ABSTRACT

The evolution of wireless communication standards has led to new requirements and challenges. From the 1st generation standard, which only supported voice, the 2G, 3G, and subsequently 4G standards have brought support for high-speed data and associated range of applications. In next generation wireless standards like 5G and beyond, a host of new applications like massive machine-type communications, ultra-low-latency, densification of networks, etc., have been proposed. To implement these applications, we need to design wireless systems which provide high spectral efficiencies, support large bandwidths and have minimum power consumption, i.e., high energy efficiency. To realize these requirements, Multiple Input Multiple Output (MIMO) systems have been developed to enable multiplexing in the spatial domain for simultaneously serving multiple users. The performance of MIMO systems depends on the amount of spatial multiplexing gains it can provide, which depends on the application. The channel models supply the specifications of the application scenario. There are various channel models proposed, the most important of which is the 3GPP LTE advanced channel model defined for polarized full-dimensional MIMO systems operating in different real-world environments. To design MIMO systems and assess their performance, we need to know the degree of spatial multiplexing it can support. The knowledge of the spatial correlation matrices for the MIMO system is necessary for that purpose.

The first contribution in this thesis involves using the channel model parameters defined by 3GPP to develop an analytical formulation of the spatial correlation matrices at both transmitter and receiver. It is known that the analytical expression for the spatial correlation matrix ($\mathbf{R}_R/\mathbf{R}_T$) depends on the channel model parameters through the power angular spectrum (PAS). The PAS depends on the spatial parameters specified by the channel model. In this contribution, a model for the PAS has been analytically developed using the 3GPP channel parameters. This PAS model has been used to derive an analytical expression for the spatial correlation between any two pairs of antennas in the MIMO system. The advantage of deriving the spatial correlation matrices analytically is getting more profound insights into how the application scenario affects link-level BER and spectral efficiencies. Different operating scenarios demand different performance parameters, and hence, an analytical model for the MIMO channel becomes necessary.

In the previous contribution, an analytical model for the PAS was developed using the parameters provided by the 3GPP channel model. However, in practical cases, these parameters may not be available at the receiver and thus needs to be estimated. Hence, in the following contribution, the PAS parameters of the 3GPP channel model, like the mean angles of arrival/departure and cluster angular spreads, have been estimated. The estimation has been done iteratively by using the space alternating generalizee expectation maximization (SAGE)

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algorithm. The estimated PAS is used to recreate the spatial correlation matrix and compared to the actual spatial correlation matrix. It is also used to analyze the performance of a precoding scheme that explicitly uses the estimated spatial correlation matrix instead of the exact MIMO channel matrix at the transmitter.

While maximizing the performance of MIMO systems operating in real-world channels is essential, one has to ensure that the wireless systems support many users and the net power consumption of the wireless system is not very high. Hence, another essential requirement for 5G and beyond is the maximization of energy efficiency (EE), especially for futuristic technologies like non-orthogonal multiple access(NOMA) based Radio Access Networks (RAN). It is important to observe the energy efficiency behavior of a next-generation wireless system operating in a realistic environment specified by 3GPP channel models. Hence, in the final contribution of this thesis, the performance of an energy-efficient NOMA system has been compared for different channel environments specified by 3GPP. The energy efficiency has been maximized by iteratively allocating powers to the users. The SIC scheme for the NOMA system has been assumed to be imperfect. The NOMA system is equipped with a MIMO transmitter with Hybrid Precoding. The power allocation has been done by employing the fractional programming technique and some additional transformations. The scheme's performance has been compared under two different environments specified by 3GPP.

From the brief descriptions of the work items provided in this thesis, it can be said that this thesis offers techniques that will be of great importance in system design for 5G and beyond. It creates analytical models for the spatial correlation, which are beneficial in determining the design parameters for the MIMO transceivers. It also provides a technique for maximizing the energy efficiency of future technology like NOMA, a vital part of the 5G standard.

Keywords:MIMO, Uniform Planar Array, 3GPP, LTE, Channel Model, Spatial Correlation, Power Angular Spectrum, Gaussian, Laplacian, Mean Angles, Cluster Angular Spreads, BER, Spectral Efficiency, Maximum Likelihood, SAGE Algorithm, EM Algorithm, NOMA, Energy Efficiency, Fractional Programming

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