An analytical consideration of quantised CSI feedback on the performance of a Multi-User OFDM-system

Alexander Kühne, Anja Klein
Darmstadt University of Technology, Communications Engineering Lab,
Merckstr. 25, 64283 Darmstadt, Germany, a.kuehne@nt.tu-darmstadt.de

I. Extended Abstract

OFDMA is considered to be a suitable candidate for future radio network systems where high data rates are required. In a multicarrier scheme like OFDMA, the overall channel can be divided in several resources. Having channel knowledge at the transmitter side in a multi-user system, the resources can be allocated to the different users in an optimal manner in terms of a certain criterion, e.g. the maximum capacity. For that purpose, channel state information (CSI) of the resources of the different users has to be known at the transmitter. Having perfect channel knowledge at the transmitter, adaptive subchannel allocation schemes achieve very good performances [1] [2] [3].
However, in a realistic scenario only imperfect channel knowledge is available at the transmitter which leads to a performance degradation using adaptive techniques compared to the maximal achievable performance. The use of diversity is an alternative way to achieve performance enhancements without channel knowledge at the transmitter. Applying frequency hopping [4] or applying a DFT-precoding of the data [5] together with interleaved carrier allocation are examples for techniques to exploit frequency diversity in an OFDMA system. However, the achievable performance using diversity is also worse than the maximal achievable performance using adaptive schemes with perfect channel knowledge. Hence, a comparison between adaptivity with imperfect channel knowledge and diversity has to be made. In [6] [7] [8] first comparisons between adaptivity and diversity has been investigated. In [9] we compared adaptive subcarrier allocation with imperfect channel knowledge to diversity techniques in an OFDM-system. As CSI we employed the instantaneous signal-to-noise ratio (SNR) of the different subcarriers, which was assumed to be outdated and estimated.
In this paper, the CSI is assumed to be quantised and fed back over a feedback channel, where we consider CSI feedback bit errors which occur during the transmission over the feedback channel. As system model we consider a one cell OFDMA downlink SISO scenario with one base station (BS) and multiple mobile stations (MS) in a FDD system, where is it assumed that each user has the same requirements in terms of data rate. We assume that the channel coefficients of adjacent subcarriers are independent from each other and Rayleigh distributed with the same average SNR. We employ a Max-SNR Scheduler that favours the users with the best SNR conditions to allocated the different subcarriers to the different users, i.e. one subcarrier is allocated to only one user exclusively. The imperfectness of the CSI feedback now leads to four effects resulting in a performance degradation. First, the signalled CSI is already outdated at the time instant of transmission, modeled by correlation with the correlation coefficient ρ. Second, the SNR values available at the MS are estimates, modeled by an additional complex Gaussian distributed error term with variance σ_e^2. Hence, the estimated SNR values are possibly quantised in the wrong quantisation interval. Thirdly, due to the feedback bit errors, the SNR values are possibly assumed to be in the wrong quantisation interval at the BS. And finally, due to the quantisation, the BS can not distinguish between users with the same quantisation value, i.e. the scheduler has to choose randomly between those users. We provide an analytical derivation of the ergodic capacity as function of the correlation coefficient ρ, the error variance σ_e^2, the number of quantisation bits N_Q and the feedback bit error rate p_b. We compare this capacity to the capacity achievable by exploiting frequency diversity without any channel knowledge at the transmitter and determine the bound where adaptivity with imperfect CSI feedback is still better than diversity.
In Fig. 1 the ergodic capacity per scheduled subcarrier is presented as function of the feedback bit error rate p_b for different correlation coefficients ρ and for a fixed error variance $\sigma_e^2 = -5$ dB with one bit feedback per subcarrier. We assume a system with $N = 8$ subcarriers, $U = 10$ users and an average SNR of 10 dB. The dashed black curve represents the capacity achievable by exploiting frequency diversity. Apparently, even with an imperfect one bit feedback one can achieve a better capacity compared to capacity exploiting frequency diversity as long as the correlation is higher than $\rho = 0.7$, which corresponds to a MS velocity of $v_{MS} = 24,5$ km/h assumimg a Jake's scattering model with a carrier frequency of $f_0 = 2$ GHz and a time delay of $T = 4$ ms for an error variance of $\sigma_e^2 = -5$ dB, i.e. the power of the error term is about

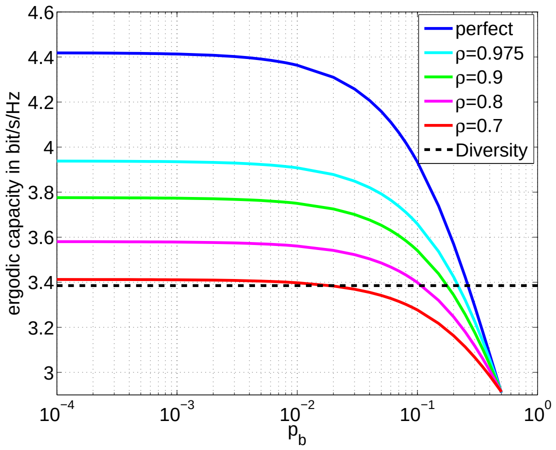

Fig. 1. Ergodic capacity for $N_Q = 1$ bit feedback and $\sigma_e^2 = -5$ dB versus feedback bit error rate p_b

32% of the channel power. Furthermore, it is sufficient to ensure a feedback bit error rate of $p_b = 10^{-2}$ over the feedback channel to achieve a good performance.

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