Iterative MIMO Detection for Large Wireless MIMO Systems

1 Research context

Since the early 2000's, multiple-input multiple-output orthogonal frequency-division multipexing (MIMO-OFDM) has been recognized as a key technology to support the physical layer of cellular and wireless local area networks. Large-scale MIMO systems help meet the increasing demands for higher spectral efficiency and improved quality of service. [11] [9]. The term *large* means MIMO systems with an order of magnitude more antennas than in currently deployed systems, say a few tens to a hundred antennas. MIMO networks pose new challenges, particularly on the receiver side: Channel parameter estimation, increased number of radio frequency (RF) chains, modeling of RF imperfections, calibration issues to ensure time-division duplex (TDD) reciprocity, fast, coherent and possibly distributed signal processing, detection of a high number of (complex) signals taking values in finite alphabets. The latter aspect is the main subject of this study. The research about detection for large-scale MIMO is a hot topic also because the term extends to many other problems where the dimensions become large: Total number of antennas in multiuser MIMO systems or distributed antenna systems, sensor nodes in wireless sensor networks, modes in optical fibers, etc.

2 Projet objective

In this project, we investigate iterative detection and decoding algorithms for large-scale MIMO systems. MIMO detection is a vast research area [13]. Probabilistic graphical models [7] and belief propagation (BP) [2, 8, 10] is the best approach as long as we are able to control the computation complexity. The increase in problem dimensionality lends itself naturally to complexity reduction approaches. While revisiting this issue, our motivation is twofold. Firstly, we would like to provide a unified view of many proposed algorithms, including recent ones, in terms of approximations of standard BP. Indeed, not all Authors in the community of iterative "turbo" receivers are familiar with this formalism and, even when they are, they do not always make the effort to express clearly the mathematical approximations they make to modify (and usually simplify) conventional best known instances of BP. Secondly, we are interested in finding new reduced-complexity instances of BP able to provide close to optimal performance in extreme situations like highly spectrally efficient, massively interfering, and/or severely overloaded systems, for which the subtle effects of simplifying approximations have dramatic consequences on the final performance. We propose several algorithms which are based on the following combined ideas: discrete-continuous space-space models arising from the forced Gaussian approximation of some variables in subgraphs as a new degree of freedom to exploit, clustering of nodes (functions and variables), setting up of multiple clusters corresponding to distinct approximate computation models for the same local computational problem, and fusion rules of messages emanating of variable nodes in clusters corresponding to distinct approximate computation models. The performance of the algorithms must be compared to other classes of algorithms, e.g., based on the principle of subspace detection by triangulation of the channel matrix (Choleski or QR) allowing the creation of different groups of symbols to be detected, without [3] or with overlaps [4] ; based on Markov chain Monte Carlo (MCMC) [5] methods ; or based on simplified, bounded complexity versions of the sphere decoding algorithm [1, 6, 12].

3 Work plan

The work consists in validating a new research path to improve iterative MIMO detection, which will require deepening knowledge of some mathematical and algorithmic methods seen in the course "Channel coding, graph codes and iterative decoding". Part of the project will focus on the implementation of algorithms. The applications of this research concern recent areas of 5G and 6G: massive multiaccess for IoT, massive MIMO, cooperative multicell processing, cell-free communication networks, etc.

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