

Chapter 30

Wireless Collaboration: Maximizing Diversity through Relaying

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ABSTRACT

To achieve performance gains in the wireless channel, spatial diversity is employed. These higher order transmit diversity gains generally require multiple transmit antennas at the source. This requirement is not always possible in real world applications, where practical concerns limit the number of antennas a wireless device can have. Recently, a new method to achieve transmit diversity has been proposed: collaborative communications. In this framework, a node in a wireless network can use the resources of other idle nodes and form what can be viewed as a virtual transmitting antenna array. This chapter presents an overview of the development of collaborative communications. Two-phase protocols that can achieve collaboration are presented. A discussion on the improvement of collaborative communications protocols is given. A broader perspective of collaborative communications is given by discussing ideas such as power allocation and multiple relays.

INTRODUCTION

Multiple-input multiple-output (MIMO) communication (Foschini, Gans, 1998) is a method by which several transmitting and receiving elements are used at the source and destination to achieve high spectral efficiency in wireless communications by using available spatial diversity. Spatial diversity is obtained by transmitting the same data

through independent fading channels given by the multiple transmitting and receiving elements. The idea of MIMO led to the development of so-called space-time codes (Tarokh, Seshadri & Calderbank, 1998). MIMO technologies have been implemented in many existing wireless communication technologies (i.e. Wi-Fi), and is planned to be included in many future systems such as WiMAX.

Recent work has shown that traditional MIMO falls under a much bigger umbrella referred to as multi-user (MU) MIMO. This includes any tech-

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nology which provides spatial diversity in the wireless channel by allowing adjacent network nodes to collaborate. It is in this realm that we find collaborative communications – a system which allows transmitting nodes, each with a single antenna, to collaborate with nearby idle nodes to achieve similar performance as using multiple transmit antennas.

Collaborative communications is an attractive technology for the future deployment of 4G networks since it helps achieve several of the objectives set forth. Increasing spatial diversity allows one to improve the spectral efficiency (in b/s/Hz) of a system. For 4G to achieve its high data rate targets, spectrally efficient technologies, such as collaborative communications, are a must.

Fourth generation networks are expected to have seamless connectivity across multiple networks. Collaborative communication can be considered a component of ad hoc networking, where communication need not be point-to-point. As such, using collaboration can be a tool used to achieve connectivity between different networks.

Another objective of 4G networks is to achieve high data rate between any two points in the world. Having nearby nodes collaborating with each other significantly increases their useable range. Collaborative communications can also be deemed one step in a multi-hop system. Such a system can further ensure connectivity and thus achieve the “anytime, anywhere” credo of 4G networking.

It is because of all of the above that relaying concepts using some form of collaboration have been proposed to be included in future 4G technologies. Newer releases of the LTE standard (LTE Advanced) have discussed the use of various concepts for relay nodes. This is also true for future generations of WiMAX such as WiMAX-m.

The purpose of this chapter is to introduce the reader to the concept of collaborative communications and provide a mathematical framework to perform analysis of collaborative communica-

tions. First, some basic principles of collaboration are discussed: things such as decode-and-forward, coded collaboration, variable time-fraction, etc... This allows the reader to get a better understanding of the challenges presented in collaborative communications. Next we include more recent results on the performance of collaborative communications. From these the reader can better appreciate the value of using collaborative communications.

Using the tools provided in the discussion on performance, we provide some more advanced methods to further improve the performance of collaborative communications. These include using power allocation algorithms and multiple relaying nodes.

The topics discussed in this chapter provide a tutorial overview of collaborative communications. There are many complicated issues that must be addressed before collaboration can be implemented practically: the type of collaboration used, symbol timing, transmitting and receiving architecture of the wireless nodes, etc... Some of these are addressed in this chapter, and the interested reader is referred to the future work section and to the list of additional reading for more information.

The chapter is presented as follows: In section II, a review of the work which led to the development of collaboration is presented. Section II also provides the basic assumptions as well as basic results required to fully appreciate the benefits of collaboration. The use of two-phase protocols to achieve collaboration is presented in section III. Protocols such as Detect-and-Forward, Amplify-and-Forward, Decode-and-Forward as well as variable phase length and collaborative coding, are examined in this section.

The next two sections provide performance results of collaborative communications. Section IV provides results for both a coded collaborative communications scheme using variable time-fraction, as well as a higher order modulation collaborative communications scheme. In section

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