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★ *The final extended abstracts of these papers were not available at time of print. Therefore, an extract of the originally submitted papers was included, instead.*

On the Construction of Efficient Multilevel Coded Modulations

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The methodology of multi-stage iterative decoding with exchange of soft information has recently been applied to a wide range of error-controlling codes with remarkable success, including parallel/serial concatenated convolutional/block codes [1] and generalized concatenated convolutional codes [3]. A theoretical explanation of this decoding mechanism has recently been proposed [6] via the belief propagation algorithm (BPA) [7], well-known in the artificial intelligence community. It is shown that, by representing a turbo code with a Bayesian belief network, the application of BPA directly leads to the turbo decoding algorithm. In fact, it is argued that the decoding algorithms for all the aforementioned variations of the turbo coding construction as well as a wide range of low-density parity check codes can be explained by this principle.

It becomes evident from this Bayesian network perspective that the now classical turbo coding approach imposes unnecessary differentiation on parity checks and specifies a seemingly arbitrary sequential activation order of the network [6]. Low-density generator matrix (LDGM) codes are proposed as a generalization of turbo codes in which the parity bits are treated uniformly [2]. These codes can be encoded and decoded with complexity linear in the code length. Contrary to the turbo decoding paradigms where sequential processing is accomplished by very powerful central units, the proposed decoding algorithm based on BPA is formulated in a distributed parallel form. The decoders can thus enjoy modular pipeline design and the systems, therefore, seem more suitable for practical applications. The performances of these codes, as marked in Fig. 1 by cross-plus signs, are 1 dB or so of the channel capacity. They are superior to several optimal convolutional codes with either Viterbi or sequential decoding, and, when used with QPSK (without any coded modulation techniques), are comparable to some trellis coded modulations [8], though with marginal lower spectral efficiency.

To achieve higher frequency efficiency, LDGM codes are combined with M -ary signaling schemes using multilevel coding methods [5]. Instead of the traditional design rule of balanced squared Euclidean distances, component codes for individual partition levels are chosen such that their rates are matched to the corresponding equivalent channel capacities of the levels [4]. BP decoding algorithm for LDGM codes is applied to decode individual levels and hard estimates of the codewords are then fed to the lower levels. The performances for two such coded 8PSK using Ungerboeck's partitioning rules [8], as shown in Fig. 1 by circled-cross-plus signs, are about 1 dB of the channel capacity and superior to some (multi-dimensional) trellis coded modulations. Some partitioning rules other than Ungerboeck's are investigated and shown to provide a range of flexible coding systems, e.g., unequal error protection.

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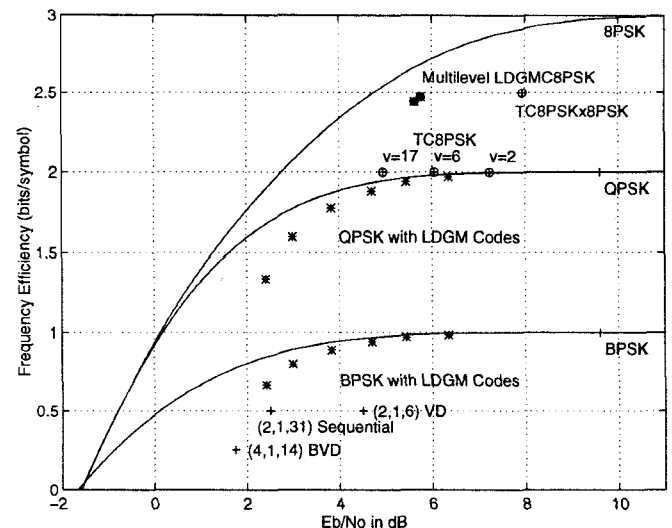


FIGURE 1 Spectral efficiency comparison of codes. (Marks for specific coding systems are based on the code rates and the required E_b/N_0 for $\text{BER}=10^{-5}$.)

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