Molecular Receptor Antennas for Nano Communication: An Overview

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Abstract- Recent innovations in electronics and nano-photonics have covered the way for manufacturing of computer processors, memories sections, batteries, transceiver, antennas and sensing units at nano-scales. A nano based gadget is an integrated device with dimensions in nano regime and able to do simple tasks Antennas are very important parts of electronic assemblies and play significant role during communication. Antennas are actually hardware based powerful communication tools working at lower and very high frequency operations. Molecular antennas can play an important role in applications such as dentistry, biomedical, environmental monitoring, industrial and defense purposes. Many novel nano-scale communication options have been currently proposed. However, there are four main nano-scale communication techniques such as nano mechanical, acoustic, molecular and electromagnetic communications. In this review paper, basic concept, features/properties, fabrication modals for molecular level antennas have been discussed. Nano level antennas are the backbones for future nano electronics or molecular electronics based applications.

Keywords: *Molecular receptor antenna, nano-electronics, nano communication networks.*

I. INTRODUCTION

Nanotechnology has opened up the opportunity to manipulate individual molecules to design molecular-size machines, i.e., nano devices, which can perform very basic tasks such as sensing, actuating, computing and data storing. A nano object is an integrated device around 10 nm to 100 nm in size and able to do simple tasks such as sensing, plain computation, communication and molecular receptors acting as antennas [1]. A nano-network is formed by connecting nano devices or machines; therefore it is able to perform more complicated tasks such as drug delivery, health monitoring and detection of biological or chemical attacks in nano-scale environments by cooperation of nano based devices [2]. By networking of nano devices, they can carry out macro level objectives and work over a larger area. Due to small size and limited capabilities of nano devices, traditional communication mechanisms are inapplicable in nano-networks [3]. Many novel nano-scale communication approaches for designing molecular antennas are currently proposed. In general, there are four main techniques in nano-scale communication: (i) nano mechanical (ii) acoustic (iii) molecular and (iv) electromagnetic communications [4].

In nano mechanical communication, the information is transmitted by a mechanical contact between transmitter and receiver. An acoustic communication is defined as the transmission of information through acoustic energy such as pressure variations. In molecular communication, the information is encoded in molecules which move as carriers from the transmitter nano-machine to receiver nano-machine. Electromagnetic communication is based on the modulation and demodulation of electromagnetic waves using components that are made based on novel nano materials [1-2, 5]. In acoustic communication, the traditional acoustic transducers and radio frequency transceivers cannot be integrated at a nano-scale device because of their size and communication principle. Moreover, in nano mechanical communication, a physical and direct contact is needed between transmitter and receiver nano-machines. Therefore, the molecular and electromagnetic communications are the most promising approaches for nano-networking [6]. This paper discusses the molecular receptor antenna as most studied nano-scale approach for molecular wireless communication.

II. MOLECULAR TRANSMISSION RECEPTOR ANTENNAS

Due to the extremely small size of nano-machines, the physical communication channels in nano-networks differ from those of conventional wired or wireless channels used in todays popular network realizations. In nano-networks, in addition to physics, chemistry and biology are also important for modeling the physical layer communications, in con trast to the conventional communication networks [6]. Nano devices can be artificially made from nano materials or naturally found in biological systems such as biological cell. There are three approaches for the development of nano based devices: (i) Top-down (ii) bottom-up and (iii) bio-inspired approaches. Top-down approach is defined as downscaling of microelectronic and micro-electro-mechanical devices to develop a nano device. For this goal, techniques such as electron beam lithography and micro-contact printing are used. The resulting nano device keeps the architecture of micro-scale components that they are manufactured from. In the bottom-up approach, the nano devices are developed by arranging the molecules unit together as molecular building blocks. But the technologies that can manufacture the molecular nano devices by this approach do not exist yet.

The third approach for the development of new nano objects or integrating them into a more complex system such as nano-robots/ molecular robots are bio-inspired. This approach is based on the features of future nano devices that already exist in a living cell, which can be seen as a self-replicating collection of nano devices [4, 7].The many of the biological nano objects can be found in cells, including nano-biosensors, biological data storing components, tools and control units [8]. The synthesis of molecular receptor antennas goes by chemical route. The synthesis modal for molecular receptor antenna during communication at nano scale is shown in this figure (1). A molecular transmission system should have three key elements consisting of the transmission, propagation and reception processes.

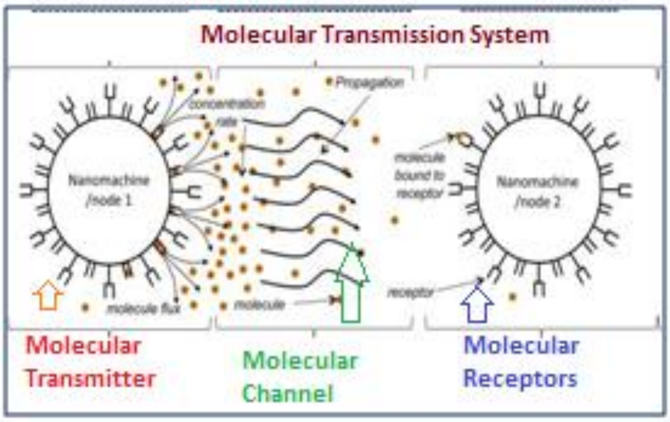

Fig.1: Molecular Transmitter-Receiver Communication

The transmitter nano devices in molecular systems use molecules for encoding and transmitting information [2]. Each transmitter has a limited store of messenger molecules. Whenever there is a message for transmission, the transmitter emits a specific amount of messenger molecules into the environment, which constitutes an information symbol.

In this molecular communication, the transmitter nano-device encodes the information in molecules and transmits them into the environment. The molecules move through the environment to the receiver nano-device with a certain probability [9].

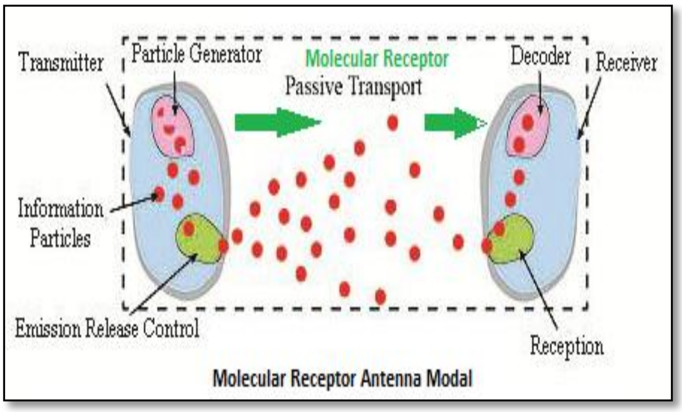

Fig.2: Molecular communication based on antenna receptors

Fig. (1) shows a scheme of a molecular nano-network with two transreceive nodes. Molecular communication uses active and passive transport methods to exchange information in the molecules (shown in figure 2). In active transport, the information is moved by chemical energy and consumes it to overcome its random motion in environment.

In passive method, information is randomly moved without using chemical energy and by forces in environment. It is clear that a high viscosity environment leads to slower diffusion of molecules. The transmitter involves the release and capture of molecules into/from the environment, as shown in figures (1) and (2). Molecules are released or absorbed by means of a molecule flux which is able to modulate the molecule concentration rate at transmitter location as a function of the time. During the diffusion process the molecules diffuse between the transmitter and the receiver following the trend of homogenizing their concentration. The molecule movement propagates the message that was encoded in the molecule concentration rate at the transmitter location. The channel delivers the message through variations on the molecule concentration at the receiver location, as a function of the time. In fact, the molecules are flowed based on a concentration gradient. Molecular communications is based on the idea of using molecules as information carriers. When a chemical receptor is bound to a molecule, it produces constant signal as output. The sum of all the receptor outputs provides the receiver with a reading of the local molecule concentration. Finally, the receiver decodes the message from the molecule concentration rate. Following a bio-inspired approach, it is envisioned that information can be encoded into concentration or type of molecules, and molecular messages can be delivered through diffusion in a fluid medium.

III. CODING AND TRANSMISSION METHODS OF MOLECULAR RECEPTORS

Two types of coding methods are introduced in nano communication based on molecular receptors antennas. The first method uses temporal concentration of specific molecules in the medium. According to the number of molecules per volume, the receptor antenna decodes the received information. This is similar to transport of information by time-varying sequences in traditional electronic communication networks. The second method for encoding information uses internal parameters of the molecules such as chemical structure, relative positioning of molecular elements or polarization. However, for decoding of information, the receiving receptor antenna must be able to detect these specific molecules [9].Transmission among various nano devices may employ three molecular modulation techniques for communications:

Concentration Shift Keying (CSK): It is similar to PAM modulation. In this modulation, only one type of molecule is used and messages are encoded by different levels (amounts) of released molecules.

Pulse Position Modulation (PPM): only one type of molecule is used and messages are encoded by transmitting single pulses in different time shifts.

Molecule Shift Keying (MoSK): In this keying messages are encoded by transmission of different types of molecules. The propagation of emitted messenger molecules in molecular communication channels is accomplished mainly by a thermally activated diffusion mechanism in which messenger molecules advance from regions of high concentration to those of low concentration via random collisions with the underlying medium.

IV.COMMUNICATION RANGES FOR MOLECULAR RECEPTORS

Basically there are three types of communication ranges for molecular receptor antennas**.** These are (i) Short range (ii) Medium range and (iii) Long range molecular receptor communications.

In the short-range molecular receptor communications, the communication ranges is from nm to mm such as intra cell and inter cell communications. Molecular motors and calcium signaling are two examples of short range communications techniques.

Molecular motors are biological nano-devices or machines for transporting vital particle among living organisms. Molecular motors such as Kinesin and Dynein are protein complexes that convert chemical energy to motion [1,10]. They are communication carrier for nano-machines within a short-range communication [6,8].The molecular motors move uni-directionally along microtubules. The polarity of microtubule determines the direction of molecular motors. For example, kinesin moves toward the (+) end and dynein tends to the (–) end of the microtubule.

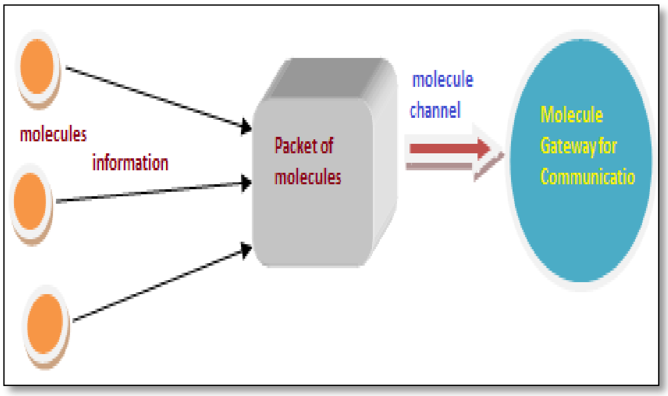

Fig.3: Molecular Processing Unit for Communication

Therefore, the use of different molecular motors such as kinesin and dynein or a pair of opposite microtubule between two nano-machines can form a bidirectional communication link.

In short-range molecular communication such as molecular signaling, the transmission delay of a particle in a certain distance, increases quadratically with distance. Thus, the existing short-range molecular communication schemes are not effective for the distances longer than a few µm. Hence medium-range molecular communication is used for distances from µm to mm. In this type of communication, the nano devices will be able to communicate by DNA nucleotides, including Adenine, Thymine, Cytosine and Guanine (A, T, C, G). The transmitter nano device inserts the information into a set of DNA base pairs that called DNA packet. The whole DNA sequence is encapsulated in a vesicle and is transported by short-range communication to the transmitter gateway. When this information reaches to the transmitter gateway, it will identify the location of receiver's gateway as shown in figure (3). If the receiver nano device is located at the transmitter gateway domain, it will send the DNA packet by using the point-to-point link to the receiver. Otherwise, the gateway will multiplex the packet and will send it by medium-range communication to the receiver's gateway [10].

V. APPLICATIONS OF MOLECULAR ANTENNAS

Recently molecular receptor antennas had been used in nano sensor networks for graphene and its derivatives such as CNTs (carbon nano tubes) and GNRs based molecular communication due to their prominent sensing capabilities. The usage of common frequency spectrum band ranges from hundreds of MHz to several GHz means that the size of antenna will be a few centimeter, which is impossible for nano-scale communication. If the size of classic antenna is reduced to a few hundred of nanometer, then it should be used for extremely high operating frequency in THz band. The graphene can be used to build nano antenna. A graphene nano antenna with length in micrometers can emit the electromagnetic waves within the range of few terahertz bands. Graphene like structres can be used to build an atom-precise antenna. A nano-dipole antenna can be manufactured by a single or a set of carbon nanotube. A single graphene nano ribbon can also be used to build a nano patch or nano array anteena. Besides of these applications, molecular receptor antennas can be used in molecular FET and chemical nano-sensor based networks.

VI. CONCLUSION

In this review paper the basic concept, features/properties, fabrication modals for molecular level receptor antennas have been discussed. Nano level antennas are the backbones for future molecular electronics based applications and are the promising communication options for nano-devices. Molecular receptor antennas may be useful for nano-transceiver, nano-power, nano-processor and nano-memory based communicative devices. The coding methods introduced in nano communication based on molecular receptors antennas will be totally different than the present communication techniques. Structural properties and optoelectronic properties etc. can affect the performance of such molecular devices.

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