Editorial—Special Issue on Molecular Communications for Diagnostics and Therapeutic Development of Infectious Diseases

THE COVID-19 pandemic in the last year has brought along numerous challenges on all fronts for humanity. Besides the high number of fatalities, economic and societal impact, the virus has also raised a question on the current approaches and methodologies for combatting pandemics. An important factor in this global fight against the pandemic, is the fact that key experts within the fields of biotechnology, virology and immunology have to return to the drawing board to develop new approaches to treat the virus. This has triggered a multi and inter-disciplinary research drive to bring in new concepts, techniques and methodologies that can be used to understand the virus in order to develop novel treatment techniques. The field of molecular communications, which is just over a decade old, is one area of research in the field of communications and networking that can contribute towards understanding of virus and their infection process. This is the aim of this special issue, where we have collected a number of publications from key researchers in the field of molecular communications that can contribute towards understanding the viral properties and behavior, which can be used to support the current as well as future pandemics.

The first publication selected by the guest editors - "Molecular Communications in Viral Infections Research: Modeling, Experimental Data and Future Directions," aims to collect vital data for a number of well known viruses that can be used by molecular communications researchers to model and simulate their propagation behavior. Examples of these viruses that have been analyzed in this paper include SARS-CoV-(1, 2), MERS-CoV, Ebola, Dengue, Zika, and Hepatitis C. The paper discusses a number of different propagation methods within the body, such as through the lungs, circulatory systems, between cells, as well as propagation behavior when respiratory clouds are secreted from people. The objective is to entice a new direction in molecular communications, where the community can use the data set to simulate accurate propagation scenarios in order to provide support for virologists and immunologists in better understandings of the virus.

In the second publication "VIVID: *In Vivo* End-to-End Molecular Communication Model for COVID-19," the authors aim to understand the transmission and propagation dynamics of coronavirus inside the respiratory system. The paper models the transmission and propagation of coronavirus inside the respiratory tract, starting from the nasal area to alveoli using concepts from molecular communications, and simulated using COMSOL multi-physics modeling tool. The analysis conducted includes the end-to-end communication model of path loss, delay, and gain.

The publication "Molecular Communication Theoretical Modeling and Analysis of SARS-CoV-2 Transmission in Human Respiratory System" models and analyzes the SARS-CoV-2 transmission through the human respiratory tract using concepts from molecular communication. The analysis considers the virus diffusion within the mucus layer, and found that the shape of the respiratory tract does not play a role in the transmission process. The publication also presents a unique impulse response of SARS-CoV-2 and its binding process to the angiotensin-converting enzyme 2 (ACE2) expressing cells to determine the proportion of the virus in different parts of the lungs. The significance of this study is the relationship that has been established between high mucus flow rate that impacts on the virus migration to the lower part of the respiratory tract.

The publication "A Molecular Communications System for the Detection of Inflammatory Levels Related to COVID-19 Disease" analyzes the excessive interleukin (IL)-6 level and its evolution in the blood vessels using molecular communications theory. The publication considers the mechanism for the SARS-CoV-2 to bind to ACE2 expressing cells, which are found in the endothelium lining of the circulatory system, to diffuse through and lead to endothelial inflammation. This then leads to the stimulation of cytokine storms as part of the immune response. The work developed in this publication was analyzed using the BiNS2 simulator, to characterize the flow-based molecular communications in blood vessels, as well as Markov models of the endothelium.

In "A Molecular Communication Perspective on Airborne Pathogen Transmission and Reception via Droplets Generated by Coughing and Sneezing," the spreading mechanism of infectious disease by airborne pathogen transmission is modeled using concepts from molecular communications. The airborne propagation model considers the impact of the gravity, initial velocity and buoyancy for the droplets as it propagates through the air. The results from the study found that a number of factors that impact the infection process, such as the exposure time, and the angle of sneezing, can have an impact on the propagation behavior. The results of this study can contribute to designs of novel mask structures that prevent the maximum quantity of droplets from diffusion into the environment, as well as appropriate social-distance.

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The publication "Viral Aerosol Concentration Characterization and Detection in Bounded Environments" proposes a respiratory model for breathing, coughing, and sneezing of aerosol droplets propagation as a molecular communication system that is detected through a biosensor within an environment. The propagation modeling considers the secreted molecules as a cloud and analyzes the spatial-temporal virus concentration propagated within a bounded environment. A contribution from this publication is a closed-form expression for the virus concentration. The analysis is based on simulations that analyze the detection efficiency of the biosensor. The contribution of this publication can lead to optimal placements of the biosensors within an environment to maximize the detection of secreted droplets from people.

The publication "Duality Between Coronavirus Transmission and Air-Based Macroscopic Molecular Communication," analyzes the airborne aerosol and droplet transmission viral infection process as an air-based molecular communication system. The aerosol and droplet transmission is modeled as a multiuser molecular communication scenario employing respiratory-event-driven molecular variable-concentration shift keying modulation process. Based on molecular communications testbeds that have been previously proposed for characterizing the air-based molecular communication testbed, the study proposes a simulation tool for estimating the transmission of the aerosols within an environment. This publication can lead to accurate techniques of understanding the infection processes as the virus is secreted from the respiratory system, which can lead to more accurate proposals for social distancing as well as the development of masks for people during a pandemic.

We would like to thank Chan-Byoung Chae, the Editor-in-Chief of IEEE Transactions on Molecular, Biological, and Multi-Scale Communications and Christina Tang-Bernas, the journal manager, for their endless support and guidance to make this special issue a success. The collection of publications from this special issue will hopefully attract a new research direction from the molecular communications community that can contribute towards new understanding in viral pandemics.

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