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Research Article

Cooperative Diversity in Wireless Networks

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Abstract

Transmit Diversity is an effective methodology for improving the quality and reliability of a wireless network by reducing the effects of fading. As majority of the wireless devices (i.e. mobile handsets, etc) are limited to only one antenna, especially due to hardware constraints, size and cost factors; cooperative communication can be utilized in order to generate transmit diversity [1]. This enables single antenna wireless devices to share their antennas during transmission in such a manner that creates a virtual MIMO (multiple-input and multiple-output) system [2] [3]. In this paper, we will analyze the recent developments and trends in this promising area of wireless Ad hoc networks. The article will also discuss various main cooperative signaling methods and will also observe their performance.

Keywords: Cooperative Communication, Multiple Input Multiple Output Systems, Transmit Diversity, Adhoc Networks etc.

1. Introduction

"The increasing demand for wireless multimedia and interactive Internet services, along with rapid proliferation of a multitude of communications and computational gadgets, are fuelling intensive research efforts on the design of novel wireless communication systems architectures for high speed, reliable and cost effective transmission solutions" [4]. The introduction and rapid development of MIMO (multiple-input and multiple-output) systems has promised significant improvements in reliability and throughput for Ad hoc networks; by utilizing multiple antennas at both the transmitter and the receive side. However, this technique is clearly advantageous for cellular base stations, but not feasible for mobile devices, due to their sizes and power constraints [1] [4].

An alternate to this is a newly developed technique known as multi-user cooperative diversity that allows a single antenna user to achieve transmit diversity benefits by sharing their physical resources through a virtual transmit and receive antenna array. The major benefit of this technique includes the diversity - because different paths are likely to fade independently, beamforming gain and interference mitigation [1] [5].

2. Cooperative Communication

The history of the cooperative communication can found its deep roots to the groundbreaking work of Van der Meulen [6], when he introduced the concept of relay channel model, which consists of a source, destination and relay; and whose major purpose was to facilitate the information transfer from source to destination. Later, Cover and El Gamal [7] deeply investigated the relay channel model, and provided a number of fundamental relaying techniques such as Decode and Forward (DF) and Compress and Forward (CF).

In conventional communication, data is transmitted between the source and destination, and no user provides assistance to one another (Figure 1). However, there are many neighboring nodes in a practical wireless communication network, which could be of great assistance. When one node transmits its data, all the nearby nodes overheard its transmission. Cooperative Communication aims to process and forward this overhead information to the respective destination to create spatial diversity, which can in result increase

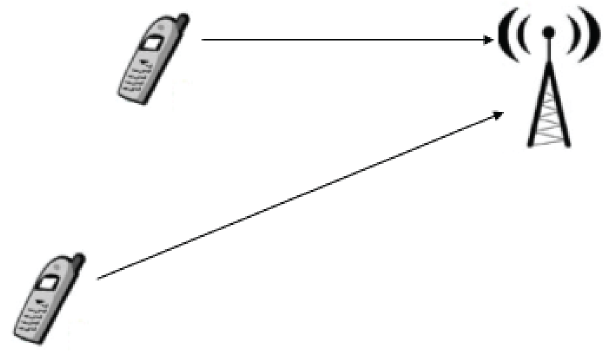

Figure 1. Conventional Communication.

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the system performance. The concept of the cooperative communication is suggested in Figure 2. [4]

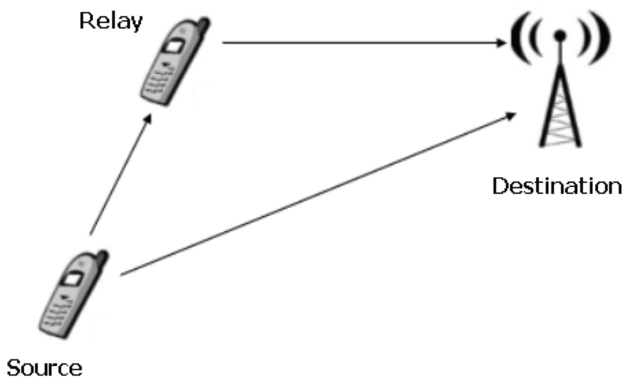

Figure 2. Cooperative Communication.

As depicted in Figure 2, the source 'S' is transmitting data to the destination 'D', while the relay station (another mobile user) 'R' is also hearing the transmission. The relay station also process and forward this message to the destination, where both of the received signals are combined. As both copies of the signals are transmitted through independent paths, this results into spatial diversity. In cooperative communication, each wireless user is assumed to transmit its own data as well as act as a cooperative agent (relay) for the other user (Figure 3). [1] [8]

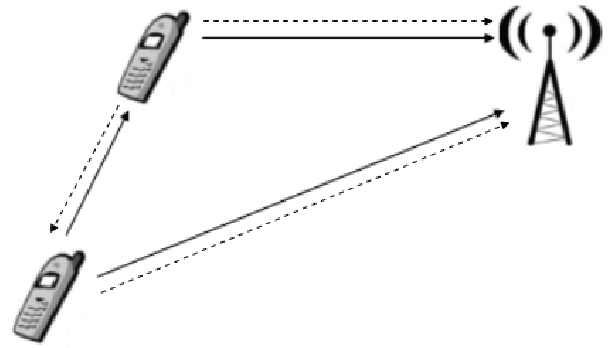

Figure 3. Cooperative Communication, where each mobile act both as a user and relay.

3. Cooperative Transmission Protocols

Cooperative transmission protocols describes that how the received data is processed at the relay station, before forwarding it to the destination. In this article, we will review and compare several cooperative strategies in brief.

A. Decode and Forward

The Decode and Forward (DF) method is the most preferred method of processing data in the relay/partners/neighboring nodes, and is closest to the idea of a traditional relay. In this technique, the relay detects the source data, decodes and then transmits it to the desired destination. The concept of the Decode and Forward technique is shown in Figure 4.

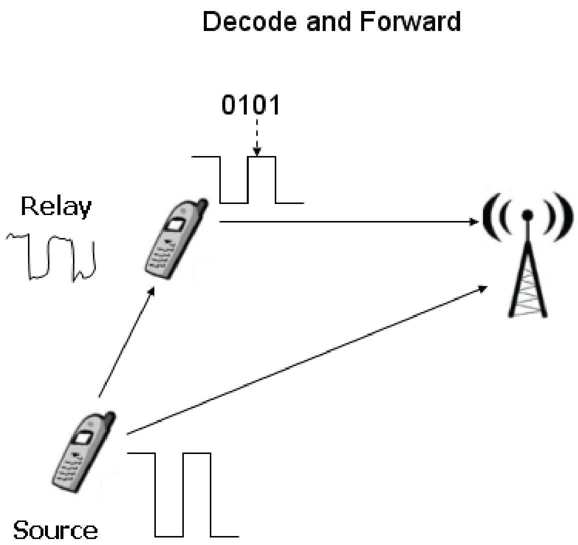

Figure 4. Decode and Forward Technique.

An error correcting code can also be implemented at the relay station. This could help the received bit errors to be corrected at the relay station. However, this is only possible, if the relay station has enough computing power [8].

B. Amplify and Forward

As the name suggests, the Amplify and Forward technique simply amplify the signal received by the relay before forwarding it to the destination. This technique was proposed by J. N. Laneman and G. W. Wornell [9], and is ideal when the relay station has minimal computing power. However, one major drawback of this technique is that the noise in the signal is also amplified at the relay station, and the destination receives two independently faded versions of the signal. The concept of the Decode and Forward technique is shown in Figure 5. The interested reader is referred to literature of J. N. Laneman and G. W. Wornell [9] for a comprehensive understanding of the Amplify and Forward technique.

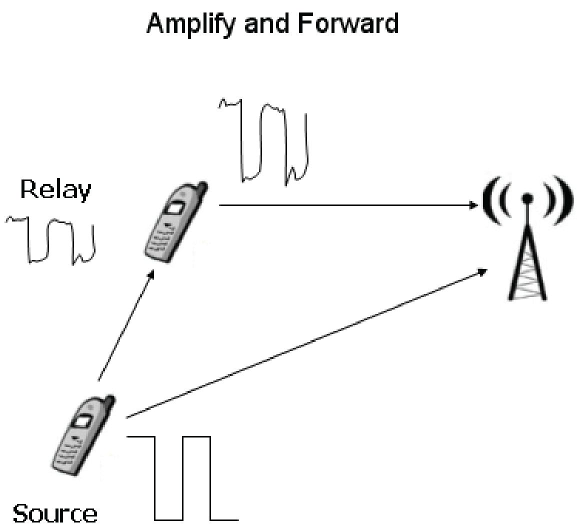

Figure 5. Amplify and Forward Technique.

4. Coded Cooperation

Todd E. Hunter and Aria Nosratinia [10] [11] proposed a new technique known as coded cooperation. In the other two cooperative strategies described above, the partner / relay station just retransmits the received data bits by decoding (DF Method) or amplifying (AF Method) [3]. Unlike these two techniques, the received data bits in coded cooperation are broken down into two parts. One part is transmitted by the user and the other part is transmitted by the partner. The concept of the two user coded cooperation system is shown in Figure 6. As depicted in the figure, the User 1 is transmitting its own half data bits in Frame 1, and the partner (User 2) half data bits in Frame 2 to the destination. However, in actual wireless cellular network, there could be more than 2 cooperative users and data transmitted by one user can be overheard by other users as well (Figure 7). Salam A Zummo [3] proposed an analytical framework for deriving and evaluating the error performance of coded cooperation with multiple cooperating users.

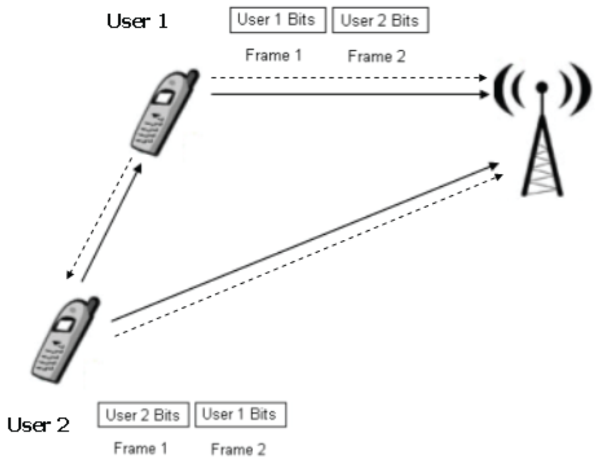

Figure 6. Coded Cooperation for 2 Users.

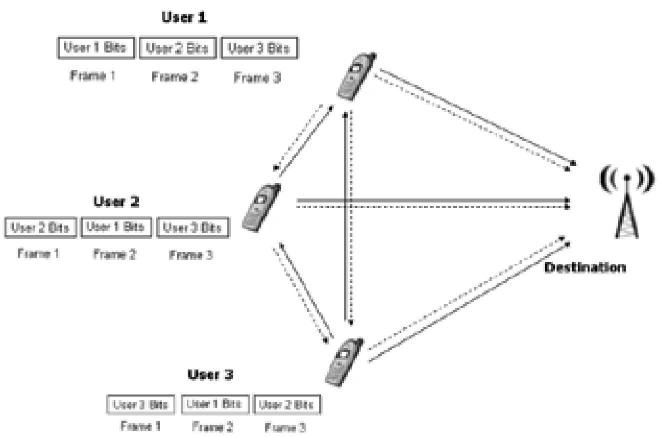

Figure 7. Coded Cooperation 3 Users.

5. Performance Analysis

Figure 8 provides the performance analysis of the already discussed cooperative strategies; Decode and Forward, Amplify and Forward, and Coded Cooperation using BPSK modulation and coherent detection at the receiver. The comparison clearly suggests that the coded cooperation technique performs better than the Decode and Forward and Amplify and Forward techniques, since it has better degradation. The graph also suggests that the error performance rate has substantially improved as a result of cooperative communication between users [1].

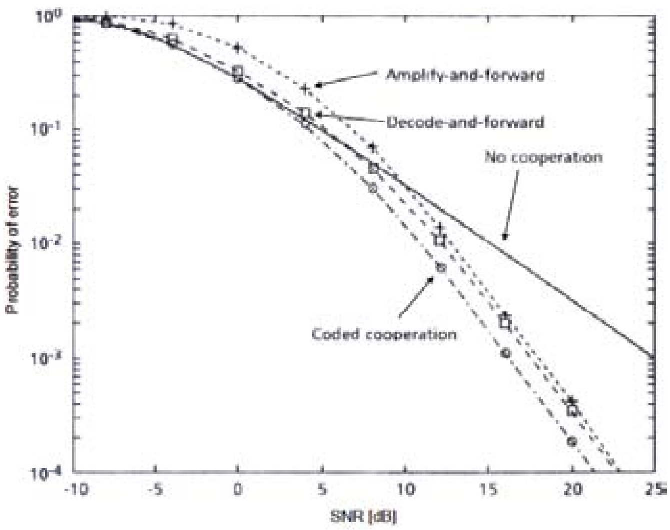

Figure 8. Performance Analysis.

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