

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

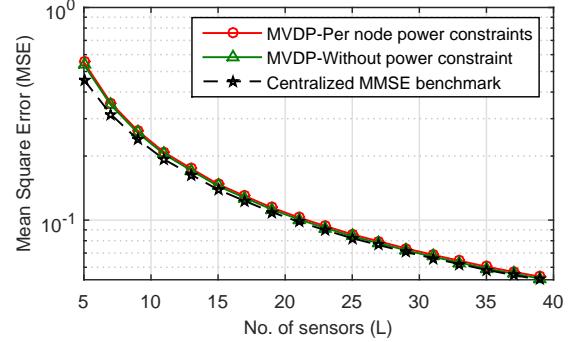


Fig. 2. Decentralized estimation with transmit power 10dBW, observation SNR 10dB, and two transmit antennas.

the analytical results. The results summarized in Fig. 2 show that the proposed MVDP precoding techniques perform close to the ideal centralized MMSE estimator.

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.