Power Efficient Communication for Joint Detection Receivers in Rician Channels

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ABSTRACT

In a multipoint to point link, where multiple streams from geographically separated points co-existing in time and frequency are jointly detected, the relative powers at which the signals are received play an important role in deciding the sum rate. Unlike Rayleigh fading, where decreasing the power of any of the streams will result only in decrease in the sum rate, Rician fading exhibits an interesting behavior where one can actually improve the sum rate by decreasing the power of one or more of the transmitted streams. This gives rise to the possibility of power efficient communications under Rician channel conditions. In this paper, the authors discuss a power control scheme where the receiver, based on the present received powers and k-factor, feeds back the optimal powers to be transmitted so that the total transmitted power is minimized without any loss in the sum rate. It can be shown that by employing such a power control scheme, considerable amount of power can be saved on the transmit side, paving way to greener communications, for LoS or near LoS links.

KEYWORDS
Joint Detection, LoS, Power Control, Rician Fading

1. INTRODUCTION

The presence of a Line of Sight (LoS) component in the fading channel makes the study of Rician fading very important. LoS or near LoS links are possible in many small cell deployments of 3GPP-LTEA systems, as well as future millimeter wave links. As is well known, the k-factor in Rician fading generalizes the Rayleigh (K=0) and AWGN (K=infinity) channels. Considerable amount of work has been done on the effect of Rician fading in various scenarios. For example, Wu et al. (2010) analyses the performance of Optimum Combining Receivers under Rician fading conditions. Nandi et al. (2010) talk about optimal transmit powers in wireless sensor networks under Rician fading conditions, while Jayaweera et al. (2003) propose an optimal signaling scheme for improvement in capacity in multiple antenna scenarios undergoing Rician fading, where the knowledge of k-factor is available at the transmitter. Reducing transmit power is an important requirement for mobile terminals on the uplink. There are many works which talk about methods to reduce the transmit power. For example, Bavianianet al. (2009) propose a power control strategy based on the total received power in the uplink of cooperative base stations. In our work, we consider a multipoint to point link in a typical uplink scenario, where transmit power is the main constraint. Hence, we propose a power control scheme with limited feedback with the aim of minimizing the transmitted power, while maintaining the same rate. Since both the streams are of interest, we look at a joint detection receiver (Grant and Cavers, 2009) and calculate the sum rate for the transmitted streams.

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The motivation for this work is as follows. Consider two transmitters transmitting to a single receiver at the same time and frequency as shown in Figure 1. Assume both the streams are QPSK modulated and are received at different powers $P_1$ and $P_2$ at the receiver, based on the path loss encountered. To understand how the sum rate varies with the received power of the two streams, let us initially consider the case where the first stream is received at -90dBm and the noise floor is at -100dBm. The power of the second stream is varied from -100dBm to -80dBm and the variation of the sum rate is plotted. It can be seen from Figure 2 that in case of Rayleigh fading, the sum rate increases monotonically with increase in the power of the second stream. However, in the case of Rician fading, the sum rate drops as the power of the second stream approaches the power of the first stream and then rises again. This is because in the equal power region, the constellation points overlap and the $d_{\text{min}}$ approaches zero and the constellation points are no more uniquely decodable.

While the Rayleigh channel does not exhibit this behaviour at all, it is observed best in the AWGN channel and also in the Rician channel with significant k-factors as shown in Figure 1. It can be seen from this figure that in the Rician case, when $[P_1, P_2]=[-90, -88]$, then the maximum achievable sum rate is 1.7. But the same sum rate can be achieved using $[P_1, P_2]=[-90, -96]$, i.e. by reducing $P_2$ by 8dB. This V-shaped region in the figure is where power efficient communication is possible. Thus, when the transmitters are geographically located in such a way that their received powers lie in this region and the receiver can smartly identify a lower power pair which can achieve the same sum rate, then the transmit side power can be considerably reduced.

In this paper, we propose a power control scheme in the above mentioned scenario. The advantage of the proposed scheme is as follows:

1. The power control scheme is not based on any Instantaneous Channel State Information (CSI). This is advantageous because:
   ◦ Only the long term fading statistics and the k-factor needs to be known which makes the system work with very low or limited feedback overhead.
   ◦ Unlike instantaneous CSI, long term fading parameters and k-factors do not vary rapidly, and hence, less frequent power control commands are sufficient.

2. All the computational complexity regarding the choice of optimal transmit power is shifted to the Base Station and hence the mobile terminal has little work to do except switching the transmit powers based on the feedback.

The rest of the paper is organized as follows. Section 2 describes the system model and the simulation parameters used. Section 3 discusses the Algorithm for the proposed power control scheme. In section 4, the numerical results are provided and they are analyzed and justifications for the performance are provided. Section 5 talks about an application of the proposed idea in user pairing context. In Section 6, we conclude with the future scope of the work.

2. SYSTEM MODEL

In order to carefully understand the effect of the power control scheme, we consider a simple setup where there is a single Base Station (BS) and two mobile terminals or User Equipments (UEs) which are randomly dropped within a radius of 100m and a path loss exponent of $\alpha=2.5$. The received symbol $y$ is given by:

$$y = \sqrt{P_1}h_1x_1 + \sqrt{P_2}h_2x_2 + n$$
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