OPTIMAL TRANSCEIVER DESIGN IN MULTI-USER MULTIPLE-INPUT MULTIPLE-OUTPUT WIRELESS NETWORKS

Naveen K. D. Venkategowda, Advisor: Aditya K. Jagannatham

Dept. of Electrical Engineering, Indian Institute of Technology, Kanpur, India

ABSTRACT

In the thesis, we first investigate transceiver design for interference management towards maximizing the signal-to-interference-plus-noise ratio (SINR) of the users in multi-cell multiple-input multiple-output (MIMO) wireless networks. Next we study transceiver design for decentralized estimation in wireless sensors networks and demonstrate that precoding helps in realizing in-network signal processing to reduce the complexity and improve the estimation performance.

1. COOPERATIVE BEAMFORMING TECHNIQUES FOR MULTI-CELL MULTI-USER NETWORKS

Multi-cell MIMO cooperative beamforming, where a cluster of base stations (BS) cooperate to transmit to different users, is an effective solution for high data rates and multicast video transmission [1]. The BSs can cooperate to transmit their signals such that the inter-cell and intra-cell interference is minimized. Further, when the BSs and users employ multiple antennas, one can design the transmit and receive beamformers to support more number of users. Therefore, the challenge is to develop beamforming schemes that realize the advantages offered by multi-cell MIMO networks [1].

1.1. Contributions and Methodology

We first study transmit and receive beamforming for unicast/multicast multi-cell cooperative transmission with interference among users/user groups. An optimal successive minimum variance beamforming (SMVB) scheme is derived to maximize the sum-rate while successively maintaining orthogonality to the previously scheduled user groups. The proposed beamforming schemes maximize the SINR for each user in case of unicast scenario and maximize the sum SINR of each user group in case of multicast scenario while nulling the interference to the previously scheduled user groups.

The main principle of the proposed techniques is to increase the available degrees of freedom by tolerating interference at certain users rather than complete cancellation at every user. These degrees of freedom are exploited to increase the number number of users multiplexed by a factor of number of receive antennas in each scheduling epoch. Thus, enhancing the overall fairness of the system and sum-rate performance compared to the block diagonalization (BD) based precoding schemes [2, 3].

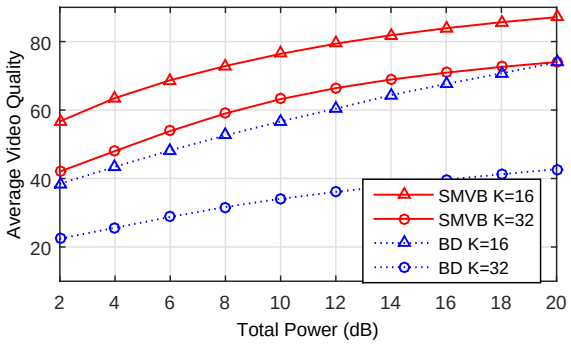

Fig. 1. Video quality of multi-user beamforming schemes with K users, $N = 4$ cooperating base stations, $N_u = 4$ transmit and $N_b = 4$ receive antennas.

Next, we consider the broadcast scenario where all the users request the same data. To ensure a minimum quality of service to all users, a generalized broadcast beamforming framework is proposed based on the max-min fairness optimization. This framework incorporates scenarios including unequal BS powers and fairness in resource allocation.

We consider the multi-cell uplink scenario and develop the successive multi-user uplink beamforming scheme which maximizes the SINR of the users at the BS. It is shown that higher data rates can be achieved due to the zero interference property of the proposed beamforming scheme.

For a practical system with only imperfect channel state information (CSI), we jointly optimize the beamformers of all the users to maximize the worst-case SINR of each user. This is based on minimizing the worst-case interference due to other users while ensuring the maximum array gain. The solution is a convex second-order cone program that can be solved efficiently in contrast to the iterative algorithms in [4, 5].

1.2. Results

Simulation results demonstrate that the proposed multi-cell transmission schemes have superior sum-rate and multi-user diversity gain in comparison to existing BD based precoders. Employing the joint scalable video model, we analyze the video quality performance and the suitability of the proposed SMVB beamforming schemes for transmission of multimedia content. For e.g. Fig. 1 shows the improvement in the video quality performance in comparison to the BD techniques.

2. PRECODING FOR DECENTRALIZED ESTIMATION IN WIRELESS SENSOR NETWORKS

In wireless sensor networks (WSN), the sensor nodes acquire observations about a phenomena of interest and transmit a summary of the data to a fusion center (FC) over a wireless multiple access channel (MAC). The FC processes the data received from the multiple sensors to accomplish tasks such as parameter estimation and event detection [6].

The challenges in designing the WSNs for decentralized estimation are manifold. First, the sensors transmit the data over a wireless MAC that is prone to fading and interference. Second, the FC should accomplish its task with minimal information, since communication with the sensors is limited due to scarcity of bandwidth. Third, the sensors are power limited as replacing the batteries is expensive or the nodes may be inaccessible. Finally, since the sensors and FC are miniature devices, algorithms employed by them should have low computational complexity.

2.1. Contributions and Methodology

In the thesis, we demonstrate that an intelligent design of the transceivers can reduce the computation and communication demands of the network without compromising on the accuracy of the parameter estimate. We propose an optimal minimum variance distortionless precoding (MVDP) framework for decentralized estimation of vector parameters over a coherent MAC in MIMO WSNs. The proposed framework yields a distortionless estimate at the FC without the necessity of additional processing in contrast to the techniques in [6, 7], which require processing at both the sensor nodes and the FC. The precoders are designed to exploit in-network signal processing and ensure the signals transmitted by the sensors interfere constructively at the FC.

The advantages of the proposed precoding framework are twofold. First, interference due to transmission from other nodes does not deteriorate the estimation performance. Second, it has a low computational complexity since no processing is needed at the FC. Further, we also show the optimality of the proposed techniques in comparison to the ideal centralized estimation scenario where the FC has access to all observations at the sensors.

Next, we develop precoding for decentralized estimation with only imperfect CSI. The proposed technique minimizes the worst-case estimation error arising due to the channel uncertainties while ensuring the maximum gain at each receive antenna. The proposed framework enables the FC to use a simple maximum ratio combiner with complexity $\mathcal{O}(N)$ to estimate the parameter, in comparison to works in [7, 8], which have a complexity of $\mathcal{O}(N^3)$.

2.2. Results

Simulation results demonstrate that the proposed precoding schemes have no loss in the MSE performance and support the analytical results. The results summarized in Fig. 2 show that the proposed MVDP precoding techniques perform close to the ideal centralized MMSE estimator.

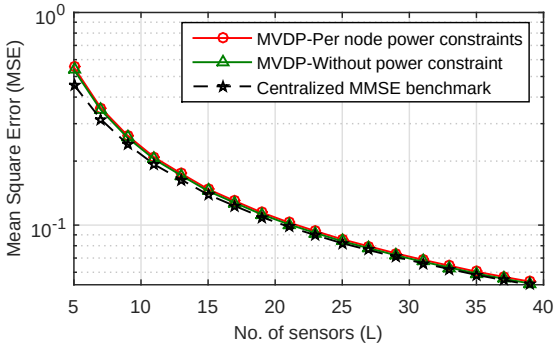

Fig. 2. Decentralized estimation with transmit power 10dBW, observation SNR 10dB, and two transmit antennas.

3. CONCLUSION

Transceiver designs have been proposed to increase the degrees of freedom to cancel interference, and enhance the sum-rate and fairness performance in multi-cell networks.Transmit precoding techniques have been proposed to reduce the computation and communication requirements without compromising the accuracy of decentralized estimation in WSN.

4. REFERENCES

[1] D. Gesbert, S. Hanly, H. Huang, S. Shamai, O. Simeone, and W. Yu, "Multi-cell MIMO cooperative networks: A new look at interference," *IEEE J. Sel. Areas Commun.*, vol. 28, no. 9, pp. 1380–1408, Dec. 2010.

[2] R. Zhang, "Cooperative multi-cell block diagonalization with per-base-station power constraints," *IEEE J. Sel. Areas Commun.*, vol. 28, no. 9, pp. 1435 –1445, Dec. 2010.

[3] H. Dahrouj and W. Yu, "Coordinated beamforming for the multicell multi-antenna wireless system," *IEEE Trans. Wireless Commun.*, vol. 9, no. 5, pp. 1748–1759, May 2010.

[4] E. Björnson, G. Zheng, M. Bengtsson, and B. Ottersten, "Robust monotonic optimization framework for multicell MISO systems," *IEEE Trans. Sig. Proc.*, vol. 60, no. 5, pp. 2508–2523, May 2012.

[5] S. He, Y. Huang, S. Jin, L. Yang, L. Jiang, and M. Lei, "Robust multi-cell joint transmission beamforming based on uplink-downlink duality," in *Proc. IEEE WCNC*, Apr. 2013, pp. 3152–3156.

[6] J.J. Xiao, S. Cui, Z.Q. Luo, and A.J. Goldsmith, "Linear coherent decentralized estimation," *IEEE Trans. Signal Process.*, vol. 56, no. 2, pp. 757–770, Feb. 2008.

[7] A.S. Behbahani, A.M. Eltawil, and H. Jafarkhani, "Decentralized estimation under correlated noise," *IEEE Trans. Signal Process.*, vol. 62, no. 21, pp. 5603–5614, Nov 2014.

[8] A. Shirazinia, S. Dey, D. Ciuonzo, and P. Salvo Rossi, "Massive MIMO for decentralized estimation of a correlated source," *IEEE Trans. Signal Process.*, vol. 64, no. 10, pp. 2499–2512, May 2016.