MIMO Wireless Propagation: Modern Channel Characterization for Emerging Applications

Michael A. Jensen
Department of Electrical and Computer Engineering
Brigham Young University
Provo, UT 84602, USA
jensen@byu.edu

The development of multiple-input multiple-output (MIMO) technology for wireless communication more than a decade ago spawned considerable research activity aimed at understanding new dimensions of multipath electromagnetic propagation. Specifically, this technology pushed the community to explore not only the temporal but also the spatial characteristics of multipath propagation, and as a result we now have a relatively complete understanding of these channel characteristics and the performance of point-to-point MIMO communication in realistic environments. This understanding is embodied in a significant collection of research literature on this topic.

While our understanding of the point-to-point MIMO channel is relatively mature as a result of these efforts, new applications of MIMO technology require that we obtain an even deeper appreciation of the nature of the propagation channels. In this talk, we discuss several examples of emerging applications that require new understanding regarding the propagation channel. The intent is to highlight new contributions and unanswered questions in these areas, demonstrating new areas of research open to those engaged in propagation modeling and channel characterization.

Multi-user MIMO Channels

Emerging networks not only use MIMO technology to increase the throughput of individual links but also to achieve spatial division multiple access (SDMA) using multi-user MIMO signaling. Assessing the performance achievable in such a scenario requires that we understand how the spatial characteristics of the different channels between users interrelate to one another. For example, if two users simultaneously communicate with the same node and are relatively close to one another, intuitively the spatial characteristics of their multipaths (complex gains, angles) have some commonality. However, looking at the eigenstructure of the channel matrices provides very little indication of commonality, as the singular vectors tend to change very rapidly with displacement. As a result, modern research focuses on capturing this similarity through exploration and modeling of the channel spatial covariance. We investigate this concept, illustrating how multi-user propagation characteristics impact network throughput performance.

Cooperative MIMO Signaling

The elevated position and sectored nature of the antennas at a base station leads to limited observed angular spread that makes it difficult to improve performance through spatial processing using multiple antennas. One potential solution to this problem involves using multiple base station sites working cooperatively, a solution that also potentially enables significant benefit in terms of interference control in multi-user signaling. We report on the analysis of fully-coherent measurements from three base station sites to a single mobile station in a macrocellular environment. The observed channels are used to explore the gains achieved with cooperative MIMO signaling to a single user and to multiple users. This analysis shows that cooperative MIMO signaling can provide multi-user throughput gains that are significantly higher than what can be achieved using more traditional multiple-access strategies under favorable channel conditions.

Physical Layer Security

Because of the inherent vulnerabilities associated with data communicated over a wireless channel, recent attention has focused on increasing wireless communication security at the physical layer. Specifically, while electromagnetic propagation is, strictly speaking, deterministic, from the perspective of an eavesdropper the multipath propagation between two legitimate nodes creates a transfer function that appears random. This principle can be used to allow establishment of secret keys between nodes based on

their reciprocal propagation characteristics. However, characterizing the performance of such systems depends on new understanding associated with multi-user MIMO channels. Furthermore, in real system implementation, the radio frequency hardware becomes an important part of the communication channel. Imperfections in this hardware lead to unique radio signatures that can be used to authenticate nodes desiring access to the network. In all of this physical layer security work, the use of MIMO technology significantly enhances the security performance.