Channel Estimation and Optimal Resource Allocation of Relay Assisted Communication Systems

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Abstract

Exploding demand for various wireless services has fueled significant development of wireless communication systems and networks in the past few decades. Wireless service providers are continuously striving to improve the design of communication systems and to enable higher data rate and more reliable wireless transmission. A major challenge in designing these systems is the random nature of the wireless transmission media due to fading process. A recent paradigm shift from the conventional point-to-point communications is the relay assisted communications. Motivated by the great success of multiple-input multiple-output (MIMO) wireless communication systems, with multiple transmit and receive antennas, the researchers have considered the relay assisted communications. Relying on the broadcast nature of the wireless media, a relay assisted communication system emulates a virtual MIMO system and exploits the spatial diversity, also known as cooperative diversity. Cooperative diversity increases the transmission reliability and coverage, without expanding the expenditure of the scarce transmission resources (power and bandwidth).

Recently, the research community has witnessed an increasing interest in studying the relay assisted communication systems. These studies include proposing novel relaying schemes, exploring ways to maximize the cooperative gain, and investigating the fundamental performance limits of these systems. The bulk of literature is based on the main assumption that the effect of fading channels (commonly referred to as channel state information) is perfectly known at the destination. In practical communication systems, however, the unknown fading channels are first estimated and the channel estimates are used for decoding the message transmitted by the source. In order to have a more realistic and accurate understanding of the benefits of relay assisted systems, one needs to study the effect of uncertainty, imposed by channel estimation error, on the fundamental performance limits. Such study can guide to a more efficient system

design and provide the optimal resource allocation between data and training (required for channel estimation).

Two widely used relay assisted wireless communication systems are: 1) a one-way relay assisted system, in which there is a source, a relay and a destination, and the relay helps the source by forwarding the overheard message to the destination; 2) a two-way relay assisted system, in which two sources are interested in mutual communication, i.e., one source is the destination of the other source. In this system the relay helps both users by forwarding the overheard messages to the intended destinations. For each system, one can envision different system designs, depending on the specific relaying scheme and the specific signal processing algorithm adopted at the relay. The most commonly used relaying schemes are Amplify-and-Forward (AF) and Decode-and-Forward (DF), where in the former the relay amplifies and forwards the overheard messages, while in the latter, the relay decodes the overheard messages and then proceeds to forwarding them.

In this thesis, we consider one-way and two-way AF relay assisted systems with a half-duplex relay. We study the impact of uncertainty, due to channel estimation errors, on the fundamental performance limits. In particular, we consider mean squared error (MSE) and the Bayesian Cramér -Rao lower bound (CRLB) for channel estimation as the estimation theoretic optimality criteria and channel mutual information lower bound and outage probability upper bound as the information theoretic optimality criteria. We explore how the negative effect of channel uncertainty can be mitigated, via optimal transmission resource allocation that maximizes or minimizes a specific optimality criteria. We also compare the bidirectional mutual information lower bounds of direct transmission without the relay, one-way AF relay and two-way AF relay systems. Furthermore, we examine the effect of joint optimization of the media access control and physical layers on the system throughput for one-way AF and DF relay assisted systems.