

Chapter 5

Source and Channel Coding Techniques for Cooperative Communications

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ABSTRACT

This chapter provides a survey of practical cooperative coding schemes currently available in the literature, with focus on those schemes that achieve performance close to capacity or the best known achievable rates. To provide an insight into the construction of practical coding schemes for various cooperative communication scenarios, we first summarize the main design principles and tools that are used. We then present a survey of cooperative communication scenarios, and the progress on practical coding schemes for each of these scenarios is discussed in detail. Throughout the chapter, we demonstrate how the common design principles and tools are exploited to construct the existing practical coding schemes. We hope that the integrated view presented in this chapter can lead to further advances in this area.

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I. INTRODUCTION

In a wireless communication channel, the signals transmitted by the terminals suffer from a variety of degradations, such as additive white Gaussian noise (AWGN), shadowing, and multi-path fading. Until recently, most of the efforts on mitigating the effects of these degradations have focused on signal processing and coding design in the physical layer for each communication link between a transmitter and receiver. Many wireless communication systems contain multiple terminals that share a common medium, and information theory indicates that in efficient communication schemes, the terminals jointly use the medium as a shared resource instead of one that is divided orthogonally among pairs of terminals.

Recently, cooperative communication techniques have been proposed that provide practical designs for wireless networks to exploit the shared medium. This resurgence of interest in multi-terminal communications was motivated by the investigation of practical approaches to user cooperation for cellular communications in (Sendonaris, Erkip, & Aazhang, 2003a, 2003b) and related work on the relay channel in (Laneman, Tse, & Wornell, 2004; Laneman, & Wornell, 2003; Laneman, Wornell, & Tse, 2001). Much of the following work has focused on the relay channels, and the term “cooperative communications” is sometimes used to refer to relay channels. However, the resurgence in interest in multi-terminal communications has also included other types of cooperation among radios, and we use the term cooperative communications in this broader sense.

The focus of this chapter is to discuss practical coding schemes for cooperative communications. In particular, we are interested in schemes that can achieve performance close to capacity or the best known achievable rates. The practical cooperative coding schemes that we discuss use some common principles and tools, three of which we discuss in Section II. The first is the discovery of practical capacity-approaching error-control coding schemes starting in the 1990s, which has been a key enabler for efficient cooperative communication schemes. In Section II-A, we provide a brief overview of two classes of such codes: turbo codes (Berrou, Glavieux, & Thitimajshima, 1993) and low-density parity-check (LDPC) codes (Gallager, 1962, 1963; MacKay & Neal, 1997) and the related irregular repeat-accumulate (RA) codes (Jin, Khandekar, & McEliece, 2000). The introduction of the turbo decoder also brought new perspectives on iterative signal processing of communication signals, which is the topic of Section II-B. Finally, in Section II-C, we discuss practical distributed source coding schemes, also known as **Slepian-Wolf** (Slepian & Wolf, 1973b) or **Wyner-Ziv** (Wyner & Ziv, 1976) coding.

The majority of this chapter is devoted to introducing various cooperative communication scenarios and progress on practical coding schemes for these scenarios. The cooperative communication schemes that we consider are shown in the network illustrated in Figure 1. The numbered circles illustrate these different cooperative communication scenarios:

- 1) Nodes A and B have information to send to node C . This is a **multiple-access channel (MAC)**, which is discussed in Section III and Section VI.
- 2) Node C has information to send to both nodes D and E . This is a **broadcast channel**, which is considered in Section IV.
- 3) Nodes F and G have correlated sensor measurements of some phenomena (here F and G observe a jeep from different locations). The nodes wish to compress their measurements and send to node D . Since the measurements are correlated, F and G can use **distributed source coding** to compress their measurements separately, while decoding is performed jointly at D . Distributed source coding is discussed in Section V.

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