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Joint Message Detection and Channel Estimation for Unsourced Random Access in Cell-Free User-Centric Wireless Networks

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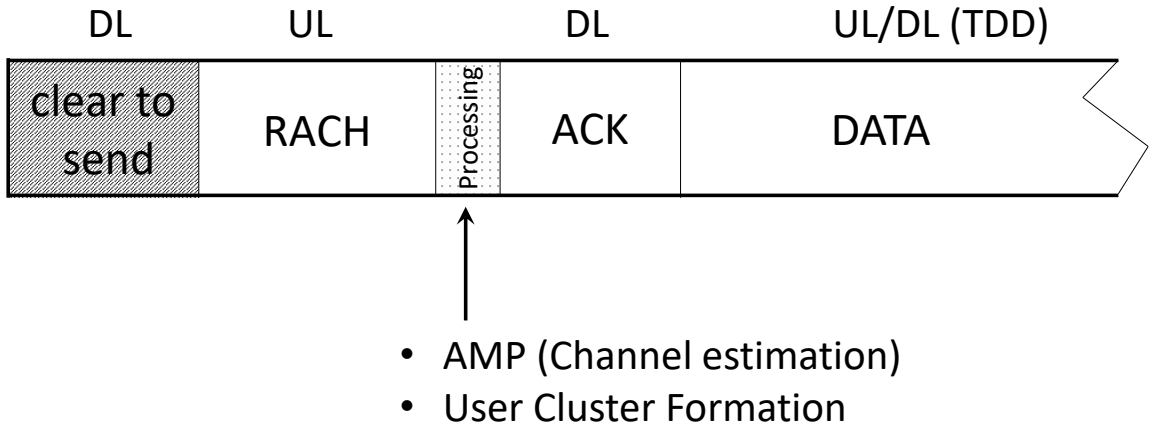
We consider the unsourced massive random access (uRA) for cell-free user-centric networks. We develop a new joint message detection and channel estimation algorithm based on Approximate Message Passing. A key question is whether such scheme can replace the complicated and slow user-centric cluster formation and pilot allocation, for systems that needs very low latency, sporadic activity, and seamless connectivity.



A conceptual illustration of a random access slot for a CF-mMIMO system. All RUs send simultaneously a ``clear to send'' signal. The users send messages from a common uRA codebook in the RACH slot. The AMP scheme detects the messages and estimates the corresponding channel vectors, and if required, respond with a DL packet and allocated traffic as in standard packet-reservation multiple access (PRMA).

KEY FINDINGS

An often ignored problem in CF-mMIMO networks is how to establish user-centric clusters and allocate UL pilots to the users. We propose a new scheme where users do not connect explicitly to any RU and the system does not allocate explicitly and permanently users to clusters of RUs. Every time a user has something to transmit in the UL (or requests something to be received in the DL), the user simply picks a codeword from a common uRA access codebook and sends it in a grant-free manner. The system uses a new AMP algorithm to jointly detect the messages and their channel vectors. Then, based on the channel vector estimates, the system can use decentralized maximal ratio transmission (or some other form of more sophisticated precoding) to transmit to the requesting users in the DL and possibly allocate more transmission resource in a PRMA fashion. We provide a novel rigorous large-system analysis of the AMP scheme which allows almost-closed form calculation of the message detection error probability and the channel estimation error. In this way, also closed forms for the achievable ergodic rate is obtained.

E. Gkiouzepi, B. Çakmak, M. Opper and G. Caire, "Joint Message Detection, Channel, and User Position Estimation for Unsourced Random Access in Cell-Free Networks," 2024 IEEE 25th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), Lucca, Italy, 2024, pp. 151-155