Characterizing the Physical Influence of Neighboring Absorbing Receivers in Molecular Communication

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ABSTRACT

This paper analyzes the influence of neighboring absorbing receivers in a point-to-point Diffusion-based Molecular communication (DMC) link, following a simulation-driven approach. It is shown that the distance from the transmitter-receiver link, the distance between receivers and their radius have a noticeable impact upon both amplitude and signal detection.

Keywords

DMC;diffusion process;SIMO;absorbing receivers

1. INTRODUCTION

In nature, most of the receptor types remove the information carrying molecules from the environment once they arrive at the receiver through ligand-binding mechanisms [1]. This fact modifies the propagation medium.

The absorption mechanisms have been considered in a Diffusion-based Molecular communication (DMC) point to-point-link while not taking into consideration the effect of the neighboring receivers. Therefore, this paper focuses on understanding the influence of neighboring absorbing receivers in a DMC point-to-point link.

To achieve this, we base our study in a well-known DMC simulator [2], and define novel metrics to evaluate the impact. Absorbing neighboring receivers present interesting trade-offs in terms of pulse amplitude and energy, by showing that optimal placement of receivers help diminishing the amplitude of the pulse tail, while maintaining its maximum amplitude.

The rest of the paper is organized as follows. In Section II, we present the system model. In Section III, results are shown and discussed. Finally, the conclusion is given in Section IV.

2. SYSTEM MODEL

The probability when no absorption of hitting molecules

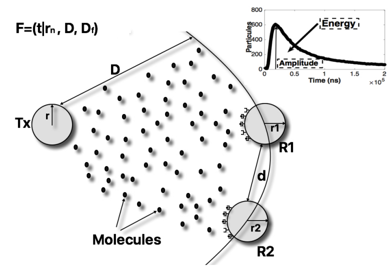

Figure 1: Considered point-to-point DMC link with interfering absorbing receiver.

has been modeled by [3]:

$$F = (t|r_n \ , D, D_f \ ) = \left(\frac{r_n}{r_n \ + D}\right) ercf \left(\frac{D}{\sqrt{4D_f \ t}}\right) \quad (1)$$

where D_f denotes the diffusion coefficient and t the time.

There is no expression modeling the probability where there are absorption of hitting molecules. Hence, we aim to characterize this situation with nearby receivers. For that we consider a point-to-point DMC link in Fig. 1, which is passively affected by an additional nearby absorbing receiver. The two receivers are located at the same distance D from the transmitter, and maintaining a distance d between them. The radius of the receivers are denoted by $r1$ and $r2$.

3. SIMULATION STUDY AND NUMERICAL RESULTS

We base our study in the simulation framework N3Sim [2]. We deploy one transmitter and two receivers as in in Fig. 1. D ranges from 400 nm to 600 nm, d from 1 nm to 800 nm and $r1$, $r2$ from 100 nm to 300 nm. The simulation time is set to 400 μs, with a time-step of 2 μs. The number of released molecules is fixed to 500000.

3.1 Impulse response

We first show the pulse-shape at the receiver under study. Fig. 2 a) shows the set of impulse responses for a distance between receivers, d, ranging from 1 nm to 800 nm. This is evaluated for three different transmitter-receiver distances. The received pulse is compared to the non-absorbing receiver case, which is set as the ideal pulse-shape. It is shown that the distance to the neighboring interfering receiver influences the received pulse shape in two different manners: first, it is observed that it attenuates the maximum pulse amplitude. This influence is diminished as the distance increases.

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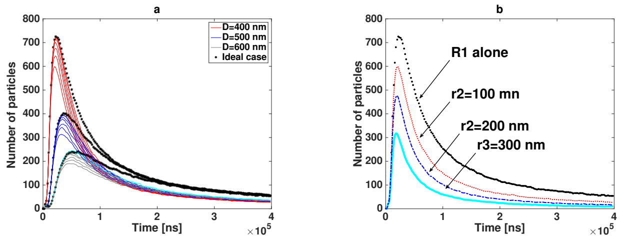

Figure 2: Set of impulse responses at the receiver for (a) different values of D and (b) different values of r2.

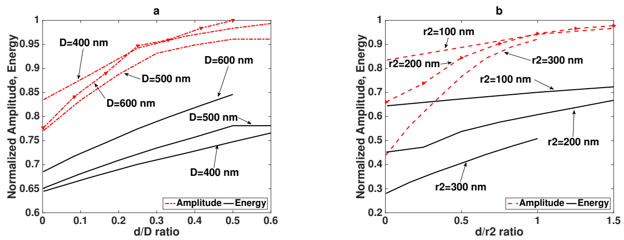

Figure 3: Normalized amplitude and pulse energy as a function of (a) d/D ratio and (b) $d/r2$ ratio.

Second, it reduces the amplitude of the tail. This has not evidenced dependency on d. Similarly, Fig. 2 b) illustrates the influence of the pulse-shape as a function of the neighboring radius size, $r2$. We observe that as this radius increases, the neighboring receiver is able to absorb more molecules, hence showing a significant reduction on both the pulse amplitude and the amplitude of its tail.

3.2 Amplitude and pulse energy

Next, we consider both the pulse amplitude and its energy as evaluation metrics. The pulse energy, refers to the total number of collected molecules at the receiver end.

In Fig. 3 a), we show the influence of d and D on the pulse amplitude as well as on the received pulse energy. To relate both magnitudes, we show the results as a function of the distance between receivers, normalized to the transmitter-receiver distance, that is d/D. The pulse amplitude and energy are also normalized by the ideal non-absorbing single receiver case. In this setup, $r1$ and $r2$ are set to 100 nm. We observe that when d increases the pulse amplitude approaches the ideal case. It is shown that the transmitter-receiver distance modulates the approaching trend. This is because of the diffusion process in the environment. For large values of D, less molecules will reach the receivers, hence their influence is less noticeable. In terms of the pulse energy, we observe a similar growing trend. However, it offers a slower growth. In particular, the pulse energy only reaches approximately the 70% of the ideal pulse energy when its amplitude has reached its maximum. Similarly, Fig. 3 b) presents the impact of d and $r2$ on the maximum amplitude as well as on the pulse energy. First, we observe that the size of $r2$ affects both pulse amplitude and pulse energy. In contrast, The increase of d approaches the pulse amplitude to the ideal considered case. The pulse energy follows a similar trend.

For a fixed pulse amplitude, larger pulse energies imply wider pulse-times and, hence, lower achievable bit rates. We define the cost function which is the amplitude over the energy as a metric to evaluate the optimum values while conserving the maximum amplitude reached with the lower

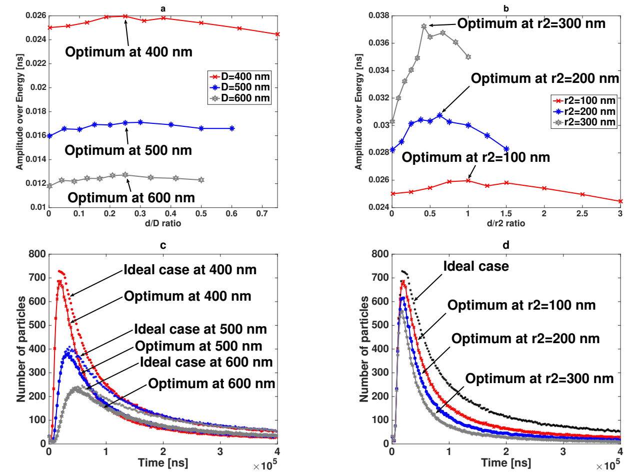

Figure 4: Amplitude over Energy ratio as a function of (a) d/D ratio and (b) $d/r2$ ratio. Set of impulse responses at the receiver for different optimum values of (a) d/D ratio and (b) $d/r2$ ratio.

energy. We evaluate this performance metric in Fig. 5 a) and b) as a function of d/D and $d/r2$ respectively where we observe that the maximum values of the evaluated metric does not shows significant dependency on d/D and it is approximately 0.25. However, no similar trend is obtained in $d/r2$, it exhibits a decreasing dependency when the length of $r2$ increase. In Fig. 5 c) and d) we evaluate the impulse response of the considered d, D, and $r2$, which correspond to the maximum values of the considered metrics, through N3Sim. In this two plots we see that the amplitude approaches the ideal case, whereas the amplitude of the tail is significantly reduce from the ideal case.

4. CONCLUSION

In this paper a simulation study of link to link DMC with two absorbing receivers is reviewed. It has been shown that optimal receivers distances will lead to a higher bit rate. In the same orientation, more realistic scenario and higher scalability of receivers will be investigated.

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