N3Sim: A Simulation Framework for Diffusion-based Molecular Communication

Ignacio Llatser[1], Iñaki Pascual[1], Nora Garralda[1], Albert Cabellos-Aparicio[1], and Eduard Alarcón[1]

Nanonetworking Center in Catalunya (N3Cat)
Universitat Politècnica de Catalunya, Barcelona, Spain
E-mail: {llatser,ipascual,garralda,acabello}@ac.upc.edu, ealarcon@eel.upc.edu

1 Introduction

Nanotechnology, the study of nanometer-scale systems, is a multidisciplinary field with potential applications in the biomedical, environmental and industrial fields [1, 2]. A nanomachine is the most basic functional unit able to perform very simple tasks at the nanoscale. These tasks include computing, data storage, sensing and actuation.

Nanonetworks, the interconnection of nanomachines, provide means for cooperation and information sharing among them, allowing nanomachines to fulfill more complex tasks [3]. Several techniques have been proposed to interconnect nanomachines. For the short range (nm to μm), one of the most promising techniques is diffusion-based molecular communication, a bio-inspired paradigm based on the use of molecules to encode and transmit information.

Several authors have developed analytical models of diffusion-based molecular communication [4, 5]. *N3Sim* (available at `www.n3cat.upc.edu/n3sim`) is a simulation framework for the general case of diffusion-based molecular communication, and will allow to validate the existing theoretical models and to create novel, more accurate models.

2 Simulator architecture

We designed *N3Sim* in order to simulate a set of nanomachines which communicate through molecular diffusion in a fluid medium [4]. The information to be sent by the transmitter nanomachines modulates the rate at which they release particles to the medium. The variation in the local concentration generated by the transmitters propagates throughout the medium. The receivers are able to estimate the concentration of particles in their neighborhood by counting the number of particles in the environment. From this measurement, they can decode the transmitted information.

Figure 1 shows a block diagram of the steps needed to run a simulation. First, the user specifies the simulation parameters in a configuration file. These parameters include the number and location of transmitters and receivers, the size of the emitted particles and the diffusion coefficient of the medium, amongst

others. A set of scripts allows the user to run multiple simulations automatically, which is useful to easily evaluate the influence of a specific parameter (e.g., the number of transmitted particles) in the system output. Next, the diffusion simulator takes the configuration file and the automation scripts as input, and performs the actual simulation of the diffusion-based molecular communication scenario. When the simulation is finished, its outputs are stored in receiver files (one per receiver), which contain the concentration measured by each receiver as a function of time. Last, another set of scripts may be used to organize the results from several receivers and graphically represent them into a single plot.

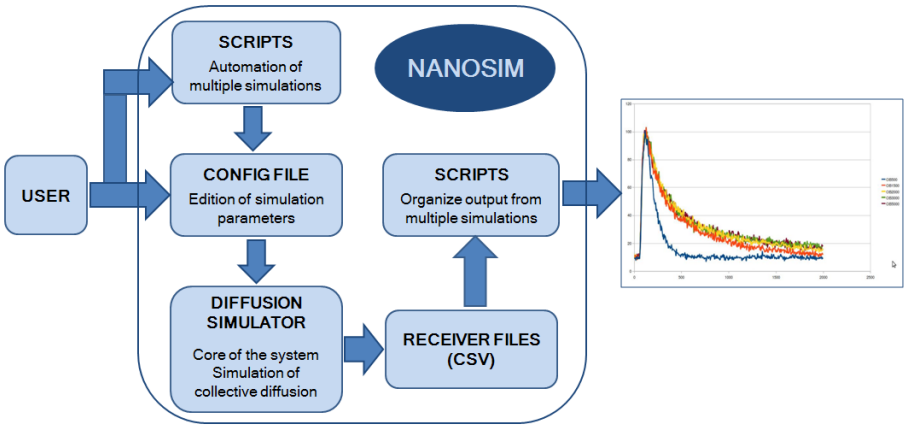

Fig. 1. Block diagram of *N3Sim*

3 Simulation results

In order to illustrate the capabilities of the simulator, we show the results of a simple simulation performed in a 2-dimensional space with a circular transmitter and receiver of 100 nm in radius. Fig. 2 shows the transmission of a Gaussian pulse consisting of 10^6 molecules, and the received signal, defined as the number of particles detected by a receiver as a function of time, at 500 and 1000 nm from the transmitter location, respectively. We observe that the molecular channel alters the shape of the pulse. As the transmission distance increases, the received pulse is lower, wider and has a longer tail, due to the effect of diffusion.

References

1. R. A. Freitas, Nanotechnology, nanomedicine and nanosurgery, International journal of surgery 3 (4) (2005) 243–6.

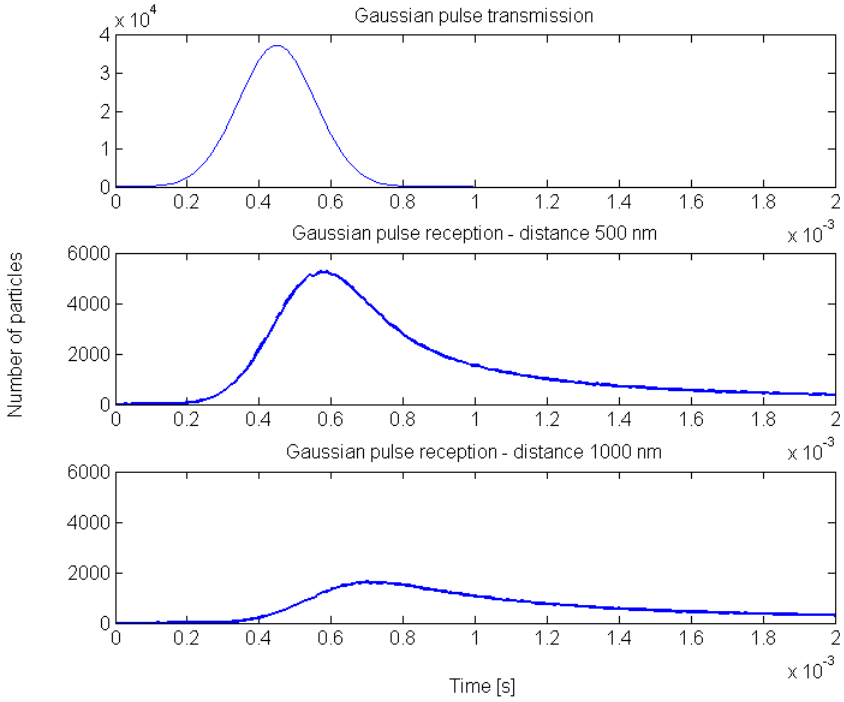

Fig. 2. Transmission of a Gaussian pulse

2. J. Han, J. Fu, R. B. Schoch, Molecular sieving using nanofilters: past, present and future., Lab on a chip 8 (1) (2008) 23–33.
3. I. F. Akyildiz, F. Brunetti, C. Blázquez, Nanonetworks: A new communication paradigm, Computer Networks 52 (12) (2008) 2260–2279.
4. M. Pierobon, I. F. Akyildiz, A physical end-to-end model for molecular communication in nanonetworks, IEEE JSAC 28 (4) (2010) 602–611.
5. A. Goldbeter, G. Dupont, M. J. Berridge, Minimal model for signal-induced Ca2+ oscillations and for their frequency encoding through protein phosphorylation., Proc. of the National Academy of Sciences of the United States of America 87 (4) (1990) 1461–5.