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RESEARCH ARTICLE

BACTERIAL NANO-NETWORK OPTIMIZATION USING WIRELESS ADHOC SENSORS

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ABSTRACT

Molecular communication is a paradigm for Nanomachines 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 Nanonetworks. The biological property of bacteria is ability to mobilize using chemo-taxis process 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. In this, multiple nano-machines are used to operate in multihop process. Thus to achieve efficiency, throughput and reduced delay by utilizing the property of social behaviour bacteria (co-operative). The simulation process is done to analyze the performance of bacterial Nanonetworks for molecular communication.

INTRODUCTION

Nano-Technology

Nano-technology is a new solutions for applications in bio-medical, industries, military etc**. . .** in nano-technology, nano-machines or nano-device is the major functional element**.** It performs like CPU which performs communication, computing, storing and also it performs sensing. There are two types of manufacturing process, they are bottom-up and top-down approaches. Manufacturing the nano-machine can be done by molecules. The assembly of such molecules are called as molecular manufacturing. Molecular engineering can develop new nano-machines for biological applications which is called molecular motors. Nano-networks are the inter-connection of multiple nano-machines or devices. Two communication approaches are developed in nano-networks such as electro-magnetic and molecular**.** The electro-magnetic is defined as the transmission and reception if electromagnetic waves**.** Molecular is defined as, the information is transmitted and received using molecules. There are various methods in molecular communication process they are walk-way based molecular, flow based molecular and diffusion based molecular.

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Molecular Communication

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. 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 vesicles 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. 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.

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, some form of chemical energy is used and propagation in a particular direction, ideally towards the meant receiver.

Bacterial nano-networks

The bacterial nano-networks consist of carrier and nodes. Here the bacteria acts as carrier and nano-machine acts as node and the nodes communicate with each other using carrier (bacteria) bacteria carry DNA molecule to the receiver through chemo-taxis. During transmission, the sender nano-machine will fetch the information into the bacteria (encoding) and then the bacteria unload the information at the receiver (decoding). The encoding of message is shown in figure.

MESSAGE: Source2XXXDestination8XXX
AminotransferasesXXXHIGH

Source TWO
TCAGATACGCGTTGCGAG ACTTGGGAT,

XXX Destination
GTAGTAGTAGATGAGTCAACTATAGACGCTACTATAGATGAC

Eight XXX
GAGATAGGGCATACTGTAGTAGTA

Aminotransferases
GCTATGATAGACGATACTCGTGCTGACTCATTTGAGCGTGCTTCAGAGTCA

XXX High
GTAGTAGTACATATAGGGCAT

Figure 2.1. Encoding process of message

The process of messages encoding into the bacteria are used in Sasitharan Balasubramaniam [4]. in the above figure, the message consist of address of source and destination and information. The information is that the enzyme aminotransferase is high in the medium. The normal message is converted into DNA base pairs such as A,G,T,C (Adinine, gynanine, thymine, cytosine).

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 quorum sensing, which 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 and 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 µm diameter. A node has a DNA Processing Unit (DPU), 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.

Co-Operative Behaviour of Bacteria

Sensing of bacteria

The cooperative behaviour of bacteria has that each individual bacterium able to sense the chemo-taxis signalling to communicate with each other for food. The mechanisms used behind the chemo-taxis process are attractive and repulsive. The bacteria will emit the attractive chemical signalling in the medium, thus to attract other bacteria for food. In case, if the food scarce occurs due to high population, bacteria emit repulsive signal to stay away the other bacteria's. Inter species message or food transferring is done by conjugation process.

Co-operative decision making

For co-operative decision making sporulation process is used. The sporulation process is that response of bacteria for growth conditions. During high population growth, bacteria should emit molecules which indicate about the growth. Thus each individual bacterium emit information about its growth population. Then decisions are taken by reading all messages i.e., information of growth and by sporulation, the majority vote is considered.

Learning

In the case of increased population growth, antibiotic is injected into the medium, to reduce the growth by killing unwanted or bacteria without message. Thus if the medium attains neutral condition (stable growth), the antibiotic effect is erased from the medium by bacteria. it is clear that bacteria can able to "learn" from the past experience. Also bacteria has memory to learnt from past.

Natural intelligence

Bacteria have the intelligence of exchanging internal and external information naturally. Especially the internally stored information is send to the external in which the information contains the condition of both internal and external.

Non co-operative Behaviour of Bacteria

The non co-operative behaviour of bacteria are clashes, competition in growth and 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.

SIMULATION RESULTS

The simulation is based on multi-hop process with considering the social behaviour of bacteria. Thus multipath route is founded and the efficient has been selected for communication between source and destination nano-machines. More number of nano-machines is used by considering that are stable in medium. Using engineered bacteria's the message are transferred. Especially using co-operative characteristic the bacteria will communicate with each other through conjugation process. Using these simulation environment can able to calculate efficiency, throughput, packet delivery ratio. The results are discussed below.

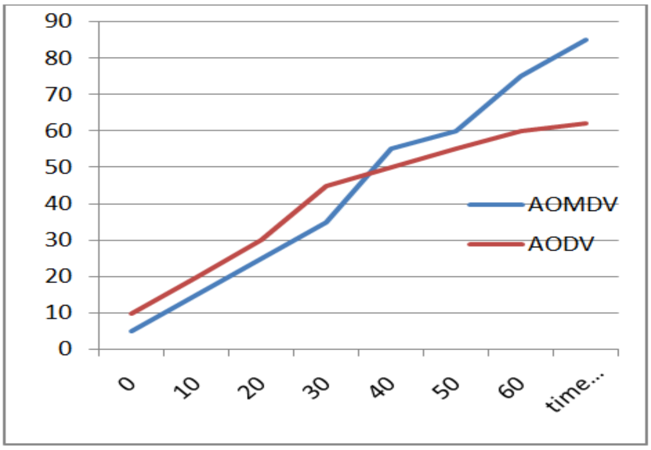

Fig. 5.1. Packet Delivery Ratio Vs Time

In the above figure, the packet delivery ratio is calculated. Using co-operative behaviour of bacteria, the packet delivery is increased. The packet delivery ratio (PDR) is defined as the ratio between the number of packet successfully transmitted to total number of packet transmitted. In these simulation process, AOMDV (Adhoc multipath On-demand Distance Vector) routing protocol is used. On comparing with AODV, AOMDV is very efficient in attains successful transmission. In AOMDV routing protocol, multipath is founded for achieving high packet delivery ratio (PDR) also it find efficient path which reduces delay. If the efficient path fail to deliver packet due to mobility of bacteria, the immediate alternate path is chosen for transmission which should efficient then previous path. Hence on using multipath, the packet delivery ratio is increased. In figure 5.2 the delay parameter is calculated. In these, the delay is defined with respect to time. When the transmission time increased i.e, delay occurs, the collusion occurs in the medium. Collusion occurs between bacteria during transmission of packet. In figure 5.3efficieny is estimated. The efficiency is defined as that the ratio between the received packets to transmitted packets. The efficiency is based on the bacteria usage. The bacteria's should efficiently communicate each other to achieve high efficiency.

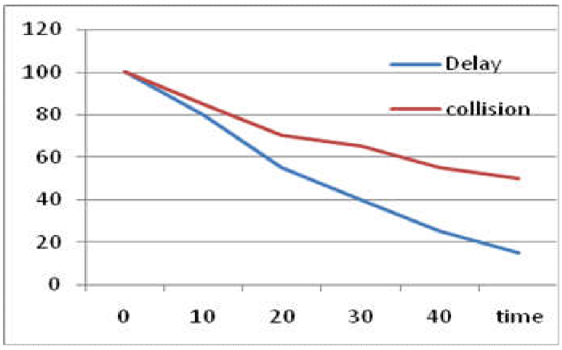

Figure 5.2. Delay Vs Collusion

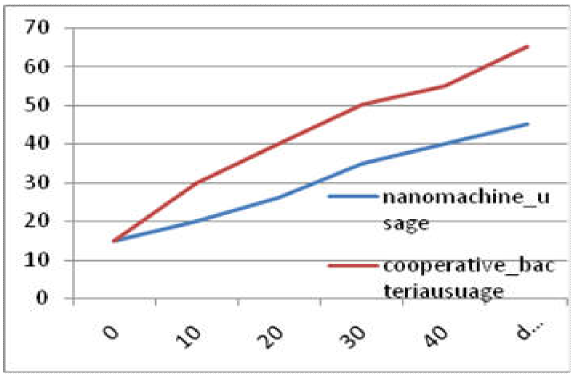

Figure 5.3. Efficiency

The efficiency is compared between normal bacterial communication and co-operative behaviour bacterial communication. In normal bacterial nano-network communication, the bacterial behaviour is not considered, the behaviour of bacteria are sensing, memory, learning etc. Such that utilizing these characteristics the efficiency is increased. increased population growth, antibiotic is injected into the medium, to reduce the growth by killing unwanted or bacteria without message. Thus if the medium attains neutral condition (stable growth), the antibiotic effect is erased from the medium by bacteria. it is clear that bacteria can able to "learn" from the past experience. Also bacteria has memory to learnt from past.

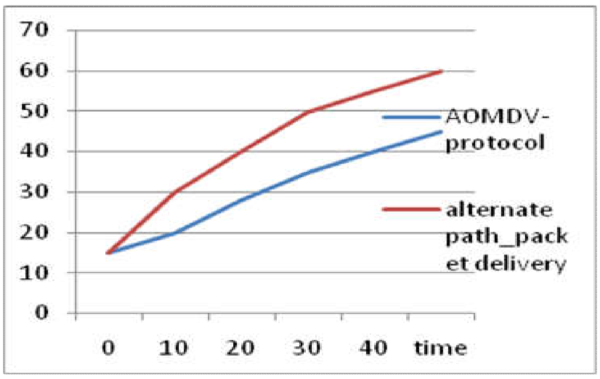

Figure 5.4. Throughput Vs Time

The throughput is determined using the one of the characteristic of bacteria is, co-operative decision making sporulation process is used. The sporulation process is that response of bacteria for growth conditions. During high population growth, bacteria should emit molecules which indicate about the growth. Thus each individual bacterium emit information about its growth population. Then decisions are taken by reading all messages i.e., information of growth and by sporulation, the majority vote is considered. Due to these co-operative behaviour, the throughput is effectively increased.

CONCLUSION

In this approach, analysis is done based on behaviour of bacteria by considering communication between multiple 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, throughput, packet delivery ratio, efficiency, 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 multi-link using multiple nano-machines was done.

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