Introduction to the Issue on Signal Processing for Large-Scale MIMO

LARGE-SCALE or massive MIMO techniques can tremendously improve the performance of wireless networks. Massive MIMO base stations are equipped with a very large number of antennas, possibly tens to hundreds of antennas, and simultaneously communicate with multiple users on the same frequency band. As the number of antennas grows large, the effects of noise and fast fading vanish and intra-cell interference can be mitigated using simple linear precoding and detection methods. Large-scale MIMO, therefore, has the potential to have a significant impact on future wireless communications systems. To implement such large-scale MIMO techniques in practice, several critical issues must be addressed. They range from pilot design and channel estimation in the presence of interference, to reduced-complexity precoding and detection, to energy efficient designs and experimentation. Such challenges are touched upon in the survey paper by L. Lu, G. Y. Li, A. L. Swindlehurst, A. Ashikhmin, and R. Zhang, which presents a comprehensive overview of state-of-the-art research in large-scale MIMO along with potential application scenarios. This special issue also contains 18 technical papers with original contributions addressing each of the aforementioned challenges.

Channel estimation in large-scale MIMO is known to be hampered by the phenomenon of pilot contamination due to co-channel interference. Improving channel estimation is essential as it directly affects the performance of the decoders and precoders and ultimately the entire wireless system. This special issue has several papers related to pilot design and channel estimation making use of diverse specific properties of massive array signals. The paper by L. Hanzo, J.-K. Zhang, B. Zhang, S. Chen, M. El-Hajjar, and X.-M. Mu explores CSI-based pilot predistortion for uplink channel estimation in the OFDM context. In the contribution by R. Mueller, L. Cottatellucci, and M. Vehkapera, the pilot contamination problem is addressed by a subspace projection algorithm and analysis is performed using random matrix theory. The FDD scenario constitutes a severe challenge for massive MIMO due to potentially high overhead in downlink training and uplink feedback. The paper by S. Noh, M. D. Zoltowski, Y.-C. Sung, and D. J. Love investigates how to design pilot beam patterns to improve channel estimation by taking channel statistical information into account in a FDD scenario. Finally, the paper by J. Choi, D. Love, and P. Bidig addresses training techniques that use prediction and covariance information to reduce training overhead in FDD.

The paper by N. Shariati, E. Björnson, M. Bengtsson, and M. Debbah tackles the problem of complexity reduction in channel estimation, and proposes a novel approach to estimation that makes use of a polynomial expansion model for channel inversion. The context of massive arrays in millimeter wave (MMW) cellular systems is addressed in the contribution by A. Alkhateeb, O. El Ayach, G. Leus, and R. W. Heath Jr, which shows that the poor scattering structure of the MMW channel can be exploited for complexity reduction. Finally, the paper by T. Lakshmi Narasimhan and A. Chockalingam improves channel estimation performance by exploiting the phenomenon that the columns of the uplink channel matrix in large-scale MIMO networks are asymptotically orthogonal.

With channel state information at the transmitter, pre-processing such as pre-coding and beamforming can be performed to optimize the performance of large-scale MIMO systems. Four papers in this special issue touch upon this topic. The paper by A. Kammoun, A. Müller, E. Björnson, and M. Debbah discusses linear precoding based on a polynomial expansion model of channel inversion for large-scale MIMO in multi-cell networks. The paper by J.-Y. Nam, A. Adhikary, J.-Y. Ahn, and G. Caire address complexity reduction by relying on a finite dimension property for the channel covariance matrices associated with uniform linear arrays. The paper by M. Gkizeli and G. N. Karystinos reduces overall complexity by selecting subsets of antennas to maximize signal-to-noise ratio. There are however additional strategies leading toward complexity reduction, including methods aimed at the detection problem. For instance the paper by S. Wu, L.-L. Kuang, Z. Y. Ni, J.-H. Lu, D.-F. Huang, and Q.-H. Guo formulates a low complexity approximation to the optimal detection problem by resorting to limited message passing methods in the decoder. Closer to implementation issues, the paper by M. Wu, B. Yin, G.-H. Wang, C. Dick, J. Cavallaro, and C. Studer target an efficient FPGA implementation of the detection via a series expansion of the channel inversion function.

Importantly, this special issue has contributions looking beyond the sole concept of massive co-located arrays. Drawing links between massive MMO and network MIMO, the paper by K. Hosseini, W. Yu, and R. S. Adve compares the interference mitigation capabilities in these two cases. In the paper by H. Yin, D. Gesbert, and L. Cottatellucci the massive arrays are allowed to take fully distributed topologies, akin to remote radio head systems or decentralized antenna systems. Their results evidence the existence of useful finite dimensional signal subspace properties, thereby generalizing past results obtained for the linear array case.

Finally, the topic of power efficiency is touched upon by the issue. The papers by J.-G. Joung, Y.-K. Chia, and S.-M. Sun and by Q. Zhang, S. Jin, K.-K. Wong, H.-B. Zhu, and M. Matthaiou address energy efficiency and power scaling as the number of antenna grows. The paper by J.-X. Pan and W.-K. Ma investigates constant envelope decoding in order to reduce the peak-to-average power ratio (PAPR) of the transmitted signals. As an indication that applications of massive MIMO reach beyond signal transmission and detection, the paper by T.-J. Lv, A.-Z. Hu, H. Gao, Z. Zhang, and S.-S. Yang shows how massive arrays can be exploited to perform 2-D source localization.

The use of large-scale MIMO in wireless networks is attracting more and more attention from researchers around the world. As a result, this special issue received more high-quality papers than were possible to accept. We would like to thank all

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