Molecular Communication Experiment Based on Nano-Internet of Things

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Abstract. At present, most of the molecular communication systems have strict constraints on the environment in nano-network, such as light, molecular concentration, environment and so on. Under these conditions, these systems can well complete the simulation of molecular communication in internet of things. But in reality, more application scenarios can not meet these harsh conditions, so these systems can not be widely used; we use sensors to collect molecular environment information, upload it to the single chip computer, use Arduino to detect sensor values, and use MATLAB software to make theoretical simulation system to achieve the task of theoretical simulation of molecular communication between targets.

1. Basic Contents of Molecular Communication in Nano-Internet of Things

The purpose of this project is to collect molecular environment information by sensors, upload it to MCU, use Arduino to detect sensor values, and use MATLAB software to make theoretical simulation system to achieve the task of theoretical simulation of molecular communication between targets[1]. Molecular communication is a kind of communication technology, which uses biochemical molecules as information carriers and is used in a distributed nano-network composed of several nano-machines. As a new communication mode which integrates biology, computer and communication, it has great application prospects in biomedicine, environmental monitoring, industrial manufacturing, military and other fields.

2. Research Ideas, Experimental Schemes and Results of this Project

2.1. Research Ideas and Methods of the Project

Some frontier research at home and abroad has applied some software to simulate the situation which is difficult to carry out traditional experiments. This not only saves time and effort, but also facilitates the evaluation and prediction of experimental results in advance[2]. Based on the above assessment and prediction, we have produced the molecular communication flow chart in the nano-Internet of Things as shown in the following figure.
The research on the model of molecular communication system includes three processes: transmission, diffusion and reception[3], as shown in the following figure:

**Figure 1.** Molecular communication flow chart in nano-Internet of Things

**Figure 2.** Molecular communication diagram in the Nano-Internet of Things

1) Launching process
The sending process of molecular communication is that the sender releases information molecules into the transmission medium. In the process of research[4], the emitter can be approximated as a point, which releases information molecules randomly to all sides.

2) Diffusion process
The information molecules in the diffusion process[5] follow Brownian motion (i.e. irregular motion). When the information molecule touches the system boundary, according to the specific situation of the model, the system boundary can be a viscous interface or a rebound interface. When the receiving sphere is a viscous interface, the information molecule immediately sticks to the sphere when it contacts the sphere, and the total number of molecules in space decreases. When the receiving sphere is a rebound interface, it is considered that the molecule has an elastic collision on the sphere, as shown in the figure. Typical diffusive molecular communication channel model.

3) Acceptance process

According to the model, the receiving sphere can be a viscous interface or a rebound interface[6]. When the receiving sphere is a viscous interface, the information molecule immediately sticks to the sphere when it contacts the sphere, and the total number of molecules in space decreases[7]. When the receiving sphere is a rebound interface, it is considered that the molecule collides elastically on the sphere.

2.2. The Experimental Scheme of the Project

A bounded spherical molecule communication system model is established. The receiving sphere is fixed at the center of the sphere, and a launching point which can be regarded as a particle moves inside the sphere. The influence of the location of the launching point on the receiving situation is analyzed when the boundary and receiving sphere are different interfaces[7].

1) Release and diffuse code implementation

In matlab, a matrix of N rows and 3 columns is established to store the coordinates of molecular positions in three-dimensional system. Write a function to simulate the movement of molecules, which includes the movement of existing molecules, the release of new molecules, and finally update the position matrix. By calling this function repeatedly, we can simulate and record the release of information molecules and Brownian motion.

2) Code Implementation of Boundary Processing

When the position of the molecule is updated, the distance from the molecule to the spherical center of the closed spherical system is larger than the preset radius of the spherical system (that is, the square of three-dimensional coordinates is larger than the square of spherical radius). It is known that the molecule touched the boundary in this diffusion[8]. When the boundary is a viscous interface, the coordinate of the molecule is directly reset to (0,0,0) in the matrix, and the position of the molecule is no longer updated, that is to say, the molecule is "absorbed" and the total number of molecules in the environment is reduced by one. When the boundary is a rebound interface, the position of the molecule is reset to the position before the diffusion, that is to say, the collision is treated as an elastic collision. The case of molecule touching the boundary.

3) Background conditions of experiments

1. The transmitter is the point with zero radius and zero position on the circle, that is, the transmitter is the fixed point - origin.

Figure 3. Schematic diagram of single point and single receiver for molecular communication
Two graphs: The first one is a real-time graph of the number of molecules received. In theory, the function in the graph should be a function of increasing first and then decreasing. Because at first, more and more molecules will diffuse slowly and approach the receiver, which will be absorbed by the receiver. After being absorbed, the number of remaining molecules in the rebound boundary will be less and less, which will lead to acceptance in unit time. The number of molecules is getting smaller and smaller, so the function should rise first and then fall; the second is a graph of the number of molecules accepted accumulatively, which should theoretically be more and more.

3. Number of experiments: When the last parameter is set, the initial number is 1, and the theoretical initial number is 1, the fluctuation of the first graph curve will be quite bumpy; while in the follow-up operation, the more the number of settings, the smoother the first graph will be, and vice versa, it will fluctuate greatly.

4. The parameters that need to be adjusted: the receiver spherical center coordinate is r_center[9], and the border is the boundary coordinate of the simulation environment. When border=-1, it means that there is no boundary. The Y-axis of the receiver can be slowly lowered from 10 to 1.

Specific operation of experiment
Experiments 1. Comparing the boundary conditions, the receiver is unified at 10 locations on the y-axis with a radius of 5. Firstly, in the case of no boundary, setting the boundary parameter to -1 can realize the simulation of no boundary[10]. Secondly, in the case of boundary, the parameter can be set to 20, because the receiver is circular and the radius of Y axis coordinate is 5, so 20 is more suitable.

In theory, the number of molecules accepted in the first or second graph with boundaries is much faster than that accepted in the cumulative or per unit time without boundaries.

Experiments 2. Comparing the position of receiver on Y-axis with the boundary radius set at 20, adjusting the position of receiver from 13 to 6 or from 13 to 3 to 7 can be done.

We will find that the closer the receiver is to the transmitter, that is, the closer the receiver is to the position of the Y axis from 3 to 2 to 1, the smaller the longitudinal coordinate t value corresponding to the appearance of the poles in the first graph, and the more the molecule number accepted by the unit at the poles, which is reflected in the graph that the transverse coordinate time of the poles decreases, and the vertical sitting. The scale is getting bigger.

Feasibility analysis of experiment
Some frontier research at home and abroad has applied some software to simulate the situation which is difficult to carry out traditional experiments. This not only saves time and effort, but also facilitates the evaluation and prediction of experimental results in advance.

At the same time, the College of Computer Science and Communication Engineering of Jiangsu University has the conditions to complete the research institute[11]. Mobile workstations create conditions for us to write programs and do simulation. School libraries provide us with more learning opportunities. They have electronic database resources such as IEEE/IEE, Elsevier Science, Springer, EI, SCI, and 1000 Mbp high-speed campus network, which can be timely. Convenient and comprehensive access to the latest domestic and foreign literature and research trends.

Experimental Results of the Project
The experimental results show that the simulation experiment proceeds smoothly and the simulation results are in good agreement with the expectations.
Figure 4. Simulation results of Experiment 1-1

Figure 5. Simulation results of Experiment 1-2
Figure 6. Simulation results of Experiment 1-3

Figure 7. Simulation results of Experiment 1-4
In simulation experiment 1, the number of molecules accepted after setting elastic boundaries is obviously more than that without boundaries. The cumulative number of molecules accepted increases from more than 3500 to more than 4500, and the number of molecules accepted per unit time also has an obvious upward trend, which is in line with expectations.

**Figure 8.** Simulation results of Experiment 2-1

**Figure 9.** Simulation results of Experiment 2-2
Figure 10. Simulation results of Experiment 2-3

Figure 11. Simulation results of Experiment 2-4
In simulation experiment 2, when the receiver position is moved from 13 of Y axis to 7 closer to that of Y axis of transmitter, the number of molecules accepted in cumulative or per unit time will be more and faster, which obviously meets the expectation of simulation experiment.

3. References

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