

Guest Editorial

Introduction to the Special Feature on the 6th Workshop on Molecular Communications

I. INTRODUCTION

THE Workshop on Molecular Communications (MolCom; <https://molecularcommunications.org>) has been held annually since 2016 to provide the molecular communication research community an opportunity to meet and share their work, vision, and experience in the field. Given the interdisciplinary nature of molecular communication, the Workshop promotes research beyond the conventional disciplinary boundaries between engineering, the physical sciences, natural sciences, and medicine.

MolCom was initially 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 disruption caused by the global COVID-19 pandemic included the 2020 and 2021 MolCom Workshops. While the 2021 MolCom Workshop was virtual and featured a series of invited talks, the 2020 MolCom Workshop had completed the peer review process before it was cancelled. To recognize the author contributions, the Steering Committee arranged a Special Issue in IEEE TRANSACTIONS ON MOLECULAR, BIOLOGICAL AND MULTI-SCALE COMMUNICATIONS (T-MBMC) for abstracts extended to letters. With the strong support of the previous Editor-in-Chief, Prof. Chan-Byoung Chae, the Special Issue was published in June 2021 and featured 8 letters from Workshop authors (<https://doi.org/10.1109/TMBMC.2021.3089341>).

Based on the success of the 2021 Special Issue, the MolCom Steering Committee decided to overhaul how it invites submissions. To encourage researchers to share their works-in-progress while also providing opportunity for publication, the MolCom Workshop now invites authors to submit either 2-page abstracts to post on the Workshop Website (<https://molecularcommunications.org/>) or 4-page letters for possible publication in T-MBMC. 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.

In this Special Feature, we are pleased to present the 4 letters that were accepted for presentation at the 6th Workshop on Molecular Communications (2022 MolCom Workshop). These letters have been subsequently revised and accepted for publication in T-MBMC. The 2022 MolCom Workshop was held at the University of Warwick in Coventry, U.K., in July 2022. The Workshop featured presentations from the letter authors, in addition to the presentation of 6 abstracts, 2 keynotes, a tutorial, an ethics discussion, and brainstorming ideation sessions. Recordings of many of the sessions are available to watch on the MBMC-TC YouTube channel https://www.youtube.com/playlist?list=PLZHMypeqCkO9uVC4Zsc5MZE_QEUBHI2Kg.

II. OVERVIEW OF ACCEPTED ARTICLES

The topics of the papers in this T-MBMC Special Feature for the 2022 MolCom Workshop are very diverse. They cover the three broad MC research themes of fundamental MC, application of MC, and MC testbeds.

In [A1], Rudsari et al. investigate anomalous diffusion of extracellular vesicles (EV) in a cardiac extracellular matrix (ECM). Partial differential equations are used to model anomalous diffusion, considering EV degradation and unique properties of the ECM, and an analytical solution is provided using Green’s function theorem. Through numerical results, the authors showed the impact of different parameters (e.g., anomalous diffusion type, EV degradation) on the EV biodistribution.

In [A2], Bhattacharjee et al. present an air-based macroscopic MC testbed using a highlighter-ink water-based solution as information carrier. The testbed uses a pressure sprayer, a 2m long tube, and PIN photodiode as transmitter, transmission channel, and receiver, respectively. The authors showed that the system can achieve 50bit/s with just simple on-off keying. This improves the bit rate of a testbed formerly introduced by the authors that uses multiple information carriers, higher order modulation, and camera-based detection.

In [A3], Vakiliipoor et al. introduce a method to estimate the position of an unknown fully-absorbing (FA) receiver in a diffusive MC system. To this end, molecules are instantaneously released by a point transmitter and, based on the number of

molecules captured by the known FA receivers, different likelihood maps are obtained. Each likelihood map corresponds to the position of the unknown receiver from a specific known receiver's perspective. Finally, the likelihood maps of the individual receivers are combined to cooperatively estimate the position of the unknown receiver.

In [A4], Ruzzante et al. introduce the concept of semantic information for molecular communication systems. The Kolchinsky-Wolpert (KW) model is introduced, which defines a quantitative measure of semantic information received by any physical system influenced by an external environment. This measure is applied to a smart drug delivery system, using synthetic cells (SC) as smart agents. In particular, SCs extract semantic information from an external environment (i.e., cancerous cells emitting specific signaling molecules), which triggers the production and release of toxin molecules that kill the cancerous cells. The production rate changes according to the amount of signaling molecules in the environment.

III. CONCLUSION AND ACKNOWLEDGMENT

We are grateful for the strong support of the new T-MBMC Editor-in-Chief, Prof. Sasitharan Balasubramaniam, to host this Special Feature and to continue publishing letters from future iterations of the Workshop. We are also thankful to the article authors for sharing their valuable contributions with us. The 2023 MolCom Workshop will be held at the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) in Erlangen, Germany, in April 2023. We are very pleased to share that submissions to 2023 MolCom Workshop are more than double that of the 2022 MolCom Workshop, so on behalf of the MolCom Steering Committee, we look forward to sharing more results soon.

The authors of this editorial would like to recognize the contributions of all other members of the MolCom Workshop Steering Committee, including Michael Taynnan Barros (University of Essex, U.K.), Mauro Femminella (University of Perugia, Italy), Jari Hyttinen (Tampere University, Finland), Kerstin Lenk (Graz University of Technology, Austria), Lin Lin (Tongji University, Shanghai, China), and Richard Morris (John Innes Centre, U.K.).

APPENDIX: RELATED ARTICLES

- [A1] H. K. Rudsari, M. Zoofaghari, M. Damrath, M. Veletić, J. Bergsland, and I. Balasingham, "Anomalous diffusion of extracellular vesicles in an extracellular matrix for molecular communication," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 1, pp. 8–12, Mar. 2023.

- [A2] S. Bhattacharjee, E. B. Krebs, A. Harlakin, and P. A. Hoeher, "Detection process in macroscopic air-based molecular communication using a PIN photodiode," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 1, pp. 13–17, Mar. 2023.
- [A3] F. Vakiliipoor, A. N. M. Ansari, and M. Magarini, "Localizing the unknown receiver in a diffusive SIMO molecular communication system," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 1, pp. 18–22, Mar. 2023.
- [A4] B. Ruzzante, L. Del Moro, M. Magarini, and P. Stano, "Synthetic cells extract semantic information from their environment," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, vol. 9, no. 1, pp. 23–27, Mar. 2023.

HAMIDREZA ARJMANDI, *TPC Co-Chair*

School of Engineering

University of Warwick

CV4 7AL Coventry, U.K.

E-mail: hamidreza.arjmandi@warwick.ac.uk

HAMDAN AWAN, *TPC Co-Chair*

Department of Computer Science

Munster Technological University

Cork, Ireland T12 P928

E-mail: hamdan.awan@mtu.ie

HUY TRAN, *TPC Co-Chair*

Faculty of Medicine and Health Technology

Tampere University

33520 Tampere, Finland

E-mail: huy.tran@tuni.fi

MAXIMILIAN SCHÄFER, *Steering Committee*

Institute for Digital Communications

Friedrich-Alexander-Universität Erlangen-Nürnberg

91058 Erlangen, Germany

E-mail: max.schaefer@fau.de

WERNER HASELMAYR, *Steering Committee*

Institute for Communications Engineering

and RF-Systems

Johannes Kepler University Linz

4040 Linz, Austria

E-mail: werner.haselmayr@jku.at

ADAM NOEL, *Steering Committee*

School of Engineering

University of Warwick

CV4 7AL Coventry, U.K.

E-mail: adam.noel@warwick.ac.uk



Hamidreza Arjmandi (Member, IEEE) received the M.Sc. degree in electrical engineering from the University of Tehran in 2010, and the Ph.D. degree from the Sharif University of Technology, Tehran, Iran, in 2016. He is currently a Research Fellow with the University of Warwick, Coventry, U.K. He served as an Assistant Professor with the Department of Electrical Engineering, Yazd University, Iran, from 2016 to 2021. His research interests include molecular communications and biological/biosynthetic networks. He was awarded a Research Fellowship from the European Research Consortium for Informatics and Mathematics hosted by the Department of Electronic Systems, Norwegian University of Science and Technology, Trondheim, from 2019 to 2021. He serves as an Associate Editor of IEEE TRANSACTIONS ON NANOBIOSCIENCE.



Hamdan Awan (Member, IEEE) received the Ph.D. degree in computer science and engineering from the University of New South Wales (UNSW), Sydney, Australia, in August 2017. He stayed with York University, Canada, as a Postdoctoral Fellow, for two years, from December 2017 to December 2019, where he worked on the DARPA'S Radio Bio Project. In December 2019, he joined the Telecommunications Systems and Software Research Group, Waterford Institute of Technology, Ireland, as an H2020 Research Fellow, where he worked on the FET-Open Gladiator Project. He is currently working as a Lecturer with the Department of Computer Science, Munster Technological University, Cork, Ireland. He has so far published more than 30 research papers in highly selective IEEE Transactions and the IEEE/ACM conferences. He has also coauthored the article that received the Best Paper Award from the IEEE/ACM NanoCom Conference, in 2018. His major research interests include molecular communications, nano-networks, information theory aspects of biological communication, and computer vision. He has also been a recipient of Postdoctoral Writing Fellowship after the Ph.D. degree with UNSW, for three months, from September to November 2017.



Huy Tran received the Ph.D. degree from the Tampere University of Technology, Tampere, Finland. Then, he worked as a Postdoctoral Researcher with Institut Curie and Ecole Normale Supérieure, Paris, France. He is a Biophysicist with training in signal processing and electrical engineering. His research has always been at the very interface between biology and physics, focusing on how cells perceive and process information from their surroundings. Now back to Tampere University as a Research Fellow, he is studying the linkage between biophysical transduction pathways and genetic pathways to predict the tissue behaviors in both physiological and pathological contexts.



Maximilian Schäfer (Member, IEEE) received the B.Sc., M.Sc., and Ph.D. degrees in electrical engineering from the Friedrich–Alexander–Universität Erlangen–Nürnberg (FAU), Germany, in 2012, 2015, and 2019, respectively. He is currently a Postdoctoral Researcher with the Institute for Digital Communications, FAU. His research is focused on multidimensional systems theory and the modeling of distributed parameter systems with applications in sound synthesis and molecular communications. He has given several invited talks and tutorials on the modeling of molecular communication systems. He has received a Fellowship from the Bavarian Research Institute for Digital Transformation and the Bavarian State Ministry for Science and Art, and Best Paper Awards at the 9th ACM International Conference on Nanoscale Computing and Communication in 2022 and the 25th International Conference on Digital Audio Effects in 2022. He also serves as a Steering Committee Member of the Workshop on Molecular Communications.



Werner Haselmayr (Member, IEEE) received the Ph.D. and Habilitation degrees in mechatronics and communications engineering from Johannes Kepler University (JKU), Linz, Austria, in 2013 and 2020, respectively, where he is an Associate Professor with the Institute for Communications Engineering and RF-Systems. His research interests include the design and analysis of molecular communication systems and communications and networking in droplet-based microfluidic systems. He is a co-recipient of the Best Paper Award presented at ACM International Conference on Nanoscale Computing and Communication 2022. He has given several invited talks and tutorials on various aspects of droplet-based communications and networking. He has authored two book chapters and more than 80 papers, appeared in top-level international peer-reviewed journals and conference proceedings. He currently serves as an Associate Editor of IEEE TRANSACTIONS ON MOLECULAR, BIOLOGICAL, AND MULTI-SCALE COMMUNICATIONS. He also serves as a Steering Committee Member of the Workshop on Molecular Communications.



Adam Noel (Member, IEEE) received the B.Eng. degree in electrical engineering from Memorial University, St. John's, Canada, in 2009, and the M.A.Sc. degree in electrical engineering and the Ph.D. degree in electrical and computer engineering from the University of British Columbia, Vancouver, Canada, in 2011 and 2015, respectively. He is an Associate Professor with the School of Engineering, University of Warwick, Coventry, U.K. In 2013, he was a Visiting Scientist with the Institute for Digital Communication, Friedrich–Alexander–University, Erlangen, Germany. He has also been a Postdoctoral Fellow with the University of Ottawa and the University of Montreal. His research is on biophysical signal propagation, cellular signal processing, and molecular communication engineering. He has received awards, including a Postdoctoral Fellowship from the Natural Sciences and Engineering Council of Canada and the Best Paper Award at the 2016 IEEE International Conference on Communications. He is currently an Associate Editor of IEEE TRANSACTIONS ON MOLECULAR, BIOLOGICAL, AND MULTI-SCALE COMMUNICATIONS. He also serves as Vice-Chair of the IEEE Communication Society's Technical Committee on

Molecular, Biological and Multi-Scale Communications from 2022 to 2023, as a General Chair for ACM NanoCom 2023, and as a Steering Committee Member of the Workshop on Molecular Communications.