ABSTRACT

Massive multiple-input multiple-output (MIMO) systems consist of a large number of antennas and Radio frequency (RF) chains, which increase circuit power consumption, complexity, and cost at the RF front-ends. The high-resolution analog-to-digital converters (ADCs) at the RF front end is one of the major contributors to power depletion. Thus, massive MIMO system with low-resolution ADCs at RF circuitry is seen as one of the potential solutions to reduce the power consumption and cost associated with the RF chains. However, the availability of accurate channel state information (CSI) at the base station (BS) remains a challenging task due to the quantization noise of finite-bit ADCs. Furthermore, pilot contamination in multi-cell scenarios degrades their performance to a large extent. The existing literature mostly employs pilot-aided channel estimator that demands additional pilots to improve the estimation accuracy, which in turn reduces the spectral efficiency (SE) of the system.

In this thesis, we propose an iterative semi-blind channel estimator for sub-6 GHz multi-user massive MIMO systems with low-resolution ADCs and evaluate its uplink performance. The proposed algorithm consists of two stages, namely, initialization and iteration. The initial channel estimate is obtained from the pilot based initialization stage, which is refined further in the iteration stage with the help of both pilot and a few data symbols. The inclusion of a few data symbols in the estimation process of the iteration stage enhances the CSI accuracy of the proposed scheme. In addition, the effect of pilot contamination and quantization on the estimate reduces with the increase in the data length. Thus, the proposed semi-blind estimator improves the estimation accuracy with the addition of a few data symbols in the CSI acquisition process and concurrently enhances the SE under a minimum pilot length constraint, unlike pilot based schemes. Also, we derive a theoretical lower bound on the uplink achievable rate under perfect and imperfect CSI using maximal ratio combining (MRC) and zero-forcing (ZF) receivers. Through simulations, we show that the proposed scheme achieves a significant improvement against the existing pilot based estimators in terms of estimation accuracy, bit-error rate (BER), SE, and energy efficiency (EE) at the cost of a nominal increase in the computational complexity. The proposed algorithm attains a convergence in at most two iterations for all the considered scenarios of a finite-bit massive MIMO system. Further, we demonstrate that the proposed scheme in a one-bit system achieves almost the same sum SE as that of a pilot-aided estimator in a conventional (i.e., infinite-resolution) massive MIMO system for lower values of signal-to-noise ratio (SNR). In addition, the sum SE and EE obtained by the designed semi-blind scheme of low-resolution (i.e., 3-4 bit) ADCs based massive MIMO system outperforms the sum SE and EE of conventional pilot-aided massive MIMO systems. Thus, the proposed semi-blind estimator is spectral and power efficient in comparison to the existing pilot based algorithms.

In addition to sub-6 GHz massive MIMO systems, millimeter wave (mmWave) MIMO systems need more number of antennas to compensate the huge path loss incurred in the communication due to its frequency spectrum. The requirement of one RF chain for each antenna in a fully digital architecture escalates the RF hardware complexity, cost, and circuit power consumption. In this context, a hybrid beamforming architecture with low resolution ADCs is seen to be a promising solution for energy efficient mmWave MIMO systems, where it requires less number of RF chains in comparison to the conventional mmWave MIMO systems. However, the channel estimation in hybrid millimeter wave MIMO systems with low-resolution ADCs remains a challenging task. In this thesis, we propose a group sparse Bayesian learning (SBL) algorithm for frequency selective wideband channel estimation in mmWave MIMO system equipped with hybrid architecture and finite-bit ADCs. By using Bussgang decomposition, we reformulate the non-linear channel estimation problem into a linear sparse signal recovery problem. The channel matrix is represented in terms of the beam space channel vector employing suitable transmit and receive array response dictionary matrices. The important features of the proposed scheme are that it exploits the group sparsity inherent in the equivalent beamspace mmWave MIMO channel vector and considers the effect of correlated noise in the channel estimation model. Through simulations, we demonstrate that the proposed SBL scheme achieves an improved performance compared to the existing orthogonal matching pursuit (OMP) based estimator. Also, the proposed estimator can significantly reduce the number of antenna and training overheads to achieve similar performance to the existing estimators.

Keywords: Massive MIMO, low-resolution ADCs, semi-blind channel estimator, pilot contamination, mmWave MIMO, hybrid architecture, Bussgang decomposition, sparse Bayesian learning, sparse channel estimator.

Boddupelly Srinivas