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Increasing the Performance of Bacterial Nano-Networks in Wireless AHOC Networks

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Abstract: Molecular communication is a paradigm for Nano-machines to exchange information. Due to some of the biological properties, bacteria have been proposed as a carrier for molecular communication, such communication networks are known as bacterial Nano-networks. The biological property of bacteria is ability to mobilize and carry the information encoded in deoxyribonucleic acid molecules. Bacteria have social characteristic, which provides bacteria to evolve in fluctuating environment using cooperative and non-cooperative behaviour. The reliability in communication can be achieved through optimizing the cooperative and non-cooperative behaviour of bacteria. Bacteria's are capable of self-motion, through chemo taxis process bacteria will able to reach destination nanomachine. E.coli (Escherichia coli) flagellated bacteria used a carrier. The simulation process is done to analyze the performance of bacterial Nano-networks for molecular communication.

Key words: Bacterial Nano network ・ Chemotaxis

INTRODUCTION

A molecular communication interface between senders and the propagation environment and also between the propagation system and receivers allow for a generic architecture. In the design, vesicles are used to wrap the information molecules, so that the propagation system is designed to transport vesicles information molecules [1]. This enables transport of various types of information molecules. A sender node infuses information molecules into vesicles on its surface, detaches and emits the vesicles. A molecular propagation system then carries vehicles to a receiver. On receiving vesicles, receivers obtain information molecules from the vesicles. The molecular communication may use DNAs attached on the vesicle at a sender and a receiver. Moreover, the molecular communication protects information molecules from the noise that exist in the propagation environment. [2] Also solutions of wireless and wire line epitome in molecular communication.

Wireline: In Wire line molecular communication a separate physical mechanism is used to guide the transportation of message molecules. Several mechanisms exist in nature, wired transport directionality for molecule that can be re-engineered to create nano-networks. These wire line communication provide a direct physical connection between sender and receiver and operate in a unicast mode. These solutions are cannot be affected by distance or noise [3].

Wireless: A wireless device uses radio waves that propagate through space. From a molecular communication perspective, a number of various methods have been examined for the propagation of radio waves using molecules. In wireless molecular communication, the transport of signal molecules is classified into passive and active communication. In passive communication, the signal molecules diffuse via Brownian motion in the communication channel. In Active communication [4], some form of chemical energy is used and propagation in a particular direction, ideally towards the meant receiver.

Features of Molecular Communication

Biocompatibility: Inserting nano-machines into a human body for medical applications requires Nano-machines. Biological Nano-machines function through receiving,

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interpreting and releasing molecules Biological nano-machines will be programmed to broken down after use to avoid procedures for removal or cleanup [5].

Scale: Because of the size of nano-machines, self assembly techniques based on biological systems may help to control and coordinate many nano-machines.

Information: Molecules represent information in the form of chemical structure, sequence information, relative positioning, or concentration (e.g. protein, DNA [6], calcium propagation).

Probabilistic: Nano-machines probabilistically reacting to chemicals, in which unpredictable movement of molecules in the environment and random breakdown of molecules over time. The probabilistic environment of Nano-machines affects the design of molecular communication systems [7].

Bacterial Nano-networks: The bacterial nano-networks consists of carrier and nodes. Here the bacteria acts as carrier and nano-machine acts as node the nodes communicate with each other using carrier (bacteria) bacteria carry DNA molecule to the receiver through chemotaxis. The sender nano-machine will fetch the information into the bacteria and then the bacteria unload the information at the receiver.

Bacteria as Carrier: The information carrying bacteria's are rod-shaped, 2µm long and 1µm wide. The bacteria will maintain a uniform population in the medium by regulating reproduction cycle quorum sensing is used to regulate the population among bacteria. Bacteria's are ability to self-motion in the medium that they can swim and tumble using flagella in chemo-taxis process. The receiver emits chemo-attractant signal to attract bacteria the bacteria will able to sense via chemo-receptor and reach receiver.

Nano-Machine as Nodes: Nano-machines are devices that are able to perform computing, sensing and/or actuation task. The nodes will be bio-hybrid nano-machines ranging from 5 to 100 ìm diameter. A node has a DNA Processing Unit (DPU)[8], which is capable to encode strand of DNA. Nodes are identified by a two-tier address system, where each node has a physical address and a unique network address.

Social Behaviour of Bacteria: Bacteria are used to transfer information between nano-machines. More challenges are faced by bacteria to reach destination nano-machine successfully. To ensure reliable bacterial Nanonetworks through social interaction of bacteria within environment. There are two types of behaviour of bacteria, they are cooperative and non-cooperative. Bacteria's are capable to store information, decision making and learnt from past experiences.

Cooperative Behaviours: The cooperative behaviour of bacteria is to ensure nutrients, protect themselves from enemies like anti-biotic. It is observed that the bacteria performs sensing, distributed information processing, division of labour and supports gene-regulation of individual bacteria in the medium [9]. There are various cooperative behaviour of bacteria they are hierarchical organisation, foraging, cooperative sensing and protection.

Hierarchical Organisation: Due to some environmental stress, bacteria able to form spatial organisation colony in the environment. During environmental stress, the cooperation of bacteria is the production of lubricating layer of fluids Bacteria's are capable to protect and efficient resource usage by adjusting lubricant viscosity, in order to maintain high population density [10-12]. It can also form branching patterns Bacteria make use of maximal resources and cooperative decision by using branching mechanism.

Foraging: Bacteria can found cooperation in food consuming. Also in foraging process, bacteria's are able to cooperate in their growth and food source. The cell division is utilized to extend the bacterial colony.

Cooperative Sensing: Generally, there are two kinds of signalling molecules released and sensed by bacteria. They are attractive and repulsive chemo-taxis signalling. Using attractive signalling, a bacterium emits molecules to attract others towards them. In repulsive signalling, it emits chemicals which make other colonial bacteria to repulse away from themselves [13]. For this signalling quorum sensing is used.

Protection: Bacteria can work jointly to protect from population. In colony the edge bacteria's can cooperate in reduced reproduction process for less nutrient consumption due to nutrient scarcity. In some cases, the colonial bacteria may sucidically produce some chemicals, which kills other bacteria in order to protect their species.

Memory and Learning: Bacteria have characteristics of learnt from past experiences. During environmental stress bacteria will employ some strategy, which reshapes the colony pattern. These processes are done by emitting cooperative chemo tactic attractive signalling. The distribution of information will also do by bacterial colony, so that each bacterium's are capable of storing, processing and interpreting the information. If any environmental change occurs, bacteria can adapt themselves and perform cooperatively [14].

Learning can be done in two phase. In the first phase, both the colony and individual exchange bio-chemicals with others. In second phase, analyzes and interprets the information extracted from the environment.

Non-Cooperative Behaviour: The cooperative behaviour of bacteria is beneficial for individuals. There are various non-cooperative behaviour in bacteria they are clashes [15], competition in growth, cheating.

Competition in Growth: In limited resources, the bacteria utilize the nutrients, which affect other bacteria's to live. The scarcity of nutrient resources leads the bacteria to act selfish Fast growth will decrease the productivity of bio-films.

Cheating: During QS, there exists a reduction in population growth, thus the non-cooperative behaviour will increase the level of cooperative bacteria. The entire bio-film structure will be collapse, when the non-cooperators encountered the cooperative bacteria.

RESULTS AND DISCUSSION

The simulation is done with two nano-machines (nodes) which is source and destination nodes. The bacteria used as carrier to transmit the information from source to destination node. Consider the length between source and destination as "l"1 [16] if the bacterium takes time to reach receiver, the bacteria died and considered as packet loss. The bacteria is embedded with DNA molecules and fetch into source nanomachine, then the bacteria tumble and run towards destination due to the chemical signalling released from destination node. The transmission probability is determined using □ = *Nd*/*Ns*, where *Ns* and *Nd* denote the total number of bacteria released from the source nanomachine and the number of bacteria that reach the destination nanomachine, respectively.

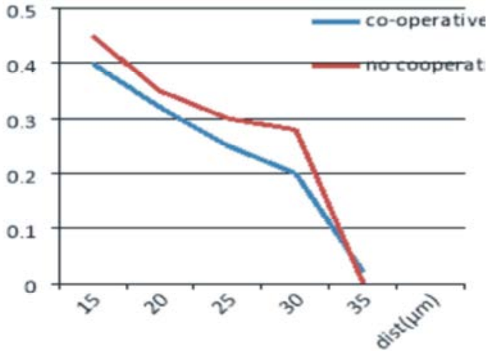

Fig. 4.1: Bacteria population vs gain

This analysis, the number of bacteria to be released in the network is shown in Fig 4.1. Here if number of bacteria increased, the relative gain gets lower. The relative gain is calculated by **Δ**□ = (□*cc* – □*nc*)/ □*nc.* where □*cc* and □*nc* denote the observed network reliability due to cooperative communication and non-cooperative communication. In these graph [17], the number of bacteria Ns=500, the percentage of relative gain is 13.6, but at Ns=300, the relative gain is 14.3. Thus, if number of bacteria exceeds certain range, the relative gain of the cooperative communication gets decreases.

In Figure 4.2 shows, the bacteria arriving the receiver by increasing the distance is analyzed. The distance is inversely proportional to the bacteria arriving at the destination node (nanomachine), since the lifetime of the bacteria is trivial. The factor is analysed by increasing distance between the bacteria's destinations.

Consider Y-axis as percentage of bacteria arriving at the receiver i.e., successful transmission, X-axis as distance between source and destination nanomachine. In these, if distance is 20, the no of bacteria arriving at the receiver is high i.e. 42%. When the distance is increased

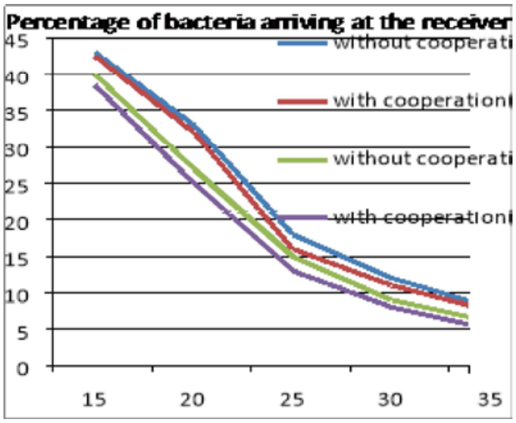

Fig. 4.2: Distance vs percentage of bacteria at receiver

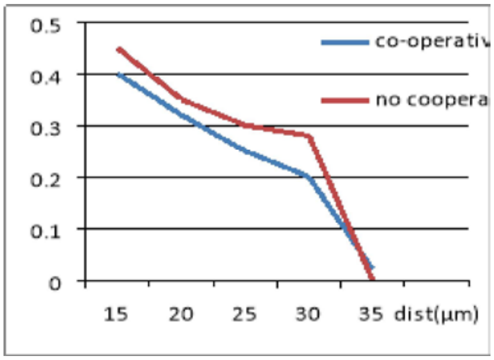

Fig. 4.3: Distance vs Successful transmission

further then the bacteria arriving rate is reduced to 13%. Thus it shows the bacteria's arriving the destination is inversely proportional to the distance between them. This is the case for the bacterium has no environmental factor issues. Now by considering the environmental condition, by issuing the packet transmission loss then analyze the same factor. For this, the distance of 20, the bacteria mobility is same as cooperative, while when the distance increased further the bacteria receiving rate decreases.

Figure 4.3 explains the successful transmission of the bacteria to the receiver. It is analyzed by increasing the distance between the destinations. The probability of successful transmission depends on the number of bacteria receiving at the receiver to the number of bacteria transmitted. It denotes for the cooperative the 60% of bacteria transmitted [18] successfully for the distance of 10 and for non-cooperative environmental factor rate becomes as 55%. While further increasing the distance [19], the successful transmission rate get decreases.

The Effect of Changes in the Chemo attractant Density is shown in Figure 4.4. In Fig. 4.4, as the density of the Chemo attractant increases, thus it increases the rate of information transfer. The bacteria reach destination successfully by which it sense the gradient of chemo attractant. However, still see the benefits of cooperative signalling, which helps to the directional movement of the bacteria toward the destination.

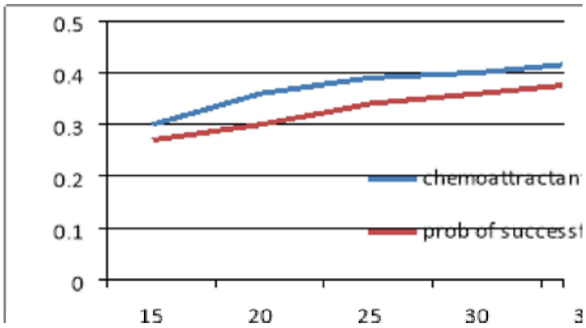

Fig. 4.4: Chemo attractant vs successful transmission

The relative gain in terms of the successful transmission probability (due to cooperation) with varying chemo attractant density is illustrated. In the low-density conditions, the effect of cooperative communication, the bacteria are unable to sense the chemo attractant gradient effectively [20], especially when the bacteria are far from the chemo attractant source. In such cases, the cooperative signalling molecules compensate the low chemo attractant density, leading to higher gains.

CONCLUSION

In this approach, analysis is done based on behaviour of bacteria by considering communication between two nano-machines (source and destination). The communication medium transfers the bacteria containing information is virtualized in the ns2 simulator. It involves the feasibility of the BN and, additionally, allows developing a Mathematical analysis of the network based on the available information on the biological phenomena. The nano-machine (node) involve as a transceiver by transferring the bacteria (packet) and by gathering the data. In this analysis, expressions for the delay, capacity of bacteria to tumble destination and communication range of the system. Based on the analyses of the bacterial communication was done.

The analyzed graph shows that, efficiency of the molecular communication using the bacteria. Using NS2 simulator conducts a performance evaluation based on varying time, distance between source and destination, density of chemical signalling, relation between number of bacteria and gain. Performance analysis for the single link using two nano-machines was done. It is extended for the group of nana-machines and parametric of the behaviour is analyze such as delay, capacity of bacteria to tumble destination and communication range of the system.

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