What can we learn about 5G performance from clustered ray-based channel models?

Abstract

The fundamental behaviour of wireless channels and system performance has been exhaustively investigated under the assumption of classical statistical models such as Rayleigh and Ricean fading. In recent years, the growth of interest in massive MIMO and millimeter-wave bands for 5G has necessitated a rethink in our channel modelling. With large numbers of antennas the relationship between the channels at different antennas becomes far more important and physically motivated channel models capture this much better. Also, at higher frequencies the channels become sparser and it is harder to argue that the central limit applies delivering Gaussian channels. Hence, it is important to consider ray-based models in many 5G systems, where the channel is broken down by clusters of scatterers into a finite number of paths.

For a broad family of such ray-based channel models, we collate the results of several recent papers to describe some of the fundamental properties of 5G systems and the performance of specific processing types. In particular, we demonstrate that favorable propagation (FP), channel hardening (CH) and the SINR of several linear combiners (ZF, MRC and MMSE)can be investigated via two key analytical metrics: the interference power between two rays from different users and the interference power between two rays from the same cluster.

Using these interference powers we are able to prove the existence of FP and CH and to derive SINR approximations for linear processing methods. Key insights from this analysis include:

- Unlike Rayleigh channels, the total interference power dominates the signal power as the number of users grows;
- The performance of different antenna layouts is largely governed by the array size in the azimuth plane;
- Wider angle spread usually improves performance, but for linear arrays increased angle spread can actually reduce performance;
- Performance is insensitive to a range of typical angular parameters;
- Ray-based models for massive MIMO arrays create very large channel correlations in comparison to statistical model;
- The presence of common clusters (scatterers seen by multiple users) degrades system performance;
- Despite the fact that typical ray-based models contain dozens or hundreds of rays, aggregating these rays into an equivalent Gaussian channel does not provide a good approximation to ray-based performance.

Bio

Peter Smith (M’93–SM’01-F'15) received the B.Sc degree in Mathematics and the Ph.D degree in Statistics from the University of London, London, U.K., in 1983 and 1988, respectively. From 1983 to 1986 he was with the Telecommunications Laboratories at GEC Hirst Research Centre. From 1988 to 2001 he was a lecturer in statistics at Victoria University of Wellington, New Zealand. From 2001-2015 he worked in Electrical and Computer Engineering at the University of Canterbury. In 2015 he joined Victoria University of Wellington as Professor of Statistics. He is also an Adjunct Professor in Electrical and Computer Engineering at the University of Canterbury, New Zealand and an Honorary Professor in the School of Electronics, Electrical Engineering and Computer Science, Queens University Belfast. He was elected a Fellow of the IEEE in 2015 and in 2017 was awarded a

Distinguished Visiting Fellowship by the UK based Royal Academy of Engineering at Queens University Belfast. In 2018-2019 he was awarded Visiting Fellowships at the University of Bologna, the University of Bristol and the University of Melbourne. His research interests include the statistical aspects of design, modeling and analysis for communication systems, especially antenna arrays, MIMO, cognitive radio, massive MIMO and mmWave systems.