Turbo Hybrid Automatic Repeat reQuest (Turbo HARQ)

None of data communication systems is absolutely reliable in practice because of noise, distortions, interferences, or other forms of impairments. Therefore, the systems need error control strategies in order to detect or to correct errors occurring in the transmission process. Controlling transmission errors in data communication systems can be performed by using either automatic-repeat-request (ARQ) or forward-error-correction (FEC) techniques.

In ARQ schemes, the purpose of adding redundancy is for error detection, and retransmission is performed upon requested. Hence, it is simple to be implemented. However, a severe drawback of ARQ systems is that its throughput efficiency decreases rapidly with increasing channel-error rate, because more retransmissions are requested with lower channel quality.

On the other hand, in communication systems where feedback channel is not available and hence retransmission request is not possible, the system has to use error-correcting codes appropriate to the operational point of signal-to-noise power ratio (SNR), to combat transmission errors. The throughput efficiency of FEC systems can be maintained constant which is equal to the code rate, given the operational point of SNR. However, this advantage arises only when the received SNR is known to the transmitter side. Furthermore, it is difficult to adjust the code parameters, if channel is time varying. Hence, ARQ is often preferred in data communication systems, for instance computer communication networks, if feedback channel is available. On the contrary, FEC is preferred when feedback channel is not available.

Hybrid ARQ (HARQ) schemes exploit the beneficial points of the both ARQ and FEC to overcome their drawbacks. HARQ systems do not discard the unsuccessful results of FEC decoding, but aims to combine it with the frame to be retransmitted. Hence, the larger the error correction capability, the more the retransmission performed, and thereby HARQ can adequately adjust the total code rate, and increases the throughput of the system, as a whole, without the knowledge of the received SNR at the transmitter side. When error(s) is(are) detected in the information part after FEC decoding, the receiver requests retransmission instead of passing the unreliably decoded message to the user or data sink. Therefore, HARQ system provides higher reliability than an FEC system alone and higher throughput than the system with ARQ only.

One way to improving the reliability of FEC is by exchanging the soft information among the decoders. Exchanging soft information in an iterative (turbo) fashion for packet combining in HARQ systems has been intensively investigated in the last decade. Since C. Berrou, A. Glavieux, and P. Thitimajshima discovered the Turbo Codes in 1993, it has been at a center of communication systems research. The turbo code not only offers near Shannon's limit performance, but also introduces a new approach to the design of communication systems, referred to as *turbo principle*.

The turbo principle is a general idea of combining decoding and detection where signal processing is integrated in an iterative structure. The turbo principle comprises the following aspects:

- serial and/or parallel concatenation of the communication chain components,
- soft-in soft-out decoding and/or detection,
- interleaving between the components, and
- extrinsic information exchange between the components in the form of probability or log-likelihood ratio (LLR)

This thesis proposes an efficient decoding strategy for Turbo HARQ. With the new strategy of HARQ protocol based on the turbo principle, it is made possible to combine and decode all (re)transmitted packets in an iterative way. In general, two packet combining schemes are applicable for HARQ: combining-before-decoding (CBD) which is based on the retransmission of the same coded bits, and combining-after-decoding (CAD) which is based on the retransmission of additional redundancy bits produced from an interleaved information version of sequence.

This thesis first examines the basic properties of CAD and CBD, and then derives the theoretical limit of the both techniques. It is shown that CAD outperforms CBD. Based on the theoretical limit comparison, this thesis proposes a doped-accumulator assisted CAD technique (ACC-CAD) with different doping rate per transmission phases for practical application. The proposed CAD performs vertical iterations (*VI*) between the decoders of the parallel-concatenated code (PCC) where extrinsic log-likelihood ratio (LLR) of the uncoded bits are exchanged via *VI*. The doped-accumulator enables the two extrinsic information transfer (EXIT) curves of the equalizer and the joint decoders to match very well and the convergence tunnel to open until a point very close to the (1.0,1.0) mutual information point.

For fair comparison, this thesis considers the latest CBD technique, presented in a literature, that combines all path energies of the received signals to achieve full diversity gain at the receiver, and then the decoding of the SCC is performed via horizontal iterations (*HI*s). This thesis also provides the decoding complexity comparison between the ACC-CAD and the CBD.

Finally, excellent performance of the ACC-CAD is verified through EXIT analysis as well as bit-error-rate (BER), frame-error-rate (FER), and throughput performances via computer simulations.

Keywords: ARQ, HARQ, Turbo HARQ, FD-SC/MMSE, Turbo Equalization, EXIT Analysis, Doped-accumulator