BODY-AREA COMMUNICATIONS: SCI-FI OR PROMISING PARADIGM?

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Abstract: Nanotechnology represents a new solution for variety of applications in the biomedical, industrial and military fields. This paper deals with the diffusion-based molecular communication in nanonetworks. Molecular communication is a novel paradigm for communication between nanomachines (machines made of biological materials; bio-nanomachines) over a short range in aqueous environment. Simulation model of nanocommunication was build in simulation tool N3Sim where several different settings in several different scenarios were performed. The main impact of this work is a compressive evaluation of nanocommunication between nanomachines using the Brown motion.

Keywords: Nanocommunication, Bio-nanomachines, N3Sim, Brown motion.

1 INTRODUCTION

The concepts of nanotechnology were first mentioned in year 1965 by Richard Feynman [1]. Nanotechnology is enabling the development of devices which are in scale ranging from one to few hundred nanometers, see Fig.1. At this nanoscale, nanomachines are the simplest devices which are able to perform the tasks as computing, sensing, information storage or actuation [1], [2]. Looking one step further when we will be able to coordinate the information transmission and sharing among several nanomachines, the range of operation on nanomachines will then expand [1], [2]. As a basic requirement for this idea, the nanonetworks should be able to reach unprecedented locations in a non-invasion way which is currently under the research of many academics and industrial bodies. In general, the nanonetworks are expected in many different areas but the main area of their applicability will be most probably in the industrial and biomedical fields [3], [4].

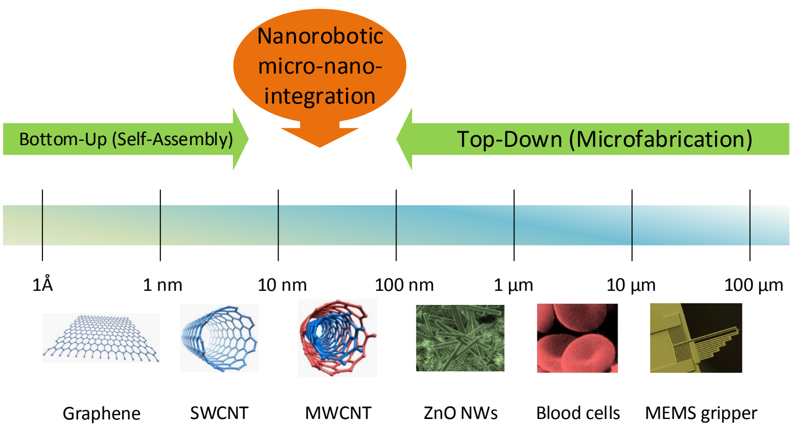

Figure 1: Comparison of different size of objects [10]

Although several papers on nano-devices have been published in last few years, it is not still clear what is the best technique for molecular communication. Currently there are several commonly known approaches for the communication between nanodevices that can be realized through nanomechanical, acoustic, nano-electromagnetic, chemical or molecular communication [1]. The research results carried out during last years pointed out that there are two most perspective ways for communication in nanonetworks: molecular communication and nano-electomagnetic communication [5]:

- Molecular communication: is defined as the transmission and reception of information which is encoded in molecules. The molecular transceivers should be easily integrated in nanodevices and should be able to react to specific molecules and release other specific molecules as a response to information stored in the received molecules [1], [6]. The big advantage, in comparison with nanomechanical communication, is that molecular communication is working over relatively large areas (transmitters and receivers do not need to be in a direct contact) [1].
- Nano-electomagnetic communication: is defined as transmission and reception of EM (electormagnetic) radiation [6]. The unique properties of the used materials influence a bandwidth for emission of electromagnetic radiation or the time lag of emission [5].

The work presented in this paper focuses on molecular communication on short and medium range, see Table 1, where the information is encoded by the nano-transmitter (emitter) in the molecule (particle) and received by a nano-receiver which is placed at the distance from the nano-transmitter. As the way of communication the calcium signaling is used.

Table 1: Type of communication in nanonetworks

Distance	Communication range	Type of motors
Short range	nm - μm	molecular motors
Medium range	μm - mm	catalytic nanomotors
Long range	mm - m	pheromones

While writing this paper, there are several simulation tools available. In our paper we used the N3Sim [7] which has been explicitly designed for simulating molecular communication. The N3Sim use the diffusion spreading which is based on the principle of Brown motion [1]. Using this simulation tool we created several scenarios for simulation of nanocommunication between two nano-devices. The results from the simulation tool N3Sim will be used as a data for calibration of the other simulation model, which will be created in NS-3 (Network Simulator 3) simulation tool [8]; this will be done as a future work based on the results from this paper.

The rest of the paper is organized as follows. The Section 2 presents the developed model in simulation tool N3Sim. The initial analysis of simulation results are provided in Section 3. Section 4 draws the conclusions and discusses planned work on the new model for nanocommunication in NS-3.

2 DEVELOPED MODEL

In the developed model created in N3Sim, the environment with changeable concentration of nanodevices was created. The generic nanonetwork's topology (a simplified version) is depicted in Fig.2. We defined the communication area bounds to 2500 nm x 2000 nm. The simulations were performed in aqueous environment with diffusion coefficient $D = 0,1 nm/ns^2$. For the better possibility to set up each simulation scenario, we divided the settings for the emitter and receiver into two separate sections in the code. In all simulation scenarios one emitter and one receiver was defined. The emitter had radius of the influence area set up to 100 nm. This value represents 10 % of vertical scale of the area which is in line with the requirements given in [9].

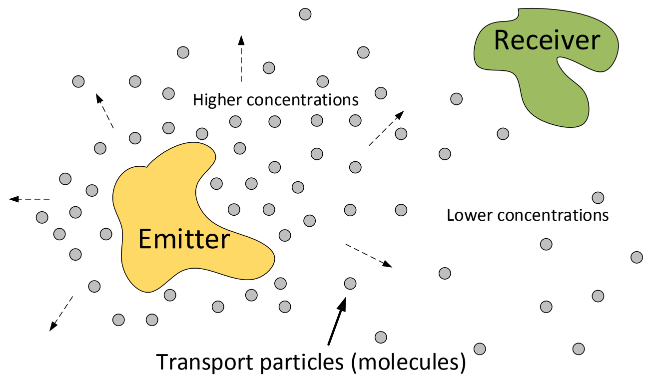

Figure 2: Generic nanonetwork's topology

3 RESULTS DISCUSSION

For the simulation, three different scenarios were created. Following the requirements in [1], [9] we identified three important parameters: the number of emitted particles, the distance between the emitter and the receiver and the simulation time. Based on that fact in our test methodology we changed only one parameter per one simulation (the rest of the parameters was fixed). All the tests were performed with and without active collisions between the emitted particles. Summary of all parameters which were changed one by one between each simulation run is given in Table 2.

Table 2: Summary of key simulation parameters

Scenario number	Simulation time	Distance	Number of emitted particles	Collisions
1	50 μs	300 nm	**1 000 – 7 000**	Disable
2	10 ms	**500 nm – 10 mm**	5 000	Disable
3	**600 μs – 15 ms**	1 mm	5 000	Disable
4	50 μs	300 nm	**1 000 – 7 000**	Enable
5	10 ms	**500 nm – 10 mm**	5 000	Enable
6	**600 μs – 15 ms**	1 mm	5 000	Enable

3.1 Variable number of emitted particles (Scenario no. 1, 3)

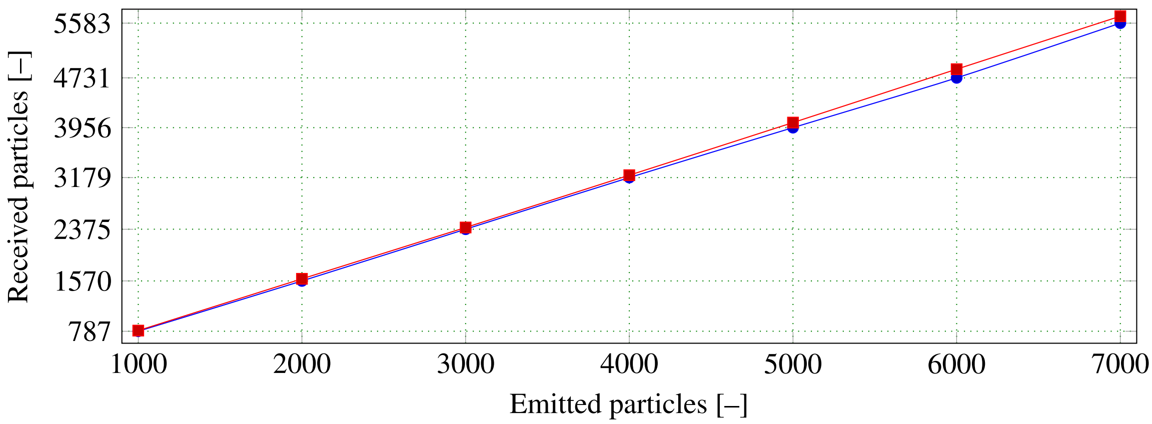

Figure 3: Comparison of scenarios with variable number of emitted particles

3.2 DYNAMIC DISTANCE BETWEEN NANODEVICES (SCENARIO NO. 2, 4)

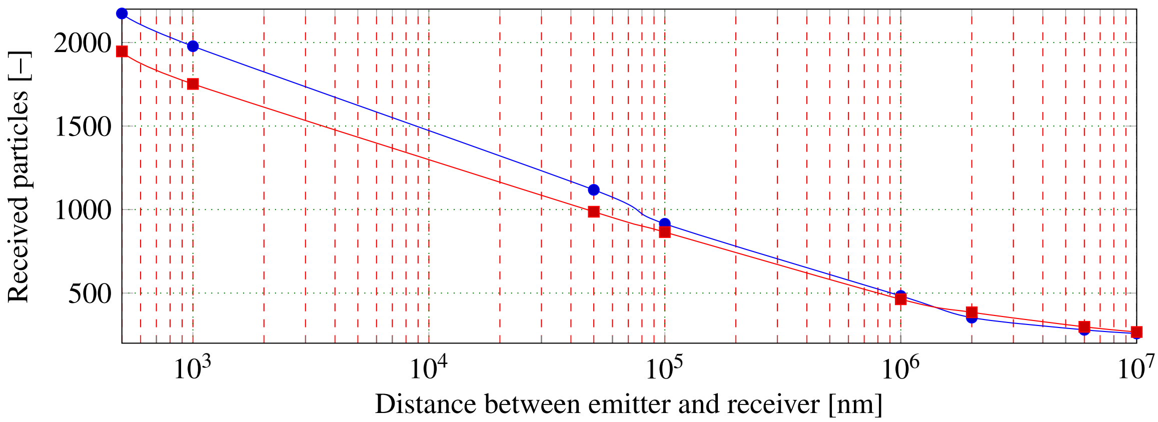

Figure 4: Comparison of scenarios with variable distance between emitter and receiver

3.3 VARIABLE LENGTH OF SIMULATION (SCENARIO NO. 3, 6)

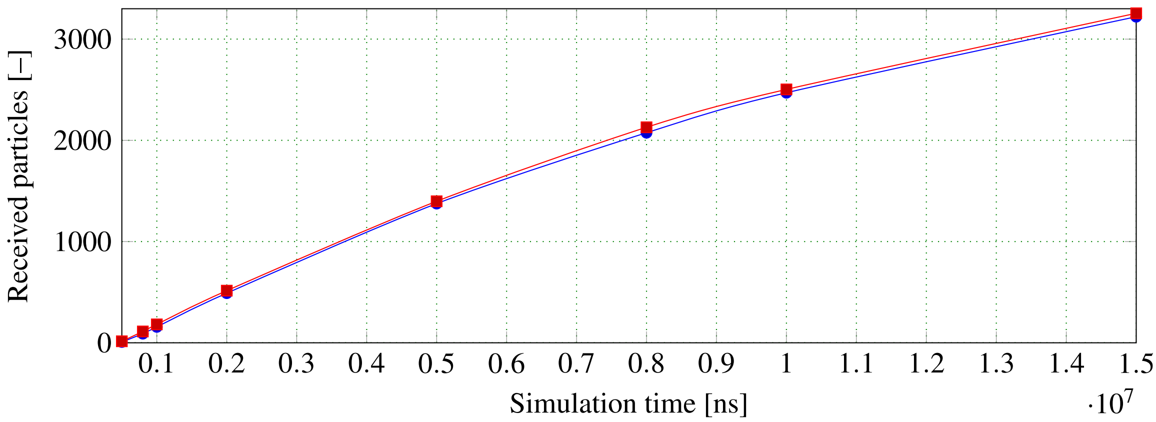

Figure 5: Scenarios with variable simulation time length

4 CONCLUSION AND FUTURE WORK

The computed results for created scenarios are depicted in Fig. 3, 4 and 5. In case of Fig. 3 and Fig. 5 we can conclude that with active collisions between the emitted particles the number of the successfully received particles on the side of the receiver is slightly higher in comparison with the blue curve (simulation without the collisions between the particles). In Fig. 4, the dynamic distance between the emitter and the receiver, the values of the successfully received particles are lower till the distance between nano-devices is lower than $d = 1{,}5\,mm$. This behavior is caused by the character of simulated space (area) which influences the results for this scenario.

Within the future work, we are going to create a completely new module of nanocommunication for the simulation tool NS-3 (Network Simulator 3). For the development of the new module the results obtained from the simulation in N3Sim will serve as a calibration set of data for our new module.

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