Fellow	Ali Etemadi
Host Organisation	Norwegian University of Science and Technology (NTNU)
Scientific coordinator	Prof. Ilangko Balasingham

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my fellowship, my research was mainly focused on modelling molecular communication mechanisms in cancer. To this end, I proposed the phase separation mechanisms which is responsible for characterization of many biological mechanisms in nature. From an MC system's perspective, the dynamics of information particles can be observed to be non-Gaussian but still Fickian. This gives rise to the development of novel modulation schemes performing based on diffusion dispersion as a bio-inspired information dissemination approach. We casted the complex phase separation problem into a novel modulation technique which we referred to as diffusion-division modulation (DDM) scheme. The proposed DDM scheme not only reveals the impact of diffusion noise in biological systems but also reveals its potential as an effective multiplexing/multiple-access technique in MC systems. Our proposed diffusion noise model can be integrated into existing ODE models in biology and build the basis for information and communication theoretical analysis of the biological networks.

In case of the DDM scheme, we analysed performance of the system in terms of the bit error rate adopted in an end-to-end MC system. We proposed a lower-bound on the performance of the DDM-based MC system which is comparable to the performance of the binary concentration shift keying (BCSK), as the most relevant modulation benchmark. We have also extended the dual-carrier DDM to multi-carrier DDM scheme and compared the results with the M-ary PPM and OOK modulation schemes.

We also extended the DDM to the novel and interesting multiplexing technique, called orthogonal diffusion-division multiplexing (ODDM) which proposed the diffusion as a new resource of information dissemination within communication systems. It also paves the way for implementing interference-free orthogonal diffusion-division multiple-access (ODDMA) technique which can be very promising in analysing biological systems with bioinformatic tools. Interestingly, performance of the M-ODDM technique remains intact by increasing the number of the carriers. Moreover, we have shown that by proper detector design, performance of the ODDM can achieve performance of the molecular division multiple-access (MDMA) technique, as the most relevant benchmark due to the orthogonality.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

I have submitted the two following papers:

1) A. Etemadi, M. Damrath, M. Veletic, and I. Balasingham, "Modulation over diffusion domain: A proof-of-concept for cellular sensing mechanisms," Submitted to IEEE Transactions on Communications, Nov. 2024. [Online]. Available: http://dx.doi.org/10.36227/techrxiv. 173144770.07680731/v1. (Submitted to IEEE Transactions on Communications, Major Revision)
2) A. Etemadi, M. Damrath, and I. Balasingham, "ODDM(A): A Novel Multiplexing/Multiple-access Technique for Molecular Communication Systems," (Submitted to IEEE Wireless Communications Letters).

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

I have attended the 8TH WORKSHOP ON MOLECULAR COMMUNICTIONS (MOLCOM'24) with the following abstract paper:

- Etemadi, et al, "Bio-inspired Locomotion Design and Modelling for Diffusive Molecular Communication Systems," Oslo, Norway.

The above work was based on my previous research in Tarbiat Modares University.
I could also attend some seminars and workshops in the Oslo University Hospital (OUS) related to my ongoing project on modelling molecular communication mechanisms in biology.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I had a visit to Fraunhofer Institute for Cell Therapy and Immunology (IZI) in January 2024, in Leipzig, Germany. I visited parts of the IZI and got familiar about how to extend my ongoing theoretical studies on molecular communications into experimental research. I also involved in many meetings regarding the molecular imaging techniques and how molecular communication systems can be implemented in in-vitro systems.