Two-Hop Relay-Systems with OFDM-IDM Space-Time Coding

F. Lenkeit, C. Bockelmann, D. Wübben, A. Dekorsy

Department of Communications Engineering
University of Bremen, Germany
Email: {lenkeit, bockelmann, wuebben, dekorsy}@ant.uni-bremen.de

I. Introduction

In mobile communication systems pathloss and shadowing are two of the main limiting factors. In order to overcome these effects, relaying has been identified as a very promissing technique. In relay-systems additional nodes are introduced to the system, which are neither source nor destination of transmissions themselves. Instead their task is to support existing transmissions and thereby effectively increase the system's reliability. Besides a reduction of the pathloss due to smaller distances between nodes, relays also offer diversity gains which can increase the robustness of the overall system. In order to exploit the offered spatial diversity, Space-Time Codes (STC) have shown to be a very flexible scheme.

II. System and Results

In this poster, we investigate Space-Time Codes based on the multiple access scheme IDMA, the so-called IDM-Space-Time Codes (IDM-STC) [1]. Rather than using a fixed scheme in order to distribute the data in time, for IDM-STCs an antenna or relay-specific interleaving is applied to achieve temporal correlation among the transmitted signals. Since previous research has shown that the performance of the well-known soft-rake-detection for IDMA-based systems suffers from strong frequency-selective channels [2], we combine IDM-STCs with OFDM in order to be able to apply the soft-rake-detection even under these circumstances. The resulting OFDM-IDM-STCs allow a soft-rake-detection in the frequency-domain independent of the number of channel paths [3]. In Fig. 1 the structure of the OFDM-IDM-STC-relays is depicted. After OFDM-specific processing, i.e., removal of the cyclic prefix and transformation into frequency-domain, the relay's received signal is matched-filtered. Using the filtered signal L-values are calculated and channel decoding is performed. Afterwards, the estimated infobits are re-encoded using the same channel code as the source and relay-specific interleaving is applied. The interleaved codebits are then mapped onto a complex valued modulation alphabet. Finally, OFDM-specific processing is performed again. After transformation into time-domain and addition of a cyclic prefix the signal is transmitted to the destination.

Due to varying channel conditions and potential subsequent decoding errors at the relay, the true codeword and the re-encoded sequence are not necessarily identical. In order to describe the imperfection of the decoding, we model the correlation between these two sequences using a binary symmetric channel (BSC) with a certain error probability as proposed in [4]. Fig. 2 shows the resulting equivalent model combining the source and the ν-th relay.

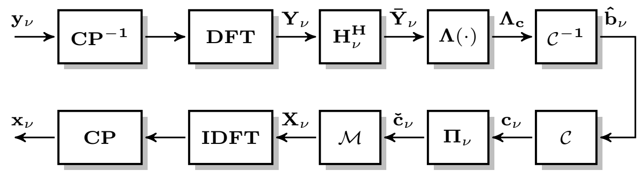

Fig. 1. Structure of the ν-th OFDM-IDM-STC-relay.

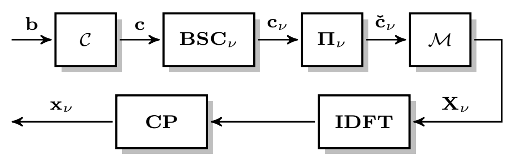

Fig. 2. Equivalent model for the transmitter and the ν-th relay based on a binary symmetric channel describing the correlation between the transmitter's codeword $\mathbf{c}$ and the relay's codeword $\mathbf{c}_\nu$.

We assume that the error probability can be determined at the relay by comparing the true and the re-encoded sequence in a framewise manner. Hence, it can be updated with each transmitted frame leading to a continuous improvement of the estimate for static scenarios. For dynamic scenarios, however, i.e., a moving source, it is not reasonable to average over all transmitted frames since the distances between source and relays and therefore the decoding reliabilities of the individual relays change over time. Hence, we introduce a moving average model, taking only a certain number of the last transmitted frames for the calculation of the error probabilities at the relays into account.

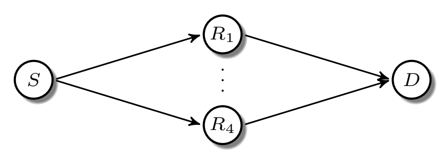

Fig. 3. Topology of the considered two-hop relay-system with one source S, one destination D and $N = 4$ parallel relays R_ν.

Knowing these error probabilities at the receiver now allows us to consider the relay's reliability during the iterative decoding process. We show that even long-term statistics are sufficent to increase the system performance considerably. Therefore, we investigate a two-hop relay-system with four parallel relays as depicted in Fig. 3. The error probabilities at the relays for different degrees of frequency-selectivity are shown in Fig. 4. After approximately 2000 transmitted frames the error rates almost reach their steady-state. It can clearly be seen that the two outer relays (solid), i.e., the relays with higher distance to the source, always lead to a higher error probability and therefore to a lower reliability than the inner relays (dashed).

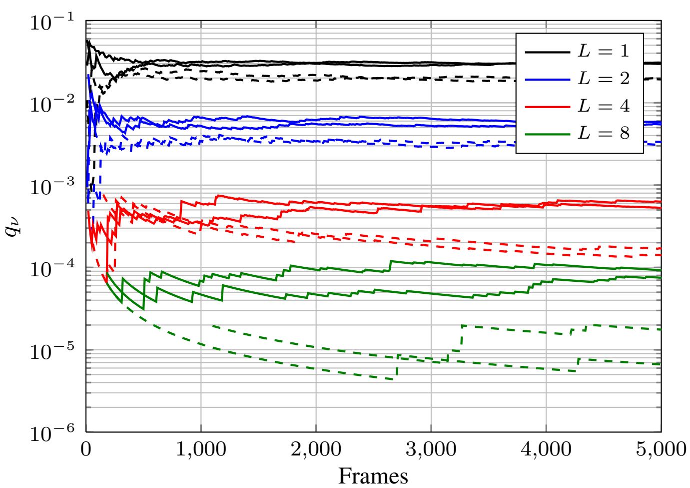

Fig. 4. Long-term statistics of the error probabilities q_ν at the relays versus the number of transmitted frames for a varying number of channel taps L at $1/\sigma_n^2 = 0$ dB. Solid: outer relays, dashed: inner relays.

Incorporating these reliabilities in the soft-value calculation at the destination leads to a clear performance gain as can be seen in Fig. 5. Here, we updated the receiver's knowledge of the error statistics with every transmitted frame. But since the statistics don't change much after the initial setup for this static scenario, an update with a much lower rate would lead to the same performance gains with just a fraction of the introduced overhead. Notice that not the absolute error probabilities themselves are of importance but rather the relations among them. For, e.g., $L = 1$ only small differences between the error rates for the inner and the outer relays can be observed, hence, only a small gain can be archieved at the destination. For stronger frequency-selectivity the differences among the error probabilities are much more significant and therefore also the achieved gains are considerably higher.

III. Summary

In the poster, we will present a combination of distributed IDM-Space-Time Codes with OFDM, so-called OFDM-IDM Space-Time Codes. We will introduce a method to describe the reliability of the decoding at the relays using a model based on binary symmetric channels and we show that incorporating

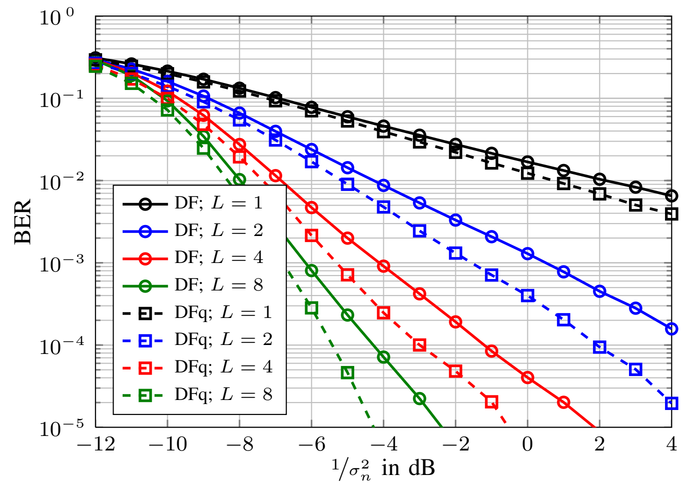

Fig. 5. Comparison of the achieved bit-error-rates with (DFq) and without (DF) considering the relay's error probabilities in the decoding process at the destination for a varying number of channel taps L. $N = 4$ relays. $(5;7)_8$-convolutional code and halfrate repetition code. Frame length $L_{\mathrm{f},c} = 1024$ codebits. QPSK signaling. Soft-rake-detection with $N_{\mathrm{it}} = 10$ iterations. $N_c = 64$ subcarriers. Length of cyclic prefix $L_{\mathrm{CP}} = 8$.

these reliabilities in the iterative detection at the receiver leads to significant performance gains. Besides the already shown results for a static scenario, we will also present results for a dynamic system model with a moving source. There, we apply a moving average model for the error probability in order to cope with the varying channel conditions. Furthermore, we will show that the number of frames taken into account for the calculation of the error probabilities is crucial for the overall system performance. Especially for fading channels a too small number of samples was observed to lead do a servere degradation. Contrary, a resonably large number of samples always leads to an improvement compared to the case where the relay's reliabilities are not taken into account during detection at the destination. Since in this case only a low update rate at the receiver is necessary, the presented method allows for significant performance gains at the cost of only a small overhead.

References

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