Optimal Relay Selection in Interference-Constrained Underlay Cooperative Cognitive Radio Networks

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Abstract

Cognitive radio (CR) promises to significantly improve theutilization of scarce wireless spectrum. In the underlay mode of CR, which is the focus of the thesis, a secondary user (SU) can simultaneously transmit on the same band as a higher priority primary user (PU) so long as the interference it causes to the PU must be constrained. These interference constraints severely limit the performance of the SUs. Cooperative relaying combined with selection exploits spatial diversity to improve the performanceof interference-constrained SUs. In it, one among the available relays is selected for every instantaneous channel power gains of the various links that include the secondary communication links as well as the interference links between the secondary transmitters and the primary receiver. The mapping between the channel power gains and the selected relay is determined by the relay selection (RS) rule employed by the secondary network. Furthermore, it alsodepends on the interference constraint, which sets underlay CRapart from conventional wireless communications. Although the peak interference constraint is well-studied in the literature on underlay CR, cooperative relaying for the less conservative average interference constraint has not been as thoroughly studied.

In this thesis, we focus on developing optimal RS rules that either minimize the average symbol error probability (SEP) or maximize the average rate of the secondary network that is subject to an average interference constraint. We first develop an SEP-optimal RS rule and its two practically implementable variants when the relays are not aware of the instantaneous state of the direct source-to-destination (SD) link. The proposed rules determine which relay to select and whether to select none of the relays at all as a function of the various channel power gains. They outperform several ad hoc RS rules proposed in the literature for underlay CR and generalize theconventional interference-unconstrained RS rule.

Next, we present a novel, SD-aware SEP-optimal RS rule for an average interference-constrained underlay CR network. Akey point that the rulehighlights -- for the first time -- is that, for the average interferenceconstraint, the signal-to-interference-plus-noise-ratio (SINR) ofthe direct SD link affects the choice ofthe optimal relay. Furthermore, as the SINR increases, the oddsthat no relay transmits increase. We also propose a low feedback and near-optimal variant of the SD-aware SEP-optimal RS rule that requires just one bit of feedback about the state of the direct SD link to the relays. Compared to the SD-unaware RS rules, these rules markedly reduce the SEP by up to two orders of magnitude.We then analyze the average SEPs and diversity order of the proposed RS rules to quantify their performance.

Thereafter, we propose a rate-optimal RS rule that maximizes thefading-averaged transmission rate of an average interference-constrained underlay CR network. It differs functionally from the several ad hoc incremental relaying schemesproposed in the literature, but requires a feedback overhead that is comparable to them. We then analyze the average rate of the secondary network for this RS rule. We gain several insights by studying the asymptotic regimes of low and high average SINRs.

Lastly, we study a practically-motivated channel state information (CSI) model for an

underlay CR network with multiple primary receivers, inwhich the channel gains of only a subset of the interference linksare available at the source and relays. Moreover, this available CSI is imperfect due to channel estimation error. Based on such incomplete and imperfect CSI, the source and relays back-off their transmit powers in order to satisfy an interference outage constraint. We derive the outage probability and average rate of the secondary network for the rate-optimal RS rule. An interesting observation that comes out of our study is that full diversity order is still achievable even with such incomplete and imperfect CSI.