

Master 2 Research Internship Proposal

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Laboratory: ETIS – CY Cergy Paris Université

Duration: 4 to 6 months

Title : Fundamental Connectivity Limits in Cell-Free Massive MIMO Uplink Systems: A Cramér–Rao Bound Analysis of Semi-Blind Channel Estimation

Project Description

Cell-Free Massive MIMO has emerged as a key architecture for beyond-5G and 6G networks, aiming at supporting massive uplink connectivity by serving a very large number of distributed users through a dense deployment of access points.

In such systems, the main limiting factor is no longer data rate, but the ability to reliably estimate the channels of all active users, especially under short pilot sequences and severe pilot reuse.

Conventional pilot-based channel estimation suffers from fundamental limitations due to pilot contamination and loss of identifiability when the number of users exceeds the pilot dimension. Semi-blind channel estimation, which jointly exploits pilot symbols and unknown data symbols, has the potential to overcome these limitations and significantly increase the number of connectable users.

This project focuses on a purely fundamental performance analysis, based on the Cramér–Rao Bound (CRB), in order to quantify how semi-blind channel estimation impacts the connectivity limits of Cell-Free Massive MIMO uplink systems.

Objectives

The main objective of this project is to:

- Characterize the fundamental limits of uplink connectivity in Cell-Free Massive MIMO systems using CRB analysis.
- Determine how semi-blind channel estimation increases the maximum number of users whose channels can be reliably estimated, compared to conventional pilot-based methods.
- Characterize identifiability and scalability regimes with respect to the system's parameters.

The study is conducted independently of any specific algorithm and focuses exclusively on information-theoretic performance bounds.

Ref :

- [1] A. El Housni, H. Wymeersch, and E. Björnson, "Distributed activity detection and channel estimation in cell-free massive MIMO," *IEEE Transactions on Wireless Communications*, vol. 21, no. 6, pp. 4033–4047, Jun. 2022.
- [2] A. Ladaycia, A. Mokraoui, K. Abed-Meraim, and A. Belouchrani, "Performance bounds analysis for semi-blind channel estimation in MIMO-OFDM communication systems," *IEEE Transactions on Wireless Communications*, vol. 16, no. 9, pp. 5925–5938, Sept. 2017.
- [3] S. Buzzi and C. D'Andrea, "Cell-free massive MIMO: User-centric approach," *IEEE Wireless Communications Letters*, vol. 6, no. 6, pp. 706–709, Dec. 2017.