Broadcast Cooperation Strategies for Two Colocated Users

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***Abstract*—This work considers the problem of communication between a remote single transmitter and a destined user, with helping colocated users, over an independent block Rayleigh fading channel. The colocation nature of the users allows cooperation, which increases the overall achievable rate, from transmitter to destination. The transmitter is ignorant of the fading coefficients, while receivers have access to perfect channel state information (CSI). We propose, for this setting, a multi-layer broadcast transmission approach. The broadcast approach transmission enables enhanced cooperation between the colocated users. That is due to the nature of broadcasting, where the better the channel quality, the more layers that can reliably be decoded. The cooperation between the users is performed over additive white Gaussian noise channels (AWGN), with a relaying power constraint, and unlimited bandwidth. Three commonly used cooperation techniques are studied: amplify-forward (AF), compress-forward (CF), and decode-forward (DF). These techniques are extended by using the broadcast approach, for the case of relaxed decoding delay constraint. For this case a separate processing of the layers, which includes multi-session cooperation is shown to be beneficial. Further, closed form expressions for infinitely many AF sessions and recursive expressions for the more complex CF are given. Numerical results for the various cooperation strategies demonstrate how the multi-session cooperation outperforms conventional relaying techniques.**

***Index Terms*—Single-user broadcasting, code layering, ad-hoc networks, amplify-and-forward, decode-and-forward, compress-and-forward, multi-session cooperation.**

I. Introduction

In recent years, interest in communication networks has increased, and various applications of it, such as sensor networks [1],[2],[3] energy sensitive networks [4],[5] and Ad-hoc networks [6], have gained popularity. In this field, networks with colocated receivers and colocated transmitters constitute a substantial part, since they allow increased cooperation [7], thus improving the overall networks' throughput [8], [9]. Specifically, many contributions deal with the various aspects of such cooperation, such as transmitters cooperation in ad-hoc networks [10], transmitters cooperation in a multiple access channel (MAC) [11], receivers cooperation [12], [13], [14], [15], [16], and both transmitters and receivers cooperation [17],[18]. In source related networks, such as the sensors network, the cooperation is slightly different, since the objective is to convey a source with a distortion (e.g. the reach-back problem [19]), rather than ensuring reliable communication. The compress forward (CF) and amplify forward (AF) techniques make use of lossy source coding techniques, to ensure high communication rates, when the cooperative receiver does not decode the message. This is studied in [20], [21], [22], among many others. Here, we deal with one transmitter that sends the same information to two colocated cooperating users, where only one of them is the destination. Receiver cooperation in general appears to be less understood than transmitter cooperation; for example, when orthogonal links exist between two colocated users, where one of them is the transmitter, the capacity region is known [11]. This is not the case for the receiver side cooperation [23].

The transmitter in our work sends the same information to two colocated receivers (where only one of them is its destination), over independent block Rayleigh fading channels, as in [24]. Such channels have zero Shannon capacity, and usually one turns to rate versus outage probability [25], [26]. When considering the average throughput or delay as figures of merit, it is beneficial to use the broadcast approach [27]. The broadcast strategy for a single-user facilitates reliable transmission rates adapted to the actual channel conditions, without providing any feedback from the receiver to the transmitter [27], [28]. The single-user broadcasting approach hinges on the broadcast channel, which was first explored by Cover [29]. In a broadcast channel, a single transmission is directed to a number of receivers, each experiencing possibly different channel conditions, reflected in their received signal to noise ratios (SNR). Here, every fading gain is associated with another virtual user. The higher the fading gain, the higher is the achievable rate. This broadcasting scheme is also referred to as the continuous broadcast approach, where every fading gain is associated with a code layer. The continuous broadcasting facilitates an upper bound on the average achievable throughput in fading channels with no transmit CSI. Although not practical for implementation, it may well serve as a design goal for finite level coding, e.g. [30].

The broadcast approach has been studied in [31], [32] for a two hop relay channel, where the efficiency of ad-hoc cooperation in a two-hop relay setting was demonstrated, when a direct link from source to destination is not available. Several broadcasting strategies were investigated for relaying techniques such as decode forward (DF), AF, and CF. In our setting, a direct link from source to destination exists in addition to the cooperation link, which motivates multi-session cooperation, and different broadcasting approaches for maximizing average throughput. In [15], cooperation among densely packed K-colocated receivers is studied, where the

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