Towards 6G: From Large-Scale To Cell-Free MIMO Towards 6G

Abstract: Massive MIMO has become a key technology in 5G, with fully digital 64-antenna base stations now widely deployed. Rather than relying on more spectrum or power, it leverages spatial resources to improve efficiency. As we move toward 6G, MIMO systems are expected to scale further—either by dramatically increasing the number of antennas (such as in the Gigantic / Holographic / XL MIMO paradigms) or through joint coordinated processing of geographically distributed antenna systems (such as in the User-Centric Cell-free Massive MIMO paradigm). Achieving this vision demands scalable, low-complexity solutions that address computational and fronthaul constraints. This tutorial explores the fundamentals and future of extremely large-scale MIMO, beginning with a review of 5G Massive MIMO and its limitations. We then focus on Cell-Free Massive MIMO as a framework for studying scalability, introducing key architectures, signal processing techniques, and decentralized algorithms that enable efficient, large-scale deployments. The session highlights how these methods can pave the way for next-generation MIMO systems in 6G.