Guest Editorial Introduction to the Special Feature on the 7th Workshop on Molecular Communications

I. Introduction

MOLECULAR Communication (MC) is a highly interdisciplinary research field whose success requires the close collaboration between researchers from different fields of science. To support and highlight this interdisciplinary character, the Workshop on Molecular Communications (MolCom; https://molecularcommunications.org/) has been held annually since 2016 to provide the opportunity to meet, and share work and experience. The Workshop tries to promote research beyond the conventional disciplinary boundaries between engineering, the physical sciences, natural sciences, and medicine.

Initially, MolCom was supported by the European Commission project "Coordinating European Research on Molecular Communications" (2015–2017; https://cordis.europa.eu/project/id/665564), which was coordinated by the Waterford Institute of Technology (now the South East Technological University) in Waterford, Ireland. After completion of the project, management of MolCom has been maintained by an independent Steering Committee, and as of 2022 has an informal agreement for on-going endorsement by the Technical Committee on Molecular, Biological and Multi-Scale Communications of the IEEE Communications Society (MBMC-TC; https://mbmc.committees.comsoc.org/).

The 7th Workshop on Molecular Communications was held at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany, in April 2023. The Workshop featured presentations from the letter and abstract authors, two keynotes, a tutorial, brainstorming sessions, and a panel discussion. To further highlight the interdisciplinary character of the research field, we organized a spotlight talk session with four presentations given by researchers from chemistry, pharmacy, and technology. Moreover, the Workshop featured a testbed-presentation session where 9 experimental molecular communication testbeds were presented. The 2023 MolCom Workshop received 24 letter and abstract submissions, which is more than twice as many as for the 2022 MolCom Workshop, indicating the increased interest in the field. Finally, we had the pleasure to welcome about 40 attendees from 11 countries and from 23 different universities and companies in Erlangen. On behalf of the MolCom Steering Committee, we are very pleased about the positive and successful development of the Workshop and we look forward to the 2024 MolCom Workshop, which will be held at the Oslo University Hospital (OUH), Oslo, Norway in April 2024 (for details, see https://molecularcommunications.org/molcom2024/call-for-papers/).

To recognize the author contributions, the MolCom Steering Committee regularly arranges a Special Issue in IEEE Transactions on Molecular, Biological and Multi-Scale Communications (T-MBMC) for the Workshop letter submissions. The submitted letters go through a more rigorous peer review process and those accepted for presentation at the Workshop can then be submitted in revised form to T-MBMC. The Special Feature of the 2022 MolCom Workshop was published in March 2023 and featured four letters from the Workshop authors (https://doi.org/10.1109/TMBMC.2023.3244020).

In this Special Feature, we are pleased to present 7 letters that were accepted for presentation at the 7th Workshop on Molecular Communications (MolCom2023). These letters have been subsequently revised and accepted for publication in T-MBMC. We are grateful for the strong support of the TMBMC Editor-in-Chief, Prof. Sasitharan Balasubramaniam, to host this Special Feature and for his commitment to continue to publish letters from future iterations of the Workshop. We are also thankful to the article authors for sharing their valuable contributions with us.

II. Summary of Papers

The topics of the papers in this T-MBMC Special Feature for the 2023 MolCom Workshop cover three broad molecular communication (MC) research themes of fundamental MC, application of MC, and MC testbeds.

In [A1], Broghammer et al. study the problem of distance estimation between the source of a diffusive process and a receiver. The Cramér-Rao lower bound (CRB) is derived given the advection-diffusion model and three estimators, namely a maximum-likelihood estimator and two low-complexity estimators, are developed. The performance of these estimators is evaluated against the CRB using numerical simulations. Furthermore, preliminary experimental results are presented.

In [A2], Emirdagi et al. propose a new multiplexing scheme for MC based on the diversity of ligand-receptor binding affinities. This method requires only a single type of promiscuous receptor on the receiver side, capable of interacting with multiple ligand types. The mean bit error probability (BEP) averaged over all multiplexed MC channels is derived analytically and the impact of the system parameters on the BEP performance is investigated via simulations.

In [A3], Gómez et al. investigate the explainability of neural networks (NNs) for symbol detection in MC channels. Based

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on MC channel models and testbed measurements, synthesized data is generated to train an NN model for the detection of binary transmissions in MC channels. Using the local interpretable model-agnostic explanation method and the individual conditional expectation, this paper demonstrates the analogy between the trained NN and the standard peak and slope detectors.

In [A4], Ruzzante et al. study MC in plants where the primary transport route for cell-to-cell communication are Plasmodesmata (PDs), porelike structures dotting the plant cell wall. The PDs opening state is influenced by several environmental damaging factors (i.e., plant viruses), and plant cells try to restore homeostasis through defense mechanisms. This paper depicts the complexity of plant-based MC and proposes a simple model that reveals the influence of the number and opening state of PDs in the transport of information in plants.

In [A5], Thalmayer et al. study the impact of passive obstacles placed in tube-shaped MC channels for the reduction of inter-symbol interference. These obstacles decelerate the fastest particles while at the same time accelerating slower particles. Numerical investigations reveal that passive decelerators can significantly reduce the dispersion of MC channels.

In [A6], Sajan et al. present a novel design of a silicon photonics (SiPh) nanobiosensor for the detection of cancer cells. This sensor employs a micro-ring resonator structure and takes advantage of the distinct optical characteristics of various cancer cells and the interaction between cancer cells and CD47 proteins.

In [A7], Gulec and Eckford propose a stochastic biofilm disruption model based on the usage of quorum sensing (QS) mimickers. A chemical reaction network (CRN) involving four different states is employed to model the biological processes during the biofilm formation and its disruption via QS mimickers. In addition, a state-based stochastic simulation algorithm is proposed to simulate this CRN. The model proposed in this paper is validated by the in vitro experimental results of Pseudomonas aeruginosa biofilm and its disruption by rosmarinic acid as the QS mimicker.

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Moreover, for their support and contribution, we also would like to thank all other members of the MolCom Workshop Steering Committee, including Michael Taynnan Barros (University of Essex, U.K.), Mauro Femminella (University of Perugia, Italy), Werner Haselmayr, (Johannes Kepler University Linz, Austria), Jari Hyttinen (Tampere University, Finland), Kerstin Lenk (Graz University of Technology, Austria), Lin Lin (Tongji University, Shanghai, China), Richard Morris (John Innes Centre, U.K.), and Adam Noel (University of Warwick, U.K.).

APPENDIX: RELATED ARTICLES

[A1] F. Broghammer, S. Zhang, T. Wiedemann, and P. A. Hoeher, "Distance estimation from a diffusive process: Theoretical limits and experimental results," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 3, pp. 312–317, Sep. 2023.

[A2] A. R. Emirdagi, M. S. Kopuzlu, M. O. Araz, and M. Kuscu, "Affinity-division multiplexing for molecular communications with promiscuous ligand receptors," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 3, pp. 318–322, Sep. 2023.

[A3] J. T. Gómez, P. Hofmann, F. H. P. Fitzek, and F. Dressler, "Explainability of neural networks for symbol detection in molecular communication channels," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 3, pp. 323–328, Sep. 2023.

[A4] B. Ruzzante, A. Piscopo, S. Salo, M. Magarini, and G. Candiani, "The influence of plasmodesmata number and opening state on molecular transports in plants," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 3, pp. 329–333, Sep. 2023.

[A5] A. S. Thalmayer, A. Ladebeck, S. Zeising, and G. Fischer, "Reducing dispersion in molecular communications by placing decelerators in the propagation channel," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 3, pp. 334–339, Sep. 2023.

[A6] A. C. Sajan, A. Singh , P. K. Sharma, and S. Kumar, "Si_3N_4-SiO_2 based silicon photonics nano-biosensor for molecular communication," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 3, pp. 340–345, Sep. 2023.

[A7] F. Gulec and A. W. Eckford, "A stochastic biofilm disruption model based on quorum sensing mimickers," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 3, pp. 346–350, Sep. 2023.

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Robert Schober (Fellow, IEEE) received the Diplom (Univ.) and Ph.D. degrees in electrical engineering from the Friedrich-Alexander University of Erlangen-Nuremberg (FAU), Germany, in 1997 and 2000, respectively. From 2002 to 2011, he was a Professor and a Canada Research Chair with the University of British Columbia (UBC), Vancouver, Canada. Since January 2012, he has been an Alexander von Humboldt Professor and the Chair of Digital Communication with FAU. His research interests fall into the broad areas of communication theory, wireless and molecular communications, and statistical signal processing. He received several awards for his work, including the Heinz Maier-Leibnitz Award of the German Science Foundation in 2002, the Innovations Award of the Vodafone Foundation for Research in Mobile Communications in 2004, a 2006 UBC Killam Research Prize, the Wilhelm Friedrich Bessel Research Award of the Alexander von Humboldt Foundation in 2007, the Charles McDowell Award for Excellence in Research from UBC in 2008, Alexander von Humboldt Professorship in 2011, a NSERC E.W.R. Stacie Fellowship in 2012, the Wireless Communications Recognition Award by the IEEE Wireless Communications Technical Committee in 2017, and the IEEE Vehicular Technology Society Stuart F. Meyer Memorial Award in 2022. Furthermore, he received numerous Best Paper Awards for his work, including the 2022 ComSoc Stephen O. Rice Prize and the 2023 ComSoc Leonard G. Abraham Prize. He served as the Editor-in-Chief of the IEEE TRANSACTIONS ON COMMUNICATIONS, VP Publications of the IEEE Communication Society (ComSoc), a ComSoc Member at Large, and ComSoc Treasurer. He currently serves as a Senior Editor of the Proceedings of the IEEE and as ComSoc President-Elect. Since 2017, he has been listed as a Highly Cited Researcher by the Web of Science. He is a Fellow of the Canadian Academy of Engineering and the Engineering Institute of Canada and a member of the German National Academy of Science and Engineering.