PERFORMANCE OF AMPLITUDE MODULATION SCHEMES FOR MOLECULAR COMMUNICATION OVER A FLUID MEDIUM

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by

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Certificate

This is to certify that the thesis entitled **"Performance of Amplitude Modulation Schemes for Molecular Communication Over a Fluid Medium"** being submitted by **Mr. Amit Singhal** to the **Department of Electrical Engineering, Indian Institute of Technology Delhi**, for the award of the degree of **Doctor of Philosophy** is the record of the bona-fide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted either in part or in full to any other university or institute for the award of any degree or diploma.

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Amit Singhal

Abstract

Molecular communication involves the use of nanomachines to perform the role of transmitters and receivers. The signals are carried in the form of molecules propagating through the medium connecting the nanomachines. It serves as a mechanism to carry information at nano-scales. The information can be encoded in the count, concentration, type or the release time of the various molecules. The quantity-based amplitude modulation schemes are found to offer a promising approach to set up molecular communication over diffusion-based channels. Before the practical deployment of such schemes, appropriate channel models and their performance potential need to be analyzed.

As a first contribution of this thesis, we consider molecular communication between two nanomachines placed in a fluid medium for three different amplitude modulation schemes. The number of molecules transmitted represents the amplitude levels for these schemes. We consider a time-slotted channel, where the information in every slot is corrupted by stray molecules from the previous slots. The capacity of such a molecular communication channel is investigated for all the three modulation schemes. Analytical expressions for the end-to-end symbol error probability are derived, considering maximum likelihood detection at the receiver. Numerical results indicate that arbitrarily

low probabilities of error can be achieved for high drift velocities. An increase in the slot length further improves the performance, albeit at the cost of data rate. The results also demonstrate the improvements offered by the amplitude modulation schemes over the previously proposed time modulation schemes.

Next, we explore the effect of molecular noise in diffusion-based molecular communication. As a molecule travels through a fluid medium, its continuous collision with the molecules of the fluid can be considered as a continuous random force acting on the molecule. This force is the source of uncertainty in the position of the molecule and can be treated as a noise. We propose a mathematical model for such noise. The role of finite life expectancy of molecules and inter symbol interference is also considered. Closed-form expressions for the probability of error and the channel capacity are derived considering a binary communication scheme. The numerical results illustrate the impact of these parameters on the performance of molecular communication techniques.

Thereafter, we extend the performance analysis for the multiple molecule case as opposed to single molecules for defining the various amplitude levels. We consider an M-ary modulation scheme and also propose an extended scheme, which is a variation of a binary modulation scheme. The received symbol is corrupted by interference from the previous symbols as well as the noise sources present in the medium. We propose an end-to-end model addressing all the relevant noise sources affecting such communication systems. Considering maximum likelihood detection at the receiver, we derive analytical expressions for the end-to-end symbol error probability and the capacity for these modulation schemes. Numerical results bring out the impact of various parameters on the performance of the system.

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