Channel Prediction for Training Overhead Reduction in Cooperative Wireless Networks

Wen-Ching Chung*, Jwo-Yuh Wu, Rung-Hung Gau, and Chung-Ju Chang

Department of Electrical and Computer Engineering
National Chiao Tung University
Hsinchu, 300, Taiwan, R.O.C.
Email: wcchung@cc.nctu.edu.tw

Extended Abstract: Cooperative communication is now widely known as a promising technique for realizing distributed spatial diversity in modern wireless networks. To achieve various performance advantages benefiting from user cooperation, knowledge of the system parameters at the relay and destination terminals is typically required. For example, to implement the distributed beamforming/precoding schemes for link reliability enhancement, the relays must know the channel state information (CSI) of the source-to-relay or/and the relay-to-destination communication links. As a result, communication overheads dedicated to CSI transmission or feedback in a cooperative wireless network are indispensable. Since the wireless relay terminals could be subject to limited infrastructure and energy resource, communication overhead reduction for relay nodes is important.

This paper considers a cooperative network, in which the relays employ the decode-and-forward protocol to realize the distributed pre-maximum-ratio-combining (pre-MRC) scheme. To obtain the CSI of the relay-to-destination links, the relays need to periodically send training symbols in each data packet to facilitate CSI estimation/update at the destination. We investigate the problem of training overhead reduction for relay terminals based on channel prediction at the destination. The proposed approach rests on the fact that in the realistic environment the channel gains between consecutive time slots are typically correlated. Hence, once the destination has acquired a record of channel estimates during the past few training phases, it is then plausible to exploit the channel temporal correlation to predict the latest CSI via certain channel prediction schemes. The beamforming weights computed based on the predicted CSI can then be fed back to the relay nodes. In this way, the relays no longer need to frequently send training signals to the destination, and the aggregated communication overheads can be reduced. A schematic description of the proposed approach is shown in Figure 1.

To ease analysis as well as algorithm implementation, the linear minimum mean square error (LMMSE) channel predictor is adopted in this paper. To exploit the spatial diversity, the predicted CSI is feedback to relays so as to realize the distributed pre-maximum-ratio-combining (pre-MRC) scheme. Assuming that the CSI obtained by training-based estimation is exact and the channel mismatch is entirely caused by prediction errors, we derive a closed-form formula for the achievable signal-to-noise ratio (SNR) when the beamforming weights are designed in accordance with the predicted CSI. The proposed analytic results are corroborated by computer simulations. Our analytic results can be used for characterizing SNR degradation of the channel prediction scheme as the duration of the prediction phase increases. We also propose one method to determine the duration of the channel prediction phase from packet delay perspectives. For a given tolerable SNR threshold, the percentage of reduction in training overheads can then be quantified. Figure 2 shows the percentage of training overhead reduction for different packet sizes $L$. The figure shows that, for a fixed $L$, the achievable reduction, as expected, decreases with the velocity $v$. 

Fig. 1. Frame structures for training based scheme and prediction based scheme.

Fig. 2. The percentage of training overhead reduction for varying packet size $L$. 

L = $5 \times 10^2$
L = $2.5 \times 10^3$
L = $5 \times 10^3$
L = $1 \times 10^4$