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Analysis and Design of Modern Coding Schemes for Unequal Error Protection and Joint Source-Channel Coding

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Abstract

In this thesis, we investigate systems based on error-correcting codes for unequal-error-protecting and joint source-channel coding applications. Unequal error protection (UEP) is a desirable characteristic for communication systems where source-coded data with different importance levels is being transmitted, and it is wasteful or even infeasible to provide uniform protection for the whole data stream. In such systems, we can divide the coded stream into classes with different protection requirements. Among the possible ways to achieve UEP, we focus on solutions based on error-correcting codes.

Regarding UEP solutions by means of coding, we first introduce an analysis of a hybrid concatenation of convolutional codes, which typically arises in the context of turbo coding schemes with unequal-error-protecting properties. We show that the analysis of such a system can be reduced to the study of serial concatenated codes, which simplifies the design of such hybrid schemes.

Additionally, we also investigate the application of graph-based codes for systems with UEP requirements. First, we perform a multi-edge-type analysis of unequal-error-protecting low-density parity-check (LDPC) codes. By means of such an analysis, we derive an optimization algorithm, which aims at optimizing the connection profile between the protection classes within a codeword of a given unequal-error-protecting LDPC code. This optimization allows not only to control the differences in the performances of the protection classes by means of a single parameter, but also to design codes with a non-vanishing UEP capability when a moderate to large number of decoding iterations is applied.

As a third contribution to UEP schemes, we introduce a multi-edge-type analysis of unequal-error-protecting Luby transform (UEP LT) codes. We derive the density evolution equations for UEP LT codes, analyze two existing techniques for constructing UEP LT codes, and propose a third scheme, which we named flexible UEP LT approach. We show by means of simulations that our proposed codes have better performances than the existing schemes for high overheads and have advantages for applications where a precoding of data prior to the channel encoding is needed.

In the last part of the thesis, we investigate joint source-channel coding schemes where low-density parity-check codes are applied for both source and channel encoding. The investigation is motivated by the fact that it is widely observed that for communication systems transmitting in the non-asymptotic regime with limited delay constraints, a separated design of the source and channel encoders is not optimum, and gains in complexity and fidelity may be obtained by a joint design strategy. Furthermore, regardless of the fact that the field of data compression has reached a state of maturity, there are state-of-the-art applications which do not apply data compression, thus failing to take advantage from the source redundancy in the decoding.

Within this framework, we propose an LDPC-based joint source-channel coding scheme and by means of the multi-edge analysis previously developed, we propose an optimization algorithm for such systems. Based on syndrome source encoding, we propose a novel system where the amount of information about the source bits available at the decoder is increased by improving the connection profile between the factor graphs of the source and channel codes that compose the joint system. Lastly, by means of simulations, we show that the proposed system achieves a significant reduction of the error floor caused by the encoding of messages that correspond to uncorrectable error patterns of the LDPC code used as source encoder in comparison to existent LDPC-based joint source-channel coding systems.