Chapter 1
Lending a Hand: Enhancing the Performance of Wireless Communication Networks Through Cooperation

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ABSTRACT
Cooperative networking is considered one of the main enablers for achieving enhanced data rates in wireless communications. This is due to the fact that through cooperation the adverse effects of fading can be alleviated significantly. Thus, more reliable communication systems deployments can be devised, and performance enhancements can be achieved. In this chapter, the authors discuss the main aspects of cooperative networking starting from the main historical milestones that shaped the idea. Then they focus on the main mechanisms and techniques that foster cooperation and continue by studying performance metrics for various possible deployments, such as capacity bounds and outage probabilities. Finally, the authors take a more practical viewpoint and discuss aspects related to medium access control design and implementation that can serve as a stepping stone for the widespread deployment of cooperative networking.

INTRODUCTION
Cooperative networking is a means of enhancing a communication node’s performance through assistance from another node in a network. In such a set up the number of the required nodes is at least three. Although cooperation is possible in fixed networks also, it is in wireless communications where its deployment leads to important performance enhancements. For example, in a wireless network cooperation enhances reliability, due to the fact that if a cooperating node exists, a signal
will reach the destination node from two different paths. The first path is normally the direct signal from the transmitter while the second path is the relayed signal from the cooperating node. The existence of two paths enhances the decoding probability at the receiver either because one of the paths carries an adequately strong signal or the combination of the two signal instances leads to an easily decodable composite version. This situation, i.e. the availability of two or more copies of the transmitter’s signals at the receiver, is called diversity and is considered one of the most important methods to enhance the performance of wireless communication networks.

Cooperative diversity is the main enabler for achieving enhanced performance in modern wireless networks and results when a set of nodes assist each other for transmitting their data more efficiently. In such a scheme a source node transmits its data to one or many cooperative relay nodes that process and forward them to the destination node. Then the receiver combines the signals received from the relays with the signal received directly from the source and a performance gain is manifested in both BER and capacity achievements. Cooperation diversity has been studied extensively by the research community and can be performed via the employment of single or multiple relays. Numerous publications and research initiatives have been performed, particularly during the last decade, that treat the subject from various viewpoints. The most representative approaches will be reviewed in this chapter.

The cooperation performance is further enhanced with the employment of techniques such as space-time coding which introduces a temporal diversity dimension apart from the already existing spatial one. The benefits of cooperative diversity and in particular its capacity enhancements are capitalized by the end users via the employment of proper networking protocols that deploy the spatial diversity created from the relay nodes. In particular specially designed MAC protocols exploit the existence of one or multiple relays so that the forwarded traffic can be treated much more flexibly and in a way that maximizes the system’s overall performance. Another important consequence from cooperation is energy savings which may result, for example, from the need to transmit in shorter distances when cooperation is enabled.

In this chapter we provide a thorough review of the latest developments in cooperative networking. We start by providing background information regarding the main milestones in the evolutionary path towards cooperative communications. The details on how cooperation diversity is achieved in fading channels are presented together with the methods via which the receivers combine receptions from different paths so as to extract a strong and easily decodable signal. Then we present the protocols that have been devised so far for achieving cooperation diversity. Subsequently we deal with aspects related to distributed space time coding as it is applied in cooperative networking deployments and then we study capacity related issues. In the sequel cooperative multiple access schemes and their incorporation in legacy wireless networks are presented. Finally power allocation aspects are discussed since they are important for the assessment of the interference in a cooperative communication environment and we close the chapter by providing future research directions and conclusions.

**BACKGROUND**

The history of cooperative communications started with the work of Edward C. Van Der Meulen who introduced the relay communication channel and analyzed their information theoretic aspects (Van Der Meulen, 1971). It has been also studied by Sato who also provided insights regarding the achievable capacity (Sato, 1976). Then Cover and Gamal provided an extensive study and closed form expressions regarding the achievable capacity of the relay channel with various options regarding
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