Design of a new generation of Turbo Codes

PhD thesis description

In the early nineties, the invention of Turbo Codes (TC) [1] was a revival for the channel coding research community. Historical turbo codes, also sometimes called Parallel Concatenated Convolutional Codes (PCCC), are based on a parallel concatenation of two recursive systematic convolutional codes separated by an interleaver. They are called “turbo” in reference to the analogy of their decoding principle with the turbo principle of a turbo-compressed engine, which re-uses the exhaust gas in order to improve efficiency. The turbo decoding principle calls for an iterative algorithm involving two component decoders exchanging information in order to improve the error correction performance with the decoding iterations.

This iterative decoding principle was soon applied to other concatenations of codes separated by interleavers, such as Serial Concatenated Convolutional Codes (SCCC) [2][3], sometimes called serial turbo codes, or concatenation of block codes, also named block turbo codes [4][5].

The near-capacity performance of turbo codes and their suitability for practical implementation explain their adoption in various communication standards as early as the late 1990s: firstly, they were chosen in the telemetry coding standard by the CCSDS (Consultative Committee for Space Data Systems) [6], and for the medium to high data rate transmissions in the third generation mobile communication 3GPP/UMTS standard [7]. They have further been adopted as part of the Digital Video Broadcast - Return Channel Satellite and Terrestrial (DVB-RCS and DVB-RCT) links [8][9], thus enabling broadband interactive satellite and terrestrial services. More recently, they were also selected for the next generation of 3GPP2/CDMA2000 wireless communication systems [10] as well as for the IEEE 802.16 standard (WiMAX) [11] intended for broadband connections over long distances.

While the well-known DVB-RCS/DVB-RCT/WiMAX 8-state double-binary parallel turbo code offer performance very close to the Shannon limit in the so-called waterfall region, it suffers from a flattening effect around $10^{-5}$ of Frame Error Rate (FER) due to a poor Minimum Hamming Distance (MHD). In future system generations, lower error rates, down to $10^{-8}$, will be required to open the way to real-time and more demanding applications, such as TV broadcasting or videoconferencing. Therefore, state-of-the-art 8-state TCs are no longer suitable for these kinds of applications and more powerful coding schemes are required. At the same time, a reasonable complexity should be preserved. Thus, from this viewpoint raising the MHD by using component encoders with 16 states instead of 8 is not an appropriate solution.

The aim of the thesis is to explore a new hybrid concatenation structure combining both parallel and serial concatenation based on a 3-dimensional (3D) code, simply derived from the classical TC by concatenating a rate-1 post-encoder at its output [12]. This architecture is expected to reach a performance/complexity trade-off never yet attained.

In particular, the following aspects of the problem will be studied:

- the search for efficient post-encoder structures, especially when transmissions over non Gaussian channels (fading channels, erasure channels) are considered,
- the effect of using time variant trellis codes as component codes for the original encoder structure,
- the design of powerful permutations suited for such code structures.
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References: