Cell-Free Massive MIMO Uplink Systems with Joint Maximum-Likelihood Detector for 6G Networks

Jeong Seon Yeom
Department of Electroncis Engineering
Chungnam National University
Daejoen, South Korea
Email: jsyem@cnu.ac.kr

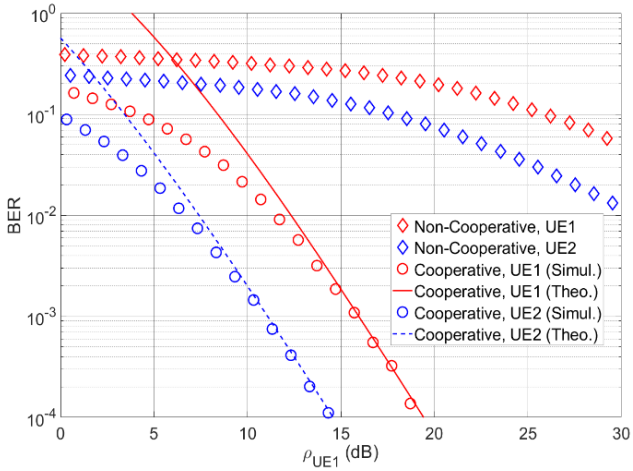
Bang Chul Jung
Department of Electroncis Engineering
Chungnam National University
Daejoen, South Korea
Email: bcjung@cnu.ac.kr

Abstract—Cell-free massive multiple-input multiple-output (CF-mMIMO) network is envisioned as one of key cellular network models in the sixth-generation (6G) wireless communication. Unlike a traditional cellular network in which a cell boundary around an access point (AP) exists, user equipments (UEs) are serviced from many APs without a cell boundary [1]. APs deliver (processed) received signals to a central processing unit (CPU) connected by backhaul, and then processing such as decoding and demodulation is *jointly* performed by the CPU from the collected signals. CF-mMIMO network structure can effectively reduce the deep fading effect and improve error performance by providing *macro diversity* due to multiple channels. However, there are challenging deployment issues such as AP deployment cost and complexity of CF-mMIMO system and network synchronization etc [2].

Many academic studies are being conducted to analyze the performance of the CF-mMIMO systems. In [3], [4], stochastic geometry approach is adopted to evaluate large scale network. In [5], [6], the spectral efficiency performance is analyzed. Practical network environment such as hardware impairment and limited backhaul capacity is considered [5].

However, studies related to error performance analysis are almost absent. There are some studies related to the outage probability [2], but no studies related to bit-error rate (BER) performance.

Therefore, we mathematically derive the closed-formed expression of BER of uplink CF-mMIMO system. For generality in this system, APs and UEs are deployed at an arbitrary location, and APs are equipped with an arbitrary number of antenna. We can observe the optimal BER performance of CF-mMIMO network, where entire processing is performed at central processing unit (CPU), i.e., “Level 4”, and a detection scheme is adopted as joint maximum likelihood detection. Through computer simulation, we verify that our mathematical analysis results are matched well with computer simulation results in the high signal-to-noise ratio regimes and this system can achieve the optimal diversity order.



Keywords—cell-free massive multiple-input multiple-output (CF-mMIMO), joint maximum likelihood (JML) detector, bit-error-rate (BER).

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