

Preface

About sixty years ago, Shannon's seminal paper laid the foundations of information theory. In particular, it characterized channel coding as a means for achieving the so-called channel capacity, i.e., to exploit the full information transfer potential of the channel. Since then, both theory and techniques for point-to-point communications have been constantly developed, up to the point that, nowadays, techniques for practically closing the gap to channel capacity exist for several simple channels. This has been made possible by the invention of powerful coding methods, such as turbo codes and low-density parity-check (LDPC) codes. The idea of turbo codes was first published in a conference paper in 1993, where the authors used powerful concatenated codes and an iterative scheme which made possible to effectively—although suboptimally—perform decoding. Since the introduction of turbo codes, a huge amount of resources in the scientific community moved to the investigation of iterative detection and decoding techniques. This eventually led to the rediscovery of LDPC codes in 1995. In fact, LDPC codes were first introduced and analyzed by Robert Gallager in the early Sixties. At that time, the limited available computational power made the use of LDPC codes impractical and prevented scientists from fully understanding their potential. After the introduction of irregular LDPC codes and of practical performance analysis tools in the late Nineties, LDPC codes became the most powerful error correcting codes, enabling reliable transmissions at rates close to the channel capacity for a number of memoryless channels.

LDPC codes were originally designed for binary input memoryless channels. Although the binary input assumption is not really restrictive—LDPC codes can in fact be easily generalized to non-binary input symbols—getting rid of the memoryless assumption is a subtle task. In fact, despite LDPC codes for binary-input memoryless channels admit a decoding algorithm which is asymptotically optimum for increasing codeword lengths—besides being optimum, in a few cases, also for finite codeword lengths—there exists no capacity-achieving coding scheme nor practical optimum decoding algorithm

for generic communications channels. Nevertheless, there are practical ways to exploit the properties of LDPC codes to obtain efficient communications also over generic channels. In particular, *LDPC coded modulations* are among the most promising techniques for achieving this goal.

In this book, we will explore the world of LDPC coded modulations intended as a means for using binary LDPC codes for obtaining close-to-capacity performance over generic communication channels. In Chapter 1, we introduce some basic concepts which will be useful in the remainder of the book. In particular, we give a short survey of important concepts, such as mathematical modeling of a communication system, modulation and channel coding, together with a short and self-contained introduction to information theory. In Chapter 2, trellis-based detection strategies for modulations and coded modulation schemes are introduced. These will be basic component blocks of LDPC coded modulations. In Chapter 3, we introduce LDPC codes, describing their structure, representation, best known decoding schemes and encoding techniques. In Chapter 4, we introduce and discuss the most relevant performance analysis techniques for assessing the performance of iterative receivers and their component blocks. In particular, we focus on Monte Carlo methods and extrinsic information transfer (EXIT) charts. In Chapter 5, we introduce the concept of LDPC coded modulations and describe how to apply EXIT charts to analyze their performance. We discuss optimization of LDPC codes for LDPC coded modulations considering some relevant optimization targets such as best power efficiency, minimum number of decoding iterations, and minimum bit error rate (BER). As a particularly relevant case study, we consider code optimization for partial response channels. In Chapter 6, we consider LDPC codes for memoryless channels and the implications of the adopted analysis technique on the structure of LDPC codes in a few interesting cases. The results, which demonstrate a low dependence of optimized LDPC codes on the particular memoryless channel, are used to devise a method for designing multilevel coding schemes using a database of LDPC codes. In Chapter 7, we apply the code design techniques described in Chapter 5 to phase-uncertain communication channels considering LDPC coded differential modulations and obtaining insights on the optimized LDPC code structure. We also describe a low-complexity detection strategy particularly suited for use in an LDPC coded modulation system. In Chapter 8, we draw some final remarks.

Last, but not least, we would like to thank Dr. Christoph Baumann, our Springer Engineering Editor, for expressing his interest and supporting this book from the very beginning, and for his patience in waiting for the final delivery.



<http://www.springer.com/978-3-540-69455-7>

LDPC Coded Modulations

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2009, IX, 197 p., Hardcover

ISBN: 978-3-540-69455-7