calculator) and to refine the optimization procedure for saving the number of quantization bits without incurring significant performance losses. This can suggest, in particular, the adoption of suitable non-uniform quantization schemes, which are able to face efficiently the clipping effect. If not controlled, this effect can cause the appearance of remarkable and unexpected error floors.

II. PROPOSED METHOD

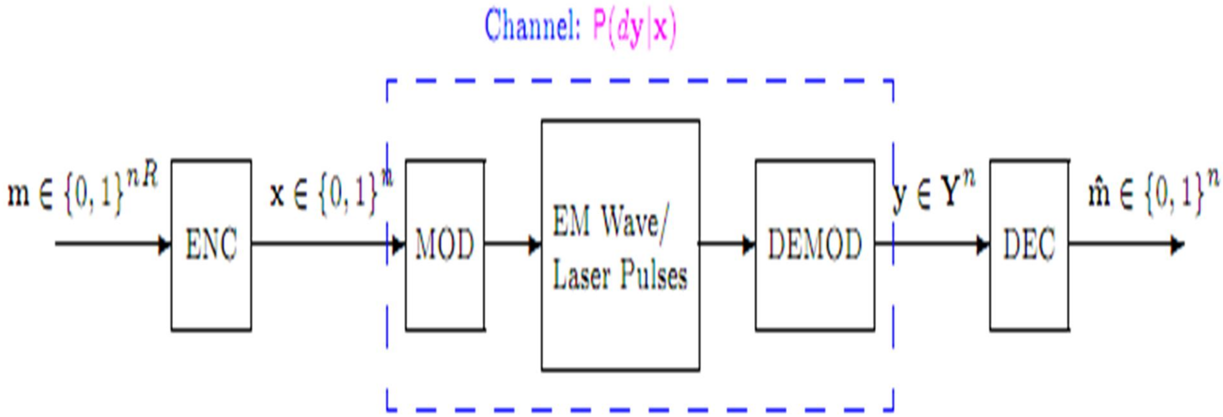
The analysis we have developed is quite general and can be applied, with some distinctions, to any value. However, for better evidence, we will mainly refer to the specific case of a 16-QAM constellation. For any M equal to an even power of 2, a Gray labeling can be adopted to match every sequence of encoded bits to each symbol. Simulations have been carried out over the AWGN channel. As the QAM constellation is not geometrically uniform, the simulated information patterns cannot be fixed (the all zero sequence would be the canonical choice) but are generated by a random, uncorrelated, source. The present invention relates to a soft-in, soft-out decoder used in an iterative error correction decoder which uses extrinsic information (prior probability information) to iteratively decode two or more code sequences. As one of error correction coding, an iterative error correction decoding method, called turbo coding, is known. This coding method creates a non-interleaved data sequence and an interleaved data sequence from a data sequence to be coded and uses a parallel concatenated convolution code (PCCC) to convolute each of these data sequences. In the decoding process of such turbo codes, two or more code sequences are sequentially and iteratively decoded. The use of the result of other decoding as the prior probability information allows the turbo coding to provide the high-performance error correction code that reaches very close to Shannon limits. During each decoding, SISO (Soft in Soft Out) decoding such as MAP (maximum a posteriori) decoding is used. In this case, extrinsic information (prior probability information) output from each decoder is stored in a memory for all data of each decode frame. However in this projection, the problem with the turbo coding described above is that, though very high performance error correction is attained, the decoder becomes complex in configuration, requires a large amount of memory, and consumes much power. To solve this problem, the log MAP decoding which converts MAP decoding calculation to the equivalent logarithm calculation is proposed. To solve the problems described above, the decoder according to the present invention comprises a plurality of metric calculators each generating a forward state metric and a backward state metric of a predetermined state for each data bit of each encoded frame; i.e. mapper and demapper block. Modern telecommunication standards, instead, often adopt high order modulation schemes, e.g. M-QAM, with the aim to achieve large spectral efficiency. This puts additional quantization problems that have been poorly debated and the choice of suitable quantization characteristics for both the decoder messages and the received samples in LDPC-coded systems using M-QAM schemes. The analysis involves also the demapper block,

A.RESEARCH AND EDUCATION ACTIVITIES OF THE PROJECT

It is primarily concerned with the study of various aspects and channel models of the free-space optics (FSO) communication channel, and the development of novel forward error-correction schemes for such channels. The motivation behind this project is that the FSO communication channel offers an excellent alternative for wireless communications for its wide bandwidth and relatively low cost, compared to RF wireless links. Optical communication through this channel is achieved by a point-to-point connection between two line-of-sight transceivers. We are interested in the FSO systems that are robust in the presence of atmospheric turbulence such as coded orthogonal frequency division multiplexing (coded-OFDM), and coded multiple-input multiple-output multi-laser multi-detector or MIMO) concept; both employing low-density parity-check (LDPC) codes.

B. ERROR CORRECTING CODES

Error-reduction in communication systems can be achieved by sending automatic repeat request (ARQ) through the feedback channel when errors occur, or by using (forward) error correcting codes (ECCs). The former of these is ancient and reliable error control scheme based on the two assumptions that a reliable, cost-effective feedback channel exists



Figer 1 shows A point-to-point logical channel governed by P(dyjx) and the error events during retransmission are independent of those in the initial transmission. On the other hand, a simple point-to-point communication system with ECCs requires no feedback channel, as illustrated in figure 3.1. ECCs achieves their error control purpose by limiting the legitimate transmission to a subset of the entire signal space. Hence, with very high probability, the corrupted received signal can be mapped inversely back to the transmitted signal, namely, the original signal can be successfully decoded. For modern wireless communication systems, error control is usually achieved by a sophisticated combination of ARQ and ECCs. Nevertheless, for deep-space communications, in which the cost of using a feedback channel is prohibitive, and for storage devices, in which the error events during retransmission are not independent, the system designer has to rely solely on ECCs to ensure reliable communications. This thesis will focus only on ECCs, and the results can benefit systems with or without ARQ.

C. ORBITAL ANGULAR MOMENTUM BASED ON MULTI CHANNEL

Orbital angular momentum (OAM) is a property of light associated with the helicity of a photon's wave front. Optical beams carrying OAM are usually called optical vortices, because they feature a phase discontinuity at their center. The momentum of a vortex field is proportional to the number of turns that this vector completes around the beam's axis after propagating a distance equal to one wavelength. This number is equal to the OAM state. The OAM state of a photon can take any integer value. This infinite set of OAM states forms an orthonormal basis. This property may be exploited in the context of optical communications. The orthogonality among beams with different OAM states allows the simultaneous transmission of information from different users, each on a separate OAM channel. Each orthogonal channel can be perfectly filtered and decoded at the receiver of a free-space optical (FSO) communication link OAM states may also be used for multilevel modulation.

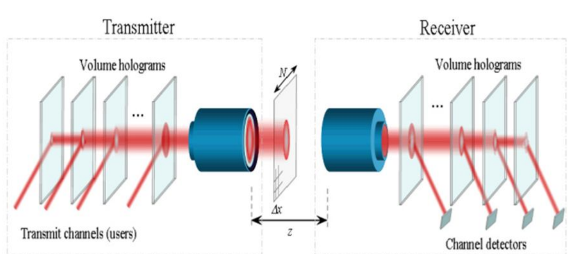
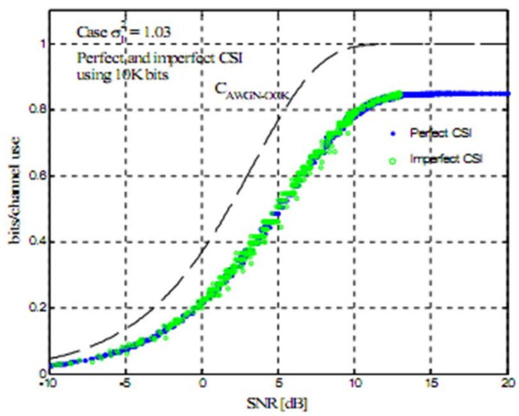


Figure 2 shows Diagram of a free-space optical communication link using multiplexed QAM channels



Figer 3 shows Effective Information Rate

The Effective information rate (in bits per channel use) achieved by the Raptor code with inner LDPC code (495, 433) on an experimentally-recorded FSO fading channel with temporal correlation τ0=3.6 ms and scintillation σ 2=1.03. The segmented curve is the capacity of an AWGN channel using OOK modulation, which serves as an upper bound. The strength of the Raptor code resides on its capability to maintain an information data stream at very low SNR values.

III. LDPC CODES

A. LINEAR BLOCK CODES

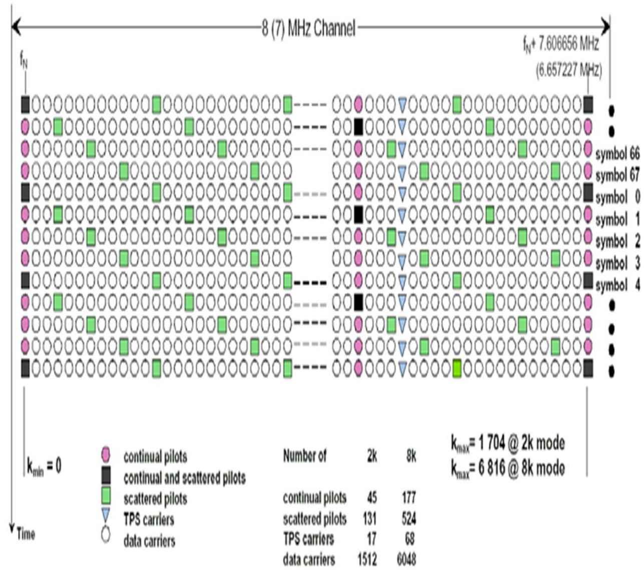
With a binary linear block code, a message is grouped into blocks of k bits, which are called the message bits. Each block of k bits is encoded into a longer block of n > k bits which is called the codeword or the coded bits. Typically, n − k redundant bits (called parity check bits) are added to the message bits to create a codeword. There are many ways of creating these parity bits, but in all cases they must be such that the message bits can be recovered by applying the inverse operation. A block code is denoted by Cb(n, k) with code rate Rc = k/n, which is the ratio of the message bits to the coded bits. In order to make linear block codes, some mathematical structures are now introduced.

B. REGULAR LDPC CODES

This section describes the characteristics of LDPC codes and a general method to construct them. A regular LDPC code satisfies the four following conditions:

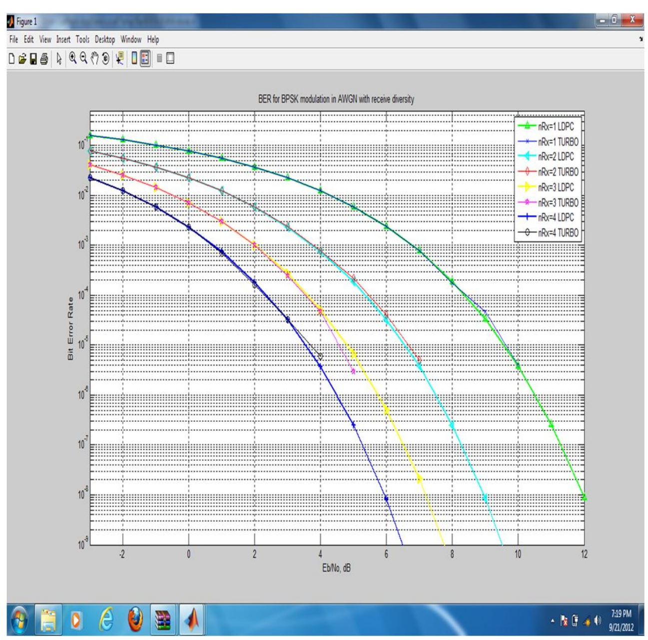
- The parity check matrix H has a fixed number of '1's per row, denoted by ρ.
- The parity check matrix H has a fixed number of '1's per column, denoted by γ.
- The number of common '1's per column and per row is at most one. This is a necessary condition to avoid short cycles in the corresponding bipartite graph.
- The number of '1's per row and per column is small compared to the code length.

LDPC codes can be classified into two categories, random LDPC codes and structured LDPC codes, based on the construction method used to generate the parity check matrix. As a general rule, random LDPC codes have slightly better BER performance in comparison with structured LDPC codes; however this benefit is achievable with an implementation that is more complex and subsequently more expensive. A random matrix construction method is employed in this thesis since it provides better performance with tolerable complexity. The random parity check matrices were selected from those constructed by Mackay2



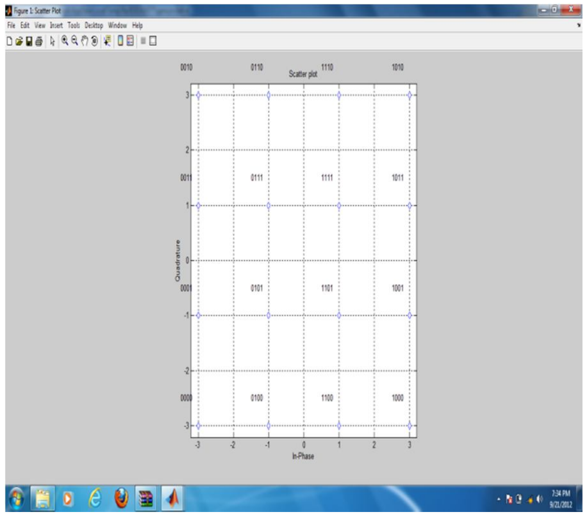
Figer 4 shows Structure of OFDM carrier

IV. EXPERIMENTAL RESULTS



Figer 5 shows : Comparison of LDPC and Turbo Codes

The above figure reports the simulated performance of the LDPC and turbo Codes, over the AWGN channel by using BPSK modulation and in the absence of quantization. It is observed that the performance of turbo codes and LDPC codes is similar at both rates. The turbo codes exhibit a slightly earlier waterfall for small signal-to-noise ratio and high error rates. For smaller error rates, however the curves of the LDPC codes show a more favorable slope and intersect those of the turbo codes.



Figer 6 shows : 16 QAM constellation

The above figure shows the 16 QAM constellation calculated for all the bit positions where k= 1 … 4.It indicates that all the values depend only on the Quadrature component.

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