Chapter 11
Diversity Combining for Cooperative Communications

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ABSTRACT

A major advantage of cooperative communications is the potential for forming distributed antenna arrays, that is arrays whose elements are not collocated, but carried by independent relaying terminals. This allows for a study and design of cooperative communications under a novel perspective, where the inherent end-to-end paths between the source and destination terminal constitute the multiple branches of a virtual, distributed diversity receiver. As a result, the well-known combining methods used in conventional diversity receivers can be implemented in a distributed fashion, resulting in novel relaying protocols and, generally, in new ways for exploiting the resources available in cooperative relaying setups. This chapter provides an overview of this distributed diversity concept, as well as a performance analysis of the corresponding distributed diversity schemes, with particular emphasis on the analysis of distributed switch-and-stay combining. Further insights regarding the potential of implementing the distributed diversity concept in practical applications are obtained.

INTRODUCTION

The benefits of cooperative communications in terms of link reliability and coverage extension are becoming more and more known to the telecommunication community, and have attracted the interest of both academia and industry in the last few years. Through the utilization of spatially distributed single-antenna terminals, cooperative communications are designed to achieve the beneficial effects of diversity in future networks without the need for employing multiple antennas at either the transmitter or the receiver end. As has been demonstrated in many research works in this area, cooperating terminals

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can form virtual antenna arrays that ensure multiple transmissions through independent channels, avoiding thus the practical limitations that multiple antenna employment entails, especially when referring to small, hand-held devices.

Taking the above into account, it naturally follows that the well-known spatial combining techniques that have been already proposed in the literature and concern the "classical" diversity concept can now be implemented in a distributed fashion through the aforementioned cooperation among the participating terminals. To be more precise, the end-to-end paths inherent in any cooperative formulation can represent the diversity branches of a virtual, distributed diversity scheme, following the concept of virtual antenna arrays. Hence, cooperative communications can be studied as well as designed under this point of view, by utilizing well-known combining methods which are already used in multi-branch diversity receivers.

Intuitively, this usually leads to more or less the same advantages and disadvantages of these techniques over each other, in the sense that they are expected to follow the same performance complexity tradeoff, i.e., offering simpler practical implementations with some cost in performance and vice versa. Nevertheless, the relative performance of the distributed diversity techniques over each other in some cases may differ from that of traditional diversity implementation, since the overall consumed power in cooperative applications is distributed among the participating terminals. Hence, the performance of distributed diversity highly depends on the assumptions made regarding the overall transmitted power, since, given a total power constraint, techniques that activate fewer relays may be preferable in the sense that significant amounts of energy are saved. Apparently, in order to gain insight into the performance of the distributed diversity concept, the above intuitions need to be verified mathematically, allowing also for further future extension. Therefore, this chapter aims at

a) illustrating relaying protocols that constitute distributed implementations of well-known diversity combining techniques over cooperative networks and
b) providing easily-tractable mathematical expressions for certain performance metrics related to the above distributed diversity schemes, such as the outage or the symbol error probability.

BACKGROUND

The main idea behind the concept of cooperative communications is the utilization of a number of relaying terminals, represented here by R_i, for wirelessly forwarding the information sent by a source terminal S to a destination one, D. This cooperative setup is illustrated in Figure 1. In general, there are two main relaying modes which the relays may operate in: The decode-and-forward (DF) and the amplify-and-forward (AF). The former relaying mode (a.k.a. regenerative relaying) consists of fully decoding the message received by the source, then remodulating the detected symbols into the same or different alphabet and forwarding the resulting data to the destination. The latter mode (a.k.a. non-regenerative relaying) consists of simply amplifying and forwarding to the destination the received signal without any further process (Laneman & Tse & Wornell, 2004).

Depending on the type of the amplification gain employed, AF relaying can be further categorized into variable-gain and fixed-gain relaying. Specifically, the relays may utilize channel state information (CSI) knowledge of the channel in its receiver end, so as to be able to amplify the received signal

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