NCC'2010 Tutorial (Half-Day)

Low-Complexity Algorithms for Large-Dimension Wireless Communications

By

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Multi-dimensional signal spaces are often used to send information in modern communication systems; e.g., *i*) in multiple-input multiple-output (MIMO) systems, information is sent using space and time dimensions, *ii*) in MIMO-OFDM (MIMO orthogonal frequency division multiplexing) systems, space and frequency dimensions are exploited, and *iii*) in direct-sequence code division multiple access (DS-CDMA), data of each user is a point in N-dimension space, where N is the number of chips per bit.

This tutorial will focus on wireless communication problems, where data can be viewed as points in *high dimensional space*. Attractive benefits are possible if communication is carried out in high dimension spaces; e.g., *i*) increasing the number of spatial dimensions in MIMO systems (by increasing the number of transmit antennas) increases the MIMO channel capacity/spectral efficiency, *ii*) a severely delay spread inter-symbol interference (ISI) channel (i.e., large number of echoes of the transmitted signal in time dimension), as witnessed in ultra-wideband (UWB) systems, can provide the opportunity for achieving increased time-diversity, and *iii*) larger the value of N in DS-CDMA, larger can be the number of active users that can be supported.

The tutorial will address a key challenge in realizing the above-mentioned and other such benefits in large-dimension wireless communications, which is the *receiver complexity*. Optimal solutions to large-dimension problems need high complexities; e.g., complexity of optimum *signal detection* grows exponentially in the number of dimensions. We will present signal detection/equalization algorithms that achieve *near-optimal performance* in large dimensions *at practically affordable complexities* (e.g., polynomial/linear complexities in number of dimensions).

Interestingly, certain algorithms rooted in machine learning/artificial intelligence show increasingly closer to optimum performance for increasing number of dimensions – an effect we refer to as '*large-system effect*.' We will present four such *large-system effect algorithms* in this tutorial. Two algorithms based on local search heuristics, including a *likelihood ascent search (LAS)* algorithm and a *reactive tabu search (RTS)* algorithm, that achieve near maximum likelihood (ML) performance will be presented. We will also present two other algorithms, one based on *probabilistic data association (PDA)* and another based on *belief propagation (BP)* on Markov random field and factor graph representations. PDA and BP algorithms achieve near maximum a posteriori (MAP) performance for large number of dimensions. Results detailing the bit error performance and complexities of these algorithms (in comparison with other known detection algorithms including ZF, MMSE, ZF-SIC, and sphere decoding) will be presented, taking signal detection in large-MIMO systems having *tens of transmit antennas* and equalization in UWB systems with *tens to hundreds of delayed paths* as examples.

Speaker Biography

- **A. Chockalingam** received the B.E. (Honours) degree in Electronics and Communication Engineering from the P. S. G. College of Technology, Coimbatore, India, in 1984, the M.Tech. degree with specialization in satellite communications from the Indian Institute of Technology, Kharagpur, India, in 1985, and the Ph.D. degree in Electrical Communication Engineering (ECE) from the Indian Institute of Science (IISc), Bangalore, India, in 1993. During 1986 to 1993, he worked with the Transmission R & D division of the Indian Telephone Industries Limited, Bangalore. From December 1993 to May 1996, he was a Postdoctoral Fellow and an Assistant Project Scientist at the Department of Electrical and Computer Engineering, University of California, San Diego. From May 1996 to December 1998, he served Qualcomm, Inc., San Diego, CA, as a Staff Engineer/Manager in the systems engineering group. In December 1998, he joined the faculty of the Department of ECE, IISc, Bangalore, India, where he is a Professor, working in the area of wireless communications and networking.

  Dr. Chockalingam is a recipient of the Swarnajayanti Fellowship from the Department of Science and Technology, Government of India. He served as an Associate Editor of the IEEE Transactions on Vehicular Technology from May 2003 to April 2007. He currently serves as an Editor of the IEEE Transactions on Wireless Communications. He also served as a Guest Editor for the IEEE JSAC Special Issue on Multiuser Detection for Advanced Communication Systems and Networks. He is a Fellow of the Institute of Electronics and Telecommunication Engineers and a Fellow of the Indian National Academy of Engineering.