

## ABSTRACT

The upcoming 5G system is envisioned to cater the future data rate demands and user experience. Massive multiple-input multiple-output (MIMO) and small-cells have emerged as one of the key ingredients in the 5G and beyond communications. Massive MIMO uses large antenna systems to obtain spatial multiplexing which enhances both spectral efficiency (SE) and energy efficiency (EE). Small cells use cell densification for improved system capacity in an energy-efficient manner. Since both technologies are a paradigm shift from the conventional network, it introduces several new challenges to the research community.

In the first work, we concentrate on the channel state information (CSI) acquisition method for massive MIMO which is an important prerequisite to attain its large-scale benefits. Given the limited coherence interval availability and minimum pilot length constraint, we design a space-alternating generalized expectation maximization (SAGE) based semi-blind estimator for uplink (UL) time-division duplexing (TDD) based multi-user (MU) massive MIMO systems. It utilizes both pilot and a few data symbols for channel estimation through two stages, namely initialization and iterative SAGE (ISAGE). We obtain an initial channel estimate with the help of a pilot-aided method in the initialization stage. The acquired initial estimate is then iteratively updated by semi-blind based SAGE algorithm in the ISAGE stage. Through simulations, it is observed that the designed estimator obtains a considerable improvement over the pilot based schemes in terms of mean squared error (MSE), bit-error rate (BER), SE, and EE with a nominal increase in complexity and limited iterations. Besides, on average, it converges to the derived modified Cramer-Rao lower bound (MCRLB) in almost two iterations with large BS antennas and data length. Additionally, the tightness of the evaluated theoretical bounds on UL achievable rates are validated through simulation results.

The dense packing of small-cells over a given area experiences severe inter-cell interference and fierce competition for shared resources. In the second work, we address the resource allocation problem in an interference prone small-cell network under time-invariant and time-variant communication links. We formulate a decentralized state based potential game for the resource sharing problem to maximize users quality of experience (QoE). Additionally, we propose a low complex subgradient scheme for the joint optimization of spectrum allocation, power selection, and user scheduling to attain stationary state Nash equilibrium (NE) with limited iterations. Through extensive simulations, we show that the designed algorithm surpasses the existing schemes in terms of QoE, computational complexity, and convergence rate for stable resource allocations. Furthermore, it is robust and consistent under varied link loss models, link failure probabilities, and state transition rates. Besides, it

suffers relatively less performance degradation compared to the existing schemes while using imperfect CSIs.

Recently, researchers have harnessed highest SE and EE by combining massive MIMO and small-cell technologies. Therefore, in the third work, we implement the state based game approach to jointly optimize the channel, power, and number of activated antennas selections in massive MIMO small-cell networks while maximizing the QoE based objective function under link failure possibility. We propose a subgradient based distributed resource allocation algorithm for the formulated game to realize the stationary state NE with limited iterations. We also demonstrate that the proposed scheme using lesser SBS antennas outperforms the conventional methods employing the highest antenna structure in terms of QoE, computational complexity, and iterations needed for stable resource allocations. Through simulations, we note that the proposed algorithm is power efficient and suitable for massive MIMO small-cell networks under various practical impairments such as inaccurate CSI, pilot contamination, and link loss rates.

**Keywords:** Massive MIMO, semi-blind estimator, SAGE algorithm, pilot contamination, MCRLB, decentralized optimization, resource allocation, QoE, state based games, subgradient method, small-cell networks, user scheduling, massive MIMO small-cell networks.