Hybrid equalization strategies for iterative equalization and decoding

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Abstract — **Joint iterative equalization and decoding is a very successful approach to dealing with severe inter-symbol interference in band limited communication channels. We propose and investigate adaptive iterative methods that yield performance close to Turbo equalization while requiring considerably smaller complexity.**

I. Concept

We consider the problem of coded data transmission over a channel that is subject to inter-symbol interference (ISI) depicted in Fig. 1. The setup can be thought of as serial concatenation of channel code and ISI channel. A successful approach to jointly equalize (or detect) and decode in the receiver of such a system is iterative equalization and detection (Turbo equalization) pioneered by Douillard et al. [2]. A number of such systems are proposed in the literature, which differ in the soft-input soft-output equalizer, i.e employing an a-posteriori detector [2], linear equalization (LE) [4], or matched filtering (MF) [1]. The motivation for developing these algorithms is to decrease the computational complexity of equalization, which ranges from a behavior that is exponential in the ISI channel impulse response length (APP-based approaches) to a linear behavior (LE,MF).

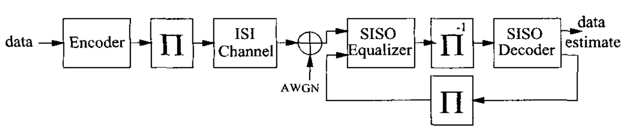

Figure 1: A system for coded data transmission.

A purely APP-based solution for equalization and decoding outperforms all other combinations both in convergence rate as well as bit error rate (BER) [4]. Unfortunately, for channels with long impulse response or higher order signal constellation, APP detection quickly becomes unfeasible. However, other equalization algorithms perform nearly as well for specific situations. The goal of this paper is to investigate the possibility to match different algorithms over different ranges of the iteration process. For example, while MF typically fails in early iterations, it turns out to work very well once the "extrinsic" information in the iterative procedure is "good enough". Other methods typically work well in early iterations but fail to improve. We will call methods that adapt the choice of algorithms to the state of the iterative procedure hybrid strategies. A convenient tool in predicting the behavior of different schemes are extrinsic information transfer (EXIT) charts developed for analysis of iterative decoding convergence of concatenated convolutional codes [3]. This analysis tool models each receiver component as a device mapping an input sequence of log-likelihood ratios (LLRs) to an output LLR sequence. Both sequences are described with a *single* parameter distribution. Thus, the iterative process can be characterized by the evolution of this particular parameter.

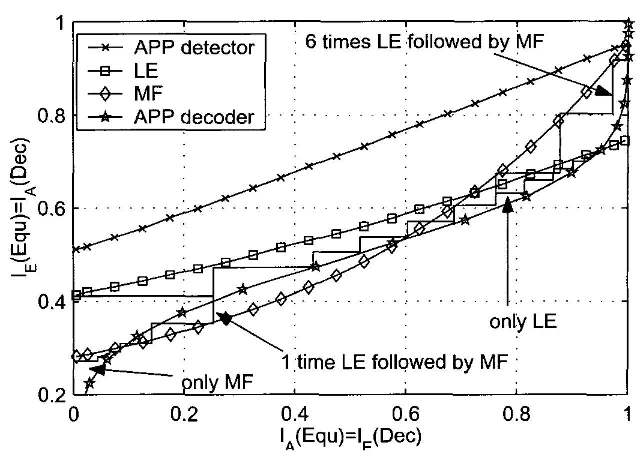

Figure 2: Motivation for hybrid equalization.

For the EXIT chart, the considered parameter is the mutual information between the input, $I_A(\cdot)$, and output LLRs, $I_E(\cdot)$, and the transmitted bits, which ranges from 0 (no knowledge about transmitted bits) to 1 (the transmitted bits are known).

II. Results

Figure 2 depicts EXIT charts of an APP decoder for the rate $\frac{1}{2}$ convolutional code $(1+D^2\ 1+D+D^2)$ and 3 equalizers (APP detection, LE, MF), which process symbols transmitted over a length 5 channel with severe ISI at a fixed signal-to-noise ratio. Also included is the trajectory (measurement of the mutual information after each equalization and decoding step) of an actual system using length $6\cdot 10^4$ data bit blocks. We observe that LE yields a significant error floor, but APP detection and MF yield the same BER, after convergence. Unfortunately, MF exhibits a poor starting behavior, which disqualifies it for use in the first iterations. However, by combining LE (first iterations) and MF, we can achieve the good MF performance *after* convergence. In general, selecting suitable equalization algorithms for every iteration according to their EXIT charts can save complexity tremendously. These hybrid equalization schemes therefore adapt the complexity to the locally required amount with the cost of more required iterations.

References

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