EE360 project: Interference Alignment for MIMO interference channel using Imperfect CSI

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1 Prior work

Cadambe and Jafar [1] propose a novel method in which K transmitter-receiver pairs possibly interfering with each other can communicate for 30 minutes each in one hour without effects of interference. They achieve this by alignment of interference in one dimension and placement of the signal in another orthogonal dimension. The disadvantage of the proposed technique is that it assumes perfect CSI at both transmitters and receivers. The capacity can be achieved at high SNRs using only simple linear codes. A related work by Jafar and Shamai [2] considers the case of 2 transmitter-receiver pairs with M antennas for each transmitter and receiver. They prove that $\lfloor \frac{4}{3}M \rfloor$ degrees of freedom can be achieved. They also used linear codes to achieve the proposed $\lfloor \frac{4}{3}M \rfloor$ degrees of freedom.
Recently Thukral and Bolcskei [3] presented a technique that assumes perfect CSI at receivers, but imperfect CSI at transmitters and still implements interference alignment successfully. They proved that $K/2$ degrees of freedom can be achieved for the K-user interference channel provided the number of feedback bits broadcast by each destination is atleast $M(L-1)\log P$. (The authors assume frequency selective channels with L taps each). In another work, Ghasemi, Motahari and Khandani [4] investigate the achievable degrees of freedom for the more general K user MIMO interference channel with M transmit antennas per transmitter and N receive antennas per receiver. They obtain inner and outer bounds and special cases when the bounds coincide. They assume perfect CSI at both transmitter and receiver.

2 A brief analysis

A brief intuitive analysis of the results in [3] is as follows: Suppose that one wants to evaluate a function $f(x, y)$. If x is known only to n bit accuracy, one can intuitively argue that that knowing y to more than n bit accuracy will in general not be that benificial in improving the accuracy of $f(x, y)$. Following this line of reasoning, and the fact that it makes information theoretic sense to "know" the signal only up to an accuracy of $\log P$ bits, it makes sense that each of the channel coefficients $h_{ij}(m)$ need be known by the transmitter to an accuracy of only $\log P$ bits. It follows immediately that each receiver needs to broadcast only $ML \log P$ bits (Since there are M transmit antennas and L taps each). A careful analysis of the quantization error formally proves the result.

3 My proposal

Following the above line of reasoning, one can argue that for the K user MIMO interference channel with M antennas per transmitter and N antennas per receiver, each receive antenna needs to broadcast atmost $KML \log P$ bits (where L is the number of taps). In my project, I propose to formally prove this result using analysis that is similar to the one in [3]. For the interference alignment technique, I propose to use the same achievability results presented in [4]. The authors make use of a new technique for interference alignment based on arguments from the field of Diophantine approximations in Number Theory, wherein properties of rational and irrational numbers are used to perform interference alignment. It appears that the intuitive argument for the amount of feedback bits required still holds. A formal proof that analyses quantization noise on the lines of [3] will be attempted.

4 Future work

The authors in [3] proved only an achievable result for the amount of feedback required. Further research will be required to determine the minimum number of feedback bits required to perform interference alignment without any loss of dof. This will be attempted if time permits. Note that the actual amount of feedback depends on the rate at which the channel changes. Thus for a slow fading channel, the feedback bits will cause only a small overhead, whereas for a fast fading channel feedback may not even be possible. In such a situation, imperfect feedback entails the loss of dof and the exact tradeoff between available feedback bits and achievable dof is still a matter of speculation.

References

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[4] Akbar Ghasemi, Abolfazl Seyed Motahari and Amir Keyvan Khandani, “Title: Interference Alignment for the K User MIMO Interference Channel,” arXiv:0909.4604v1 [cs.IT], 25 Sep 2009.