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Editorial

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Traditional wireless technologies are confronted with new challenges in meeting the ubiquity and mobility requirements of cellular systems. Hostile channel characteristics and limited bandwidths in wireless applications provide key barriers that future generation systems must cope with. Advanced signal processing methods, such as

(i) the expectation-maximization (EM) algorithm,
(ii) the SAGE algorithm,
(iii) the Baum-Welch algorithm,
(iv) per-survivor processing,
(v) Kalman filters and their extensions,
(vi) hidden Markov modeling,
(vii) sequential Monte Carlo filters,
(viii) stochastic approximation algorithms,

in collaboration with inexpensive and rapid computing power provide a promising avenue for overcoming the limitations of current technologies. Applications of the advanced signal processing algorithms mentioned above include, but are not limited to, joint/blind/sequence detection, decoding, synchronization, equalization, as well as channel estimation techniques employed in advanced wireless communication systems, such as OFDM/OFDMA, space-time-frequency coding, MIMO, CDMA, and multiuser detection *in time- and frequency-selective MIMO channels*. In particular, the development of suitable algorithms for wireless multiple-access systems in nonstationary and interference-rich environments presents major challenges to the system designer. While considerable previous work has addressed many aspects of this problem separately, for example, single-user channel equalization, interference suppression for multiple-access channels, and tracking of time-varying channels, the problem of jointly combining these impairments in wireless channels has only recently become significant. On the other hand, the optimal solutions mostly cannot be implemented in practice because of their prohibitively high computational complexity. The statistical tools implemented by the advanced signal processing techniques above provide promising new routes for the design of low-complexity signal processing techniques with performance approaching the theoretical optimum for fast and reliable communication in the highly severe and dynamic wireless environment.

Although over the past decade such methods have been successfully applied in a variety of communication contexts, many technical challenges remain in emerging applications, whose solutions will provide the bridge between the theoretical potential of such techniques and their practical utility.

Key knowledge gaps here concern the following.

(i) Theoretical performance and convergence analyses of these algorithms.
(ii) New and efficient algorithms need to be developed for the problems mentioned above.
(iii) Computational complexity problems of these algorithms when applied to on-line implementations of some algorithms running in digital receivers must be handled.

(iv) Implementation of these algorithms based on batch processing and sequential (adaptive) processing depending on how the data are processed has not been completely solved for some of the techniques mentioned above.

(v) Although research on sequential Monte Carlo signal processing has only recently begun, many optimal signal processing problems found in wireless communications, such as mitigation of various types of radio-frequency interference, tracking of fading channels, resolving multipath channel dispersion, space-time processing, and exploiting coded signal structures, represent a few problems waiting to be solved under the powerful Monte Carlo signal processing framework.

The call for papers for this issue solicited papers describing state-of-the-art research in advanced signal processing algorithms, that is, methods and techniques specifically designed for the next-generation wireless communication systems. Except for the two invited papers, the papers that follow this editorial were selected on the basis of blind peer review. The papers selected cover several key research topics, and specifically, the following:

(i) EM algorithms and techniques,
(ii) sequential Monte Carlo methods,
(iii) iterative RLS techniques.

Four papers follow on the subject of EM algorithm applications. In the paper, "A receiver for differential space-time $\pi/2$-shifted BPSK modulation based on scalar-MSDD and the EM algorithm," Riediger et al. address the problem of blind detection of Alamouti-type differential *space-time* (ST) modulation in static Rayleigh fading channels. They apply an iterative *expectation-maximization* (EM) algorithm which performs joint channel estimation and sequence detection. To further increase receiver performance, this algorithm uses minimum mean square estimation to obtain channel estimates and the maximum likelihood principle to detect the transmitted sequence, followed by differential decoding. The next paper, "The extended-window channel estimator for iterative channel-and-symbol estimation" by Lopes and Barry, considers the application of the EM algorithm to channel estimation which results in a well-known iterative channel-and-symbol estimator (ICSE). But, since the EM-ICSE has high complexity, and it is prone to misconvergence, the authors propose a novel extended-window (EW) channel estimator for ICSE that can be used with any soft-output symbol estimator. Therefore, the symbol estimator may be chosen according to performance or complexity specifications. In the third paper, "Soft-in soft-output detection in the presence of parametric uncertainty via the Bayesian EM algorithm," Gallo and Vitetta investigate the application of the Bayesian expectation-maximization (BEM) technique to the design of soft-in soft-out (SISO) detection algorithms for wireless communication systems operating over channels affected by parametric uncertainty. In particular, the authors analyze the problems of SISO detection of spread-spectrum, single-carrier, and multicarrier space-time block-coded signals and show that BEM-based detectors perform close to the maximum-likelihood receivers under perfect channel state information as long as channel variations are not too fast. The last paper on EM algorithms entitled "A theoretical framework for soft-information-based synchronization in iterative (turbo) receivers," by Noels et al., is concerned with turbo synchronization by an EM algorithm. The algorithm makes use of soft-data information to estimate parameters like carrier phase, frequency, or timing offsets within a turbo receiver. In the paper, a general theoretical framework for turbo synchronization is provided, which enables the derivation of parameter estimation procedures for carrier phase and frequency offsets, timing offset, and channel gain.

Sequential Monte Carlo technique with applications to wireless communications is examined in the following two papers. In the first paper, "Adaptive blind multiuser detection over flat fast fading channels using particle filtering," Huang et al. propose a method for blind multiuser detection (MUD) in synchronous systems over flat and fast Rayleigh fading channels employing a low-complexity particle filtering and a mixture Kalman filtering technique. To describe the dynamics of the addressed multiuser system, they suggest a novel time-observation state-space model (TOSSM) by adopting an autoregressive-moving-average (ARMA) process to model the temporal correlation of the channels. They further propose to use a more efficient PF algorithm known as the stochastic M-algorithm. In the second paper, "Blind decoding of multiple description codes over OFDM systems via sequential Monte Carlo," the authors Z. Yang et al. develop a blind soft-input soft-output OFDM detector, which is based on the sequential Monte Carlo method. Multiple description scalar quantization (MDSQ) is applied first to the continuous source signal, resulting in two correlated source descriptions. The two descriptions are then OFDM modulated and transmitted through two parallel frequency-selective fading channels. At the receiver, a blind turbo receiver is developed for joint OFDM demodulation and MDSQ decoding. Transformation of the extrinsic information of the two descriptions is exchanged between each other to improve system performance. Finally, they also treat channel-coded systems and develop a novel blind turbo receiver for joint demodulation, channel decoding, and MDSQ source decoding.

The following two papers deal with efficient design of adaptive detectors and channel estimators based on the least mean square, the recursive least squares, and the low-complexity minimum mean square batch estimation techniques. The first paper, "Adaptive iterative soft-input soft-output parallel decision-feedback detectors for asynchronous coded DS-CDMA systems" by Zhang et al., employs adaptive algorithms in the SISO multiuser detector in order to avoid the need for a priori information which is essential for the optimum and many suboptimum iterative soft-input soft-output (SISO) multiuser detectors. After deriving the optimum SISO parallel decision-feedback detector for asynchronous coded DS-CDMA systems, they propose two adaptive versions of this SISO detector, which are based on the normalized least mean square (NLMS) and recursive least squares (RLS) algorithms which effectively exploit the a priori information of coded symbols, whose soft inputs are obtained from a bank of single-user decoders, to further improve their convergence performance. Furthermore, they consider how to select practical finite feedforward and feedback filter lengths to obtain a good tradeoff between the performance and computational complexity of the receiver. The second paper, entitled "A low-complexity KL expansion-based channel estimator for OFDM systems" by Şenol et al., proposes a computationally efficient, pilot-aided linear minimum mean square error (MMSE) batch channel estimation algorithm for OFDM systems in unknown wireless fading channels. The approach employs a convenient representation of the discrete multipath fading channel based on the Karhunen-Loeve (KL) orthogonal expansion and finds MMSE estimates of the uncorrelated KL series expansion coefficients. Based on such an expansion, no matrix inversion is required in the proposed MMSE estimator. Moreover, optimal rank reduction is achieved by exploiting the optimal truncation property of the KL expansion resulting in a smaller computational load on the estimation algorithm. The authors then consider the stochastic Cramér-Rao bound and derive a closed-form expression for the random KL coefficients and consequently exploit the performance of the MMSE channel estimator based on the evaluation of minimum Bayesian MSE. The effect of a modeling mismatch on the estimator performance is also analyzed.

The last six papers are concerned with the applications of general signal processing techniques on channel equalization, blind multiuser detection, direction-of-arrival estimation, and wideband CDMA systems. In the invited paper by H. Li and Poor, "Impact of channel estimation errors on multiuser detection via the replica method", system performance is obtained in the large system limit for optimal MUD, linear MUD, and turbo MUD, and is validated by numerical results for finite systems. The paper by Lu et al., entitled "Factor-graph-based soft self-iterative equalizer for multipath channels," considers factor-graph-based soft self-iterative equalization in wireless multipath channels. The performance of the considered self-iterative equalizer is analyzed in both single-antenna and multiple-antenna multipath channels. It is concluded that when factor graphs of multipath channels have no cycles or mild cycle conditions, the considered self-iterative equalizer can converge to optimum performance after a few iterations; but it may suffer local convergence in channels with severe cycle conditions. In the third paper, "Estimation of directions of arrival by matching pursuit (EDAMP)" by Karabulut et al., a novel system architecture is proposed that employs a matching pursuit-based basis selection algorithm for directions-of-arrival estimation. The proposed system does not require a priori knowledge of the number of angles to be resolved and uses a very small number of snapshots for convergence. The performance of the algorithm is not affected by correlation in the input signals. The algorithm is compared with well-known directions-of-arrival estimation methods with different branch-SNR levels, correlation levels, and different angle-of-arrival separations. The fourth paper by T. Li et al., "Blind multiuser detection for long-code CDMA systems with transmission-induced cyclostationarity," considers blind channel identification and signal separation in long-code CDMA systems. A long-code CDMA system is characterized using a time-invariant system model. Then a multistep linear prediction method is used to reduce the intersymbol interference introduced by multipath propagation, and channel estimation then follows by utilizing the nonconstant modulus precoding technique with or without the matrix-pencil approach. After channel estimation, equalization is carried out using a cyclic Wiener filter. Finally, since chip-level equalization is performed, the proposed approach can readily be extended to multirate cases, either with multicode or variable spreading factor. The fifth paper, "Adaptive space-time-spreading-assisted wideband CDMA systems communicating over dispersive Nakagami-*m* fading channels" by L.-L Yang and Hanzo, investigates the performance of wideband code-division multiple-access (W-CDMA) systems using space-time-spreading (STS)-based transmit diversity, when frequency-selective Nakagami-*m* fading channels, multiuser interference, and background noise are considered. The analysis and numerical results suggest that the achievable diversity order is the product of the frequency-selective diversity order and the transmit diversity order. Furthermore, both the transmit diversity and the frequency-selective diversity have the same order of importance. Taking several facts into account, an adaptive STS-based transmission scheme is then proposed for improving the throughput of W-CDMA systems. The numerical results demonstrate that this adaptive STS-based transmission scheme is capable of significantly improving the effective throughput and the bit rate of W-CDMA systems. The last paper, "Opportunistic carrier sensing for energy-efficient information retrieval in sensor networks," is an invited paper by Zhao and Tong which is concerned with sensor networks. The authors consider distributed information retrieval for sensor networks with cluster heads or mobile access points. A distributed opportunistic transmission protocol is proposed using a combination of carrier sensing and backoff strategy that incorporates channel state information of individual sensors.

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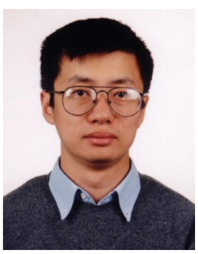

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