Iterative Source/Channel Decoding based on a Trellis Representation for Variable Length Codes

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Abstract — **A new trellis representation for variable length codes (VLC) is proposed which allows soft-in/soft-out decoding of these codes. Applying the BCJR-algorithm on this trellis either symbol-level or bit-level reliability information for the variable length coded sequence can be obtained. By using this soft-in/soft-out VLC decoder for iterative ("turbo") decoding of a serially concatenated scheme consisting of an outer variable length code and an inner convolutional code separated by an interleaver significant gains can be yielded compared to a instantaneously decoded variable length code of the same overall source and channel code rate.**

I. Introduction

Recently several schemes have been proposed to perform decoding of variable length codes by considering the overall sequence rather than decoding the VLC coded symbol stream instantaneously using the prefix property of these codes. Some of these approaches also use trellis representations of variable length encoded symbol sequences and carry out either maximum likelihood (ML)- or maximum a posteriori (MAP)-sequence estimation to decode the source symbols. Although in [2] symbol-level soft-output was proposed, the soft-output was not used for further processing. We present a soft-in/soft-out VLC decoder which can be used in an iterative decoding scheme.

II. Trellis Representation

Consider a source that independently produces outputs selected from an M-ary alphabet $\mathcal{U} = \{0, ..., M-1\}$. A vector $\mathbf{u}$ of K source output values is mapped to a vector $\mathbf{c}$ of codewords taken from a variable length code $\mathcal{C}$ for the given symbol alphabet. Let $\mathbf{l} = (l_1, ..., l_M)$ be an M-tuple that defines the lengths of the codewords. The total bit-length of the VLC vector $\mathbf{c}$ is denoted by N. Every sequence consisting of K symbols and N bits can be graphically represented by a trellis-like structure as shown in Figure 1 for $K = 4$ and $N = 6$, where the horizontal axis represents the symbol time and the vertical axis represents the bit time. The alphabet size in the example is $M = 3$ and the lengths of the codewords are $\mathbf{l} = (1, 2, 3)$. Furthermore, let the vector $\mathbf{c}$ be channel coded and transmitted over a noisy channel.

III. Decoder Structure

As the above mentioned trellis is terminated it can easily be seen that maximum a posteriori (MAP) decoding according to the BCJR-algorithm [1] can be applied on this trellis. Thereby decoding can be carried out either on a symbol-by-symbol basis along the horizontal axis or on a bit-by-bit basis along the vertical axis. If decoding is done vertically the output values of the decoder are a posteriori probabilities (APP) for the bits of the variable length coded sequence $\mathbf{c}$. Let us assume a concatenated coding scheme with a variable length code as outer code and a channel code as inner code separated by an interleaver. If the APP-VLC decoder works in the bit-level mode the soft-output can be used as a priori information for a second run of the inner soft-in/soft-out channel decoder. This results in the well known structure of an iterative decoder for a serially concatenated coding scheme.

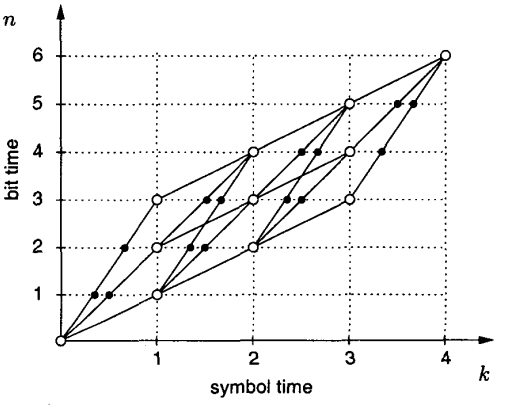

Figure 1: Example for VLC-Trellis

This new iterative approach in source/channel decoding with variable length codes results in significant performance gains compared to a system with instantaneous VLC decoding for both AWGN and fully interleaved Rayleigh-fading channel. Further detail about the proposed approach can also be found in [3].

References

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