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Mehdi HAGHSHENAS – XXXVI Cycle

PASSIVE RECONFIGURABLE INTELLIGENT SURFACES: EFFICIENT CHANNEL ESTIMATION AND CODEBOOK DESIGN

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Abstract:

Reconfigurable intelligent surfaces (RIS) have been introduced to enhance the propagation environment by manipulating incoming electromagnetic waves. Comprised of a multitude of passive elements, RIS can modify the electromagnetic characteristics of the propagation environment based on their configuration. These enhancements include increasing the signal-to-noise ratio at the receiver, expanding cell coverage, and improving communication security. To realize these advantages, effective design of the elements' phase is crucial, necessitating knowledge of the channel characteristics. However, channel estimation becomes a challenging task in the presence of passive RIS. Passive RIS lacks active elements and, consequently, the processing capability to transmit/receive pilot symbols. Therefore, channel estimation must occur at the endpoints of the communication system, such as the base station. The substantial number of elements in RIS results in a large, complex, and demanding channel matrix that requires an extensive pilot length for accurate estimation. However, the use of extended training periods is often impractical. Hence, there is a pressing need for efficient channel estimation methods. This thesis proposes multiple solutions to efficiently estimate the channel while utilizing fewer pilot symbols compared to conventional methods like Least Squares. Initially, it is demonstrated that the RIS-related channel resides within a subspace with a dimensionality lower than the number of elements. Leveraging this insight, an iterative method is developed to generate bases for the channel space, optimizing the channel estimation phase. These bases are then utilized as RIS configurations during pilot transmission, allowing exploration of the subspace where the RIS-related channel is situated. A non-parametric estimation method called reduced-space least squares is introduced, which outperforms least squares in terms of training overhead. Additionally, the specific characteristics of the mmWave channel structure is exploited to design a novel parametric Maximum Likelihood Estimator (MLE). This MLE incorporates dynamic RIS configuration selection during the training phase, further reducing the pilot overhead. The proposed MLE supports the estimation of both near-field and far-field channels by using the general array response expression, instead of relying on a far-field approximation. To enhance the efficiency of the proposed MLE, two widebeam configurations for the RIS are introduced to be used during the initial two pilot symbols. This ensures that the first two pilots deliver valuable insights into the user's location. Finally, a tracking method based on the MLE is proposed, which effectively follows a mobile user and adjusts the RIS configuration according to the user's changing location.

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