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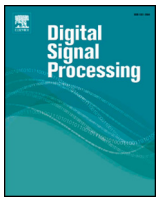

Editorial

Guest editorial for signal processing aspects of molecular communications

Molecular communication is the most widespread communication mechanism on the Earth since it is fundamental for all living entities from unicellular organisms to multicellular animals and plants to maintain their vital functionalities. For example, many unicellular organisms sense and react to molecular signals from their surroundings to control their life cycles. Some signaling molecules called pheromone are also extensively employed by a variety of insects to send and receive information to coordinate colony activities. Moreover, in the neuronal system, signaling molecules known as neurotransmitters are used in junction points of neuron cells to carry out many mental activities. In addition to the various molecular communication mechanisms in nature, the recent advances in nano- and biotechnology have shown that molecular communication is one of the most favorable choices to enable the interconnection of nanomachines such as engineered cells and bionanorobots. The network of such nanomachines, i.e., nanonetwork, is considered to make frontier biomedical applications a reality. In these applications, molecular communication can enable the nanomachines to share information so as to provide reliability and controllability. Furthermore, this can also allow different nanomachine populations to be coordinated to reach highly sophisticated behavior and increase the number of design possibilities.

The molecular communication literature is relatively new, but quickly spreading. Most of the articles in this literature have been investigating what the rate of molecular communication is and introducing a diverse set of communication methods to improve this rate. However, the investigation of how molecular signals are modeled and processed is also essential to figure out many natural phenomena such as molecular information processing in a synapsis and to design efficient molecular communication and computing systems. The main motivation behind this special issue was to reveal the signal processing aspects of molecular communication through review articles and technical contributions. At the end of the review process of the special issue, eight novel papers have been evaluated and accepted for publication. Four of those papers are review-type articles while the others focus on various technical contributions. In the following part of the editorial, the papers are briefly discussed in the running-order of the issue.

One of the hottest topics in signal processing is the detection and estimation theories and applications. The first review-type article in the issue is titled by “A Survey on Estimation Schemes in Molecular Communications” and presents a comprehensive survey on the parameter estimation and channel estimation methods. More specifically, the distance, diffusion coefficient and flow velocity estimation schemes are reviewed and the channel impulse response estimation methods are discussed by examining the impact of the noise on the estimation performance.

Besides diffusion of information-carrying molecules, chemical reactions among different molecular species in a molecular communication scenario need to be investigated to understand the dynamics of a molecular communication channel. In the second survey paper titled by “Stochastic Reaction and Diffusion Systems in Molecular Communications: Recent Results and Open Problems”, the authors review a general family of stochastic models of reaction and diffusion systems based on which modulation and detection schemes can be developed for molecular communication. The implementations of these detection schemes and related parameter estimation problems via stochastic molecular circuits are also discussed.

In molecular communication, very-low signal propagation velocity and severe inter-symbol interference restricts reliable and high data-rate communications. Therefore, most of the molecular communication literature is constituted by the articles focusing on performance enhancement strategies. In the third survey paper of the issue titled by “Towards High Data-Rate Diffusive Molecular Communications: A Review on Performance Enhancement Strategies”, an important set of such articles is reviewed and key research directions are highlighted in conjunction with important parameter estimation, synchronization and coding approaches. Furthermore, transceiver designs are discussed with an emphasis on methods for ISI mitigation and performance-complexity tradeoffs.

In molecular communication, it is important how the receiver decodes the transmitted information. In the last review-type article of the issue titled by “Implementation Issues of Diffusion-based Molecular Communications Receivers based on Transcriptional Elements”, the previously proposed reception models together with a number of signal processing techniques needed to detect and decode received signals are surveyed. As detailed in this survey paper, one of the most promising methods in the reception is based on receptor molecules on the surface of the receiver. This method is mostly inspired by the nature-made ligand-receptor binding phenomenon based on which all living cells can receive molecular information sent by other cells. The molecular communication with the ligand-receptor binding requires special attention to model and quantify the performance. In another paper of the issue titled by “Detection in Molecular Communications with Ligand Receptors under Molecular Interference”, the authors focus on the detection problem for biological molecular communication receivers employing ligand receptors to infer the transmitted messages encoded into the concentration of molecules, i.e., ligands. Regarding the reception process, the filter design is also essential for a re-

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ceiver in detection of a molecular signal. In another paper of the issue titled by "Low Complexity Receiver Design for Time-Varying Poisson Molecular Communication Channels with Memory", novel approaches for the design of the linear filter and the detection algorithms are introduced for advection diffusion-based molecular communication systems affected by inter-symbol interference.

As in the traditional communication systems, estimation of node location is also one of the most important challenges in molecular communication scenarios. In order to address such a location problem, in another paper of the issue titled by "Multiple Transmitter Localization via Single Receiver in 3-D Molecular Communication via Diffusion", the authors present a solution for localizing multiple point transmitters of molecules in a 3-D medium. In order to localize multiple point transmitters, coordinates where the molecules are absorbed on the receiver's surface are clustered and using the average coordinate values of the clusters, direction-of-arrival (DoA) for each cluster is also estimated.

In the molecular communication literature, the main metrics used to assess the performance of MC systems focus on maximizing the achievable channel capacity, observed delays, and the resulting symbol and packet error probability. In addition to those existing metrics, the achievable freshness of information is introduced for the first time by another paper of the issue titled by "Age of Information in Molecular Communication Channels". The authors argue that such a metric becomes particularly important when considering the cooperation of nanomachines to overcome their limited resources. They suggest using the concept of age of information (AoI) to quantify the achievable freshness of information. This also allows analyzing the trade-off between an increased rate of transmission and the imposed inter-symbol interference.

Finally, as the guest editors of the special issue, we would like to thank all of the issue authors for their valuable contributions through eight novel papers. We hope that those papers can draw attention in the signal processing society and lead to new breakthroughs on the signal processing aspects of molecular communications.

Barış Atakan
İzmir Institute of Technology, Turkey

Sebastià Galmés
University of Balearic Islands, Spain

Werner Haselmayr
Johannes Kepler University, Austria

Nariman Farsad
Ryerson University, Canada

Tadashi Nakano
Osaka University, Japan