Performance of the Turbo Hybrid Automatic Repeat Request System Type II

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In many applications it is necessary to maintain an error-free transmission of data. For low-quality time varying channels channel coding alone often cannot ensure this and the employment of Automatic Repeat Requests (ARQ) is unavoidable. For achieving high efficiency, a combination of both channel coding and ARQ, also referred to as hybrid ARQ (HARQ), is preferable. Using turbo codes (TC) — the most powerful of known error-correcting codes — in HARQ transmission schemes results in very efficient transmission systems [2, 3, 4], which maintain a high throughput over Additive White Gaussion Noise (AWGN) channels even for signal-to-noise ratios (SNR) as low as $E_s/N_0 = -2$ dB [2]. The aim of this article is to construct a turbo hybrid ARQ (THARQ) system of type II, which guarantees a high throughput at extremely low SNRs, where other known THARQ systems suffer from rapid throughput degradation.

For ARQ systems it is crucial to ensure reliable error detection. For this purpose examining the properties of iterative decoding (ID) can be employed. In [1] it was shown that when the output of the ID is stable and the reliability of decoded symbols is high, the decoded data has a high probability of being error-free. Generating the same decoded result in at least three successive iterative decoding steps was found to be a sufficient criterion for stable ID. In order to satisfy the above reliability criterion it was required that each symbol in the decoded block had a reliability of at least 99.999%. In the proposed THARQ system, blocks which do not fulfill these two conditions are not accepted as error-free and thus the transmitter has to transmit additional parity symbols. The Decoder processes the received block again, now taking into account also the additional parity symbols. The rate of the code actually used is now lower than the initial rate and therefore the error correcting power of the code is higher. If the decoded block does not meet the required criteria, again, more and more additional parity symbols are requested, until the ID fulfils the targeted stability and reliability criteria.

In order to implement the required code rate change, rate compatible codes are necessary. We decided to use rate compatible convolutional codes as turbo coding component codes, where both component codes are identical at any given instant. An extensive computer search of rate compatible convolutional codes of rates $\frac{2}{3}, \frac{1}{2}, \frac{1}{4}, \frac{1}{8} \ldots$ was performed. The minimum Hamming distance and the number of corresponding error events were used as the search criteria. The generator polynomials (GP) of the convolutional codes (CC) found, expressed in octal notation are

31 33 | 37 25 | 37 35 35 25 | 37 37 33 33 35 35 25 25 |.

The first polynomial was used as the recursive one. The CC of rate $\frac{2}{3}$ was constructed from the first two GPs using the puncturing pattern of $\left(\begin{smallmatrix}1 & 1\\ 1 & 0\end{smallmatrix}\right)$, the CC of rate $\frac{1}{2}$ from the first two GPs without puncturing, the CC of rate $\frac{1}{4}$ from the first four GPs, etc. Such component codes created TCs of rates $\frac{1}{2}, \frac{1}{3}, \frac{1}{7} \ldots$

The above THARQ system having a random interleaver of length 1024 was simulated. Binary PSK modulated data was transmitted over an AWGN channel. The simulation results are depicted in Fig. 1. The BERs of THARQ type I and that

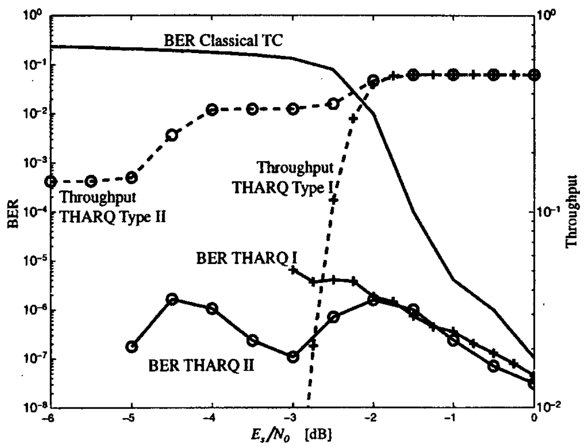

Fig. 1: BER (solid lines) and throughput (dashed) of the turbo hybrid ARQ systems type I (curves marked with "+") and type II (marker "o"), AWGN channel.

of the classical TC are also plotted for the sake of comparison. For $E_S/N_0 \leq -2$ dB, the THARQ type II scheme outperforms the THARQ type I arrangement in both BER and throughput terms. The throughput of the THARQ type II system is the best of all known ARQ systems. Its undulating characteristic is caused by the discrete change of the code rate. If necessary, the residual error rate can be further lowered by employing a CRC-code as an additional error detector. Simulations have shown that such a system provides a nearly identical throughput, but the accepted data was always error-free.

References

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