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Editorial

Signal Processing-Assisted Protocols and Algorithms for Cooperating Objects and Wireless Sensor Networks

Carles Antón-Haro,[1] Davide Dardari,[2] Osvaldo Simeone,[3] and Roberto Verdone[2]

[1] *Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Castelldefels, 08860 Barcelona, Spain*
[2] *WiLAB, the University of Bologna, 40136 Bologna, Italy*
[3] *Center for Wireless Communications and Signal Processing Research, New Jersey Institute of Technology (NJIT), Newark, NJ 07102, USA*

Correspondence should be addressed to Carles Antón-Haro, carles.anton@cttc.es

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With the advent of the so-called Internet of Things (IoTs), we will witness an unprecedented growth in the number of networked terminals and devices. In attaining this IoT vision, a class of energy- and, in general, resource-constrained systems like wireless sensor networks (WSNs), or networks of cooperating objects and embedded devices, are to play a pivotal role. However, the paradigm shift from general-purpose to application-oriented networks (e.g., for event detection, localization, parameter, or random field estimation) clearly calls for further optimization at the physical, link, and network layers. To that aim, some inspiration could be borrowed from other communication schemes, such as MIMO or cooperative communications, that were traditionally developed for wireless *data* networks. Besides, the above-mentioned estimation/detection/localization problems have been addressed for years by the signal processing community, this resulting into large number of well-known algorithms and solutions. However, the challenge now is to enhance such algorithms and make them suitable for decentralized and resource-constrained operation in large sensor networks. Complementarily, the vast literature produced by the information theory community reveals the theoretical performance limits of decentralized processing (e.g., distributed source coding), thus offering insights on the scalability properties and asymptotic behavior of such networks. Realizing the information-theoretic performance with practical decentralized networking, radio resource management schemes, routing protocols, and other network management paradigms is a key challenge, as well.

The objective of this special issue, the preparation of which was carried out under the auspices of the EC-funded Network of Excellence in Wireless Communications NEWCOM++, was to gather recent advances in the areas of cooperating objects, embedded devices, and wireless sensor networks. The emphasis was on how the design of future physical, link, and network layers could benefit from signal processing-oriented approaches. We received about 30 paper submissions by the deadline in February 2010. After extensive and careful reviews followed by the discussions at the editorial team level, we accepted 11 papers that, in our opinion, bear the highest quality and the best fit with the topic of this special issue. The accepted papers belong to three main research areas: cooperative localization and tracking, decentralized estimation and detection, and low-complexity and energy-saving communication and networking protocols.

The first group of papers report on recent advances in cooperative localization and tracking with sensor networks. Savic et al. focus on the problem of indoor positioning and propose to enhance the well-known nonparametric belief propagation (NBP) method with spanning trees (NBP-ST). The resulting scheme outperforms NBP in terms of accuracy and communication cost in highly connected networks at the expense of a slight increase in computational complexity and degraded performance in low connected networks. Also in a context of indoor positioning, Alvarez et al. investigate novel received signal strength-based (RSS-based) algorithms for an effective location of people and assets. The proposed schemes are experimentally evaluated in realistic deployment

scenarios comprising a number of ZigBee nodes. The variability of RSS measurements due to multipath propagation effects and non-line-of-sight conditions is partly mitigated by resorting to calibration and weighting techniques based on the difference between the free space field decay law and the measured RSS. In relation with this, the determination of the actual location of the sensor nodes in a network is a very relevant problem which is addressed by the third paper in this group. Fang et al. and Pang propose an innovative radio frequency-based localization algorithm, called Kcdlocation, which leverages on the knowledge of the geographical location of a limited number of anchor nodes. This scheme is suitable for wireless sensor networks, mostly for grid and linear topologies, deployed with a known coordinate database. Performance is mainly assessed in terms of positioning accuracy, scalability and fault tolerance.

The next group of papers revolve around the concepts of decentralized estimation and detection. Specifically, Matamoros and Antón-Haro study the problem of random field *estimation* in two scenarios of interest, namely, delay-constrained and delay-tolerant networks. They extensively analyze the distortion associated to a number of encoding schemes operating with and without side information at the decoder, find closed-form expressions of the optimal number of samples to be encoded in each timeslot, and identify a number of interesting distortion-buffer occupancy tradeoffs. The paper by Chaudhary and Vandendorpe, focuses on the design of adaptive power allocation schemes for decentralized parameter *estimation* with spatially correlated data and (possibly) imperfect channel state information. Here, the fusion center adopts a linear minimum mean-squared error criterion for the reconstruction distortion which turns out to be a convex function of the transmit powers. On that basis, the authors propose a novel design based on a successive approximation (the solution does not admit an analytical expression) of the LMMSE distortion, which turns out to be computationally efficient and exhibits excellent convergence properties. Next, we move on two more papers on decentralized *detection* with sensor networks. In their paper, Martalò and Ferrari address the problem of monitoring the *perimeter* of an area of interest in order to detect, for example, leakage of dangerous substances, which can be modeled as a one-dimensional edge detection problem. The authors derive the minimum mean square error detection rule at the fusion center (with or without noisy communication links) and then they propose a suboptimum detection algorithm with reduced computational complexity. Two cases of interest are addressed, namely, *analog*-like and 1-bit quantized sensor observations. Next, Martalò et al. analyze the impact of sensor *clustering* strategies on decentralized detection. In this scenario, local decisions made by the cluster-heads are followed by a (final) decision at the access point. The error decision probability, for which the authors derive an analytical expression, takes into account the effects of noisy communication links *and* packet collisions associated to the IEEE 802.15.4 MAC protocol.

Finally, we shift our attention on a number of papers more focused on communications and networking aspects. The work by Avram et al. deals with *low-complexity* cooperative transmission strategies suitable for their implementation in resource-constrained relays. More precisely, the authors propose a novel Quantize-and-Forward scheme in which the relay estimates and compensates for the rotation caused by the source-relay channel, before quantizing the phase of the received M-PSK data symbols. This does not significantly increase the complexity of the relay terminals but, interestingly, channel estimation at the destination is greatly simplified. Besides, the destination applies the Expectation-Maximization algorithm to improve the estimates of the source-destination and relay-destination channels. The emphasis in the paper by Campobello, Serrano et al. is the reduction of *energy consumption* in sensor networks. The starting point is a low-complexity packet splitting forwarding technique, based on the Chinese Remainder theorem, which was proposed by the authors in a previous work. The interest here lies on the investigation of a number of tradeoffs in terms of energy efficiency and reliability of the proposed forwarding scheme when duty-cycling techniques are considered. Kliks et al. study the problem of communicating over a distributed MIMO interference channel, which includes OFDM as a special case. Focusing on suboptimal power allocation and transmission strategies, where interference is treated as noise and time-sharing is allowed, the authors investigate game-theoretic concepts to achieve optimal rates via correlated equilibrium. A Vickrey-Clarke-Groves (VCG) mechanism design approach is then adopted to design cost functions that allow correlated equilibrium points to be achieved with some overhead information exchange among users. Finally, a self-learning algorithm based on regret-matching is proposed that converges to the solution points in the correlated equilibrium set in a distributed fashion. Last, but not least, García-Otero et al. investigate *security* aspects in geographic routing protocols for ad-hoc and sensor networks. By resorting to innovative localization techniques and isolation schemes, intruders can be accurately identified and positioned. This information, in combination with a distributed trust model, is then used in order to prevent a number of routing attacks. The proposed secure routing protocols have been implemented and experimentally evaluated on a real-world sensor network.

We would like to take this opportunity to thank the authors of all submitted papers (both those that were accepted and those that, regrettably, could not be included) for considering our special issue for disseminating their work. We are also very grateful to the numerous reviewers who refereed the manuscripts in a timely manner and provided valuable feedback to the authors: this definitely helped improve their quality. Moreover, we are indebted to authors and reviewers alike for the effort they put in keeping the deadlines set by editorial requirements. We would also like to thank the devoted staff of Hindawi for their high level of professionalism and valuable assistance through the entire editing process, and the Editor-in-Chief of the journal, Prof. Vandendorpe, for trusting us with this important assignment and helping us to fulfill it successfully. Last but not least, we thank the members of NEWCOM++ for their collaboration in submitting high-quality papers to this special issue.

Given the vast amount of research that is being carried out worldwide in the field of wireless sensor networks, we are well aware that this special issue can be no more than a sample of recent progress. Nevertheless, we hope that you will enjoy reading it as much as we did putting it together.

Carles Antón-Haro
Davide Dardari
Osvaldo Simeone
Roberto Verdone