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Editorial

Distributed Signal Processing Techniques for Wireless Sensor Networks

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Recent advances in micro-electromechanical systems (MEMSs) technology have enabled the design of low-power low-cost smart sensors equipped with multiple onboard functions such as sensing, computing, and communications. Such intelligent devices networked through wireless links have been referred to as wireless sensor networks and recognized as one of the most important technologies for the 21st century. Wireless sensor networks hold the promise to revolutionize the sensing technology for a broad spectrum of applications, including infrastructure monitoring and surveillance, disaster management, monitoring the health status of humans, plants, animals, and industrial machines, and so forth.

Wireless sensor networks can be viewed as a special case of wireless ad hoc networks, and assume a multihop communication framework with no centralized infrastructure and where the sensors cooperate spontaneously by forwarding each other's packets for delivery from a source to a destination node. The multihop nature of sensor networks is imposed by energy-consumption reasons because of the superlinear power loss of wireless transmissions with respect to the propagation distance.

In general, the design of wireless sensor networks is subjected to a number of challenges: low energy consumption which is manifested in minimal energy expenditure in each sensor node and efficient usage of power-saving sleep/wake-up modes, scalability in the presence of a large number of sensors, possibility of frequent node failures and network topology changes, collaborative signal processing and data aggregation techniques to cope with the large number of sensors which might congest the network with information, and efficient communication protocols to deal with the special broadcast communication paradigm and the increased possibility of packet collisions and congestions for nodes operating in closely spaced transmission ranges.

The goal of this special issue is to present the state of the art and emerging distributed signal processing techniques that deal with some of the above-mentioned design challenges. This special issue consists of seven papers that treat important signal processing aspects such as compression, quantization, estimation, detection, synchronization, and localization in wireless sensor networks. A short description of the contributions brought by these papers is next presented.

In the paper "Energy-constrained optimal quantization for wireless sensor networks," X. Luo and G. B. Giannakis deal with the important problem of designing efficient quantizers that ensure optimal reconstruction at the fusion center of the measurements yielded by a sensor as well as the estimation of a deterministic parameter by exploiting the measurements collected by a set of sensors. The design is carried out under power constraints and information such as channel propagation effects, modulation, and energy consumed by transceiver circuitry is considered into the analysis. The effect of channel coding on the reconstruction performance is also studied, and the optimum number of quantization bits and energy levels are derived.

The problem of designing an optimal-level distributed transform for wavelet-based spatiotemporal data compression in wireless sensor networks is addressed by S. Zhou et al. in the paper "Ring-based optimal-level distributed wavelet transform with arbitrary filter length for wireless sensor networks." This paper proposes a distributed optimal-level spatiotemporal compression algorithm based on the ring model for general wavelets with arbitrary supports. The proposed compression algorithm accommodates a broad range of wavelet functions, effectively exploits the temporal and spatial correlation of data measurements, and achieves significant reduction in energy consumption and delay for data gathering in sensor clusters.

In "Distortion-rate bounds for distributed estimation using wireless sensor networks," D. Schizas et al. address the problem of centralized and distributed rate-constrained estimation of random signal vectors by exploiting a network of wireless sensors (encoders) that communicate with a fusion center (decoder). Within the proposed framework, the authors determine lower and upper bounds on the corresponding distortion-rate function using both centralized as well as distributed estimation techniques.

The paper "Distributed event region detection in wireless sensor networks," coauthored by J. Fang and H. Li, proposes a graph-based method for distributed event-region detection in wireless sensor networks. The proposed detection scheme exploits a graphical model to take into account the fact that events occurring in geographically neighboring sensors present a statistical dependency. This scheme also admits energy and bandwidth efficient distributed implementations.

Q. Chaudhari and E. Serpedin, in the paper "Clock estimation for long-term synchronization in wireless sensor networks with exponential delays," deal with the maximum likelihood estimation of the clock parameters (phase, skew, and drift) in two-way timing exchange mechanisms and in networks with exponentially distributed delays. The paper entitled "Extension of pairwise broadcast clock synchronization for multicluster sensor networks," coauthored by K. L. Noh et al., proposes a novel clock synchronization protocol to minimize the overall energy consumption in wireless sensor networks that assume general multicluster topologies. The proposed synchronization approach relies on a receiver-only synchronization approach and it can be viewed as a generalization of the pairwise broadcast synchronization (PBS) protocol. Like PBS, the proposed synchronization approach exhibits the distinct advantage that the number of sensor nodes can be synchronized by only over-hearing time message exchanges between pairs of nodes, and therefore it reduces significantly the overall network-wide energy consumption by decreasing the number of required timing messages for synchronization.

Finally, in "Optimization of sensor locations and sensitivity analysis for engine health monitoring using minimum interference algorithms," P. Cotae et al. address the problem of optimal placement of sensors in the presence of additive white Gaussian noise (AWGN) by considering the sensors as systems that present full communications capabilities and by minimizing the RF-interference induced by the wireless communication channels among the sensor nodes. Numerical simulations and a sensitivity analysis study are presented to illustrate the robustness of the proposed algorithm.

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