

## Chapter 2

# Overview of Amplify-and-Forward Relaying

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### **ABSTRACT**

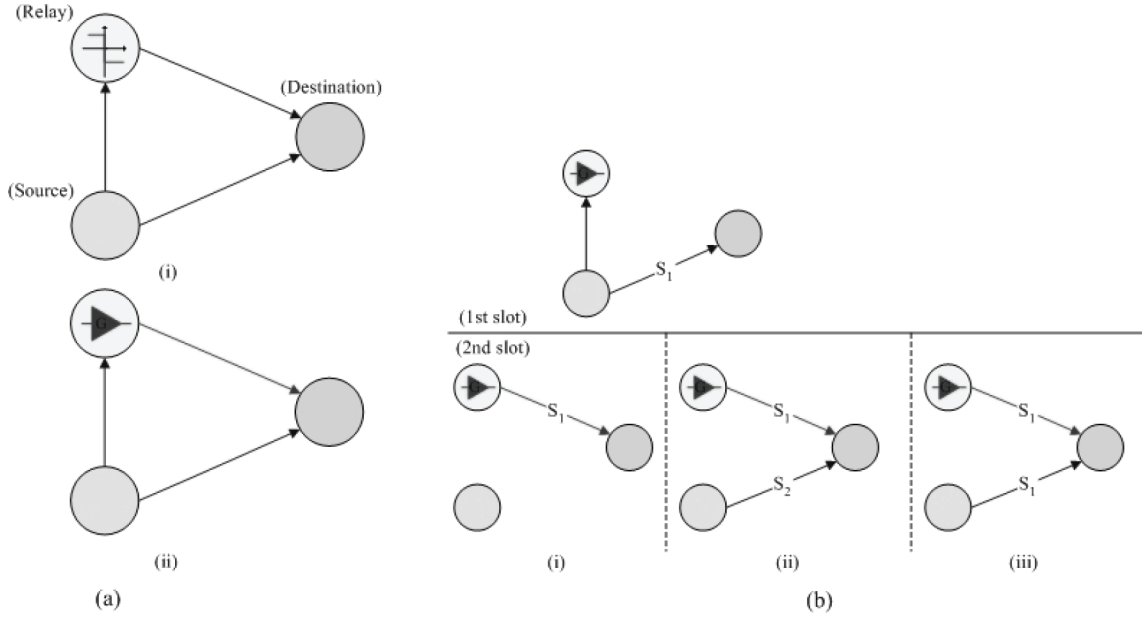
*Amplify-and-Forward (AF) is a simple cooperative strategy for ad-hoc networks with critical power constraints. It involves an amplification of the received signal in the analogue domain at the relays without further signal processing. This chapter gives an overview of the basic AF protocols in the literature and discuss recent research contributions in this area. Based on some well-defined AF-based cooperative configurations, it focuses on the behaviour of AF in block-fading channels, in power allocation problems, in relay selection, and in cross-layer coordination. Mathematical models and outage probability simulations are used in order to show the enhancements of the presented AF techniques.*

### **INTRODUCTION**

Cooperative diversity has emerged as a promising technique to combat fading in wireless communications (Sendonaris et. al., 2003a; Sendonaris et. al., 2003b). It is based on the broadcast nature of the wireless medium and enables single-antenna users to “enjoy” space diversity benefits by sharing their physical resources through a virtual transmit and/or receive antenna array. The basic relay channel model is comprised of three terminals: a source that transmits information, a destination that receives information, and a relay that both receives and transmits information in order to enhance communication between the source and the destination (Lai et al., 2006). Models with multiple relays have been also examined which can be regarded as an extension of this basic configuration (Azarian et. al., 2005; Kramer et. al., 2005; Ribeiro et. al., 2005; Yang & Belfiore, 2007; Fan et. al., 2007). Since the work of Sendonaris et al. (2003a, 2003b) that introduced the notion of cooperative diversity, a number of

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Figure 1. (a) The cooperative concept; (i) Decode-and-Forward, (ii) Amplify-and-Forward. (b) AF protocols-slot structure; (i) OAF, (ii) NAF, (iii) BFNAF.



relaying protocols have been proposed in the literature (Laneman et. al., 2004; Larsson & Vojcic, 2005; Azarian et. al., 2005). These schemes can be grouped into two basic classes: Decode-and-Forward (DF) and Amplify-and-Forward (AF). In the DF schemes, the relay decodes the received source message, re-encodes it, and forwards the resulting signal to the destination. On the other hand, in AF schemes, the relays simply amplify the received signal and resend it without any further signal processing in the analogue domain. The amplification process can be regarded as a multiplication with an amplification factor ( $G$ ) which normalizes the received power. Between these two essential cooperative schemes, AF seems to be a low-complexity solution for practical ad-hoc networks with critical power constraints as it does not require decoding process at the relays. In addition to complexity benefits, it has been shown in (Laneman et al., 2004; Nabar et al., 2004) that AF asymptotically approaches the DF scheme as far as the diversity performance is concerned. Furthermore, in some cases avoiding decoding the signal at the relay nodes actually prevents propagation of decoding errors at the relay (Yang & Belfiore, 2007). Figure 1a schematically presents the two basic cooperative schemes for a three-node configuration.

Although in the original work of Sendonaris et al. (2003a, 2003b) the nodes can transmit and receive simultaneously, in practice the nodes are limited by the half-duplex constraint so they must receive data before retransmitting it later. The first AF cooperative protocol which obeys this constraint was proposed by Laneman et al. (2002, 2003, 2004) where time division multiplexing separated the source and relay transmissions. However, this approach results in a loss of data rate (bandwidth) as the source is inactive for half of the time. In order to recover the rate loss, Nabar et. al. (2004) has proposed the Non-orthogonal AF scheme (NAF) where the source continues to transmit new data during the relaying process. Finally, for the case of block-fading channels where the channel changes during the cooperative frame, Krikidis et. al. (2008c) has proposed the Block-Fading NAF (BFNAF) scheme, where the source retransmits the same data in order to increase the diversity gain instead.

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