An Anamnesis on the Internet of Nano Things (IoNT) for Biomedical Applications

Amruta Pattar, Arunkumar Lagashetty and Anuradha Savadi

Abstract This paper holds the data of broadly anamnesis and summery on internet of nano things (IoNT) for human services. This makes great possible to give the systematic and prognostic techniques and which in this way help in the medi cations of patients through correct bound pharmaceutical transport, tranquilize convey, tumor and various distinctive contamination's. The proposed study discusses the different network models of the IoNT and the architectural requirements for its implementation, which involves the different networking models, electromagnetic and molecular communication, channel modeling, information encoding, telemedicine aspects, and IoNT protocols.

Keywords IoNT · Molecular communication · Drugs delivery

1 Introduction

The recent developments in the area of the web known as the Internet of Things (IoT) have taken it to its next level of improvement by combining the nano sensors with IoT. Major developments and advancements in the field of nanotechnology, in combination with the internet, have arisen, Since the famous lecture on nanotechnology by Richard Feynman in 1959, the field has seen great progress and has also provided sophisticated devices with important applications, such as nanosensors, which helps in diagnosis at the molecular level and in turn can provide treatments, such as targeted drug delivery to tumor patients. The IoNT is one which relates in-depth to the internet of bio-nano things (IoBNT). Bio-nano things are those which can be defined as the special identification of basic structure and the functional unit that explains the work and the connectivity within the organic conditions.

A. Pattar (✉) · A. Lagashetty · A. Savadi
Appa Institute of Engineering and Technology, VTU, Kalaburgi, Karanataka, India
e-mail: amruta.pattar@yahoo.com

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Despite various papers published on nano gadgets every year, it is still not clear regarding how communication takes place between nano gadgets. There are two major and extensive aspects which is used by nanotechnology for the IoNT and they are electromagnetic communication, which uses radiowaves as the information carrier and molecular communication, where molecules are used as the information carriers. The molecular communication turns out to be better than electromagnetic communication as it shows a high energy efficiency, biocompatibility, and also has the competency to work in an aqueous medium which makes molecular communication much better for working on nano gadgets using the IoNT.

Molecular communication shows a good level of performance while using the IoNT as a communication media. Basically, molecular communication is all about invigorating the various molecules in the biological systems, since the communication is carried out by molecules. Molecular communication is one of the media which already exists in the natural world acting as an element between the nanoscales. Natural phenomena, such as intercellular and interbacterial communication are extremely helpful in providing essential information regarding the model of a nanonetwork. Figure 1 shows a simplified model of a molecular communication system. In this communication system, the encoded information of the transmitter is loaded on the molecules which are in turn called information molecules (proteins, ions, DNA, etc.). These information molecules are subsequently loaded onto the carrier molecules (molecular motors, etc.) and are then finally propagated to the receiver.

The main contribution of molecular communication is to provide a means to send, transport, and receive the molecules and it also adapts biological and artificially-created components such as sensors and reactors, which also facilitate communication between each other with the help of molecules. This is a major goal in the treatment of diseases at their molecular level, and helps in loading the drug at the particular area on the cancer cells.

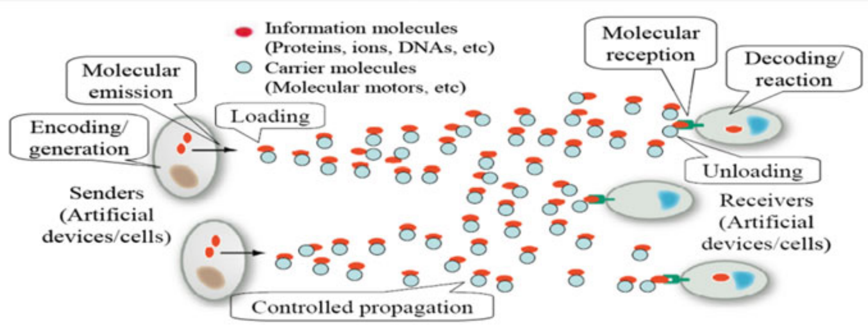

Fig. 1 A simple molecular communication system

2 Literature Review

The concept of the IoNT was initially plugged by the [1] were the author has described the summaried architecture for electromagnetic (EM) nanocommunication, which also embrace the basic concept of channel modeling, information coding, many other protocols. The author also describes the network architecture and discusses the interconnection of nanomachines with the accessible communication network system. Figure 2 characterize the basic introductory towards the IoNT which can retrieved in two distinctive manner, first the intrabody nanonetwork for healthcare, and second, the interconnected office.

The intrabody network is responsible in the facilitation of nanomachines, such as nanosensors and nanoactuators, which are deployed in the human body and can be operated with the help of remote, where the remote makes use of micro scale range by maintaining the major communication media as the internet. Whereas the interconnected office concerns each and every component regularly found in an office and an internal fragments are also equipped for a nanotransceiver which empowers them to be associated with the internet.

The paper entitled in [2] has come up with imaginative works of stack mode that allows the capture of unique characteristics of nanonetworks which is still in its early stages and is an active area of research. The author discusses the communication and networking aspects of the IoNT which involves the optimized version of layer-based models and non-layer-based models. The layer-based model is designed especially for nanonetworks and the protocol stack of this layer model is designed according to the following: application, transport, network, and finally the physical layer. It is maintained similarly from both the sender and the receiver sides. Whereas in the non-layer-based model, the protocol stack has the default assumption regarding nanonetworks, such as a multi-tiered, dynamic, and opportunistic hierarchical architecture that embraces nanomachines, nanorouters, and gateways. The author also also commented on the IoNT protocol stack,

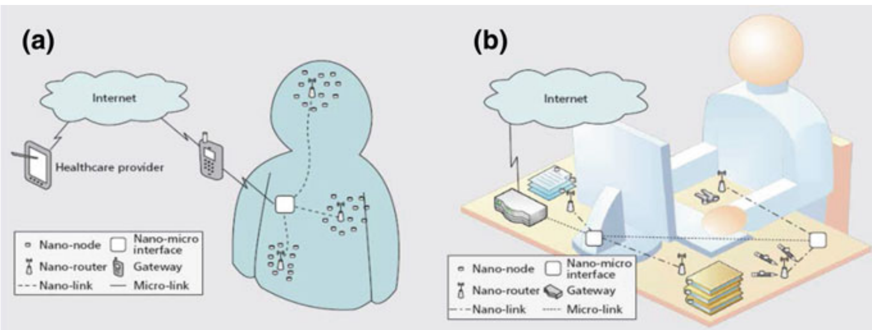

Fig. 2 Design of networks for the internet of nano things. **a** Intrabody nanonetwork for human services application. **b** The interconnected office

which includes an application layer, transport layer, network layer, medium access control layer, and a physical layer. The paper also tends to illustrate the importance towards significant applications, such as drug delivery and the effective detection of disease, for implementation in healthcare services.

The paper entitled in [3] describes the extensive study of networking and communication aspects which helps to understand the theoretical outcome of the physical implementation of molecular communication. The authors focused on the connectivity of molecular communication based on the IoNT in variable environmental conditions. The mathematical expression for connectivity is determined in terms of temperature (*temp*) and also the relative concentration of physical obstructions (x). The authors have also made use of MATLAB to reveal the state of physical obstruction when it gets implied with the change in accordance with the climate. Nanoscale network modeling is one of the major areas of study being carried out in the current research field, which also includes the major escalating of some of the parameters such as channel modeling, modulation and coding, receiver design, and reliability among others. For communication purposes, pheromones are used as signal carrier molecules, with the main drawback being that pheromones can be easily affected by changes in environmental conditions, such as temperature, or by physical obstacles resulting in a change in connectivity.

The paper entitled in [4] portrays avant-garde paradigm of the IoBNT, where the author discusses the origin of the IoBNT from a combination of synthetic biology and nanotechnology, which allows the engineering of computing devices with major help from biological components as shown in Fig. 3. The biological embedded computing device, which is based on biological cells and their functionalities in accordance with biochemical domains which incredibly promises the major purpose of sensing and actuation in the intrabody, and also helps in the environmental control of toxic agents and pollution. The author also describes the communication media used by the IoBNT, the major communication media used being molecular communication. In nature, the reciprocity of the information between cells is completely based on the synthesis, transformation, emission, propagation, and the receiving of molecules by making use of biochemical and physical processes. The challenges facing molecular communication in terms of engineering are also described by the author.

The paper entitled in [5] the author depicts the IoNT working in a telemedicine administrations chain, which also incorporates the investigation of frameworks for obtaining, preparation, and dissemination of therapeutic data which is enveloped in the worldwide creations. Figure 4 depicts remote health monitoring, which is nothing but smart healthcare. The author also discusses implants, sensors and nanosensors and their communication interface. The IBAN (implanted BAN) are one of the main specific grade, the sensors are used as implants and are placed in the human body and used as the node to communication with the outer world to improve monitoring.

As per the above figure, the architecture of remote health monitoring includes many classifications, such as

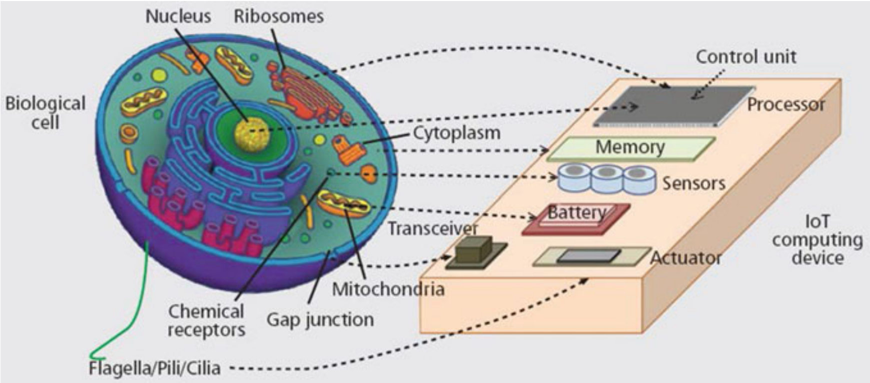

Fig. 3 Typical comonents of an IoT device and the elements of a biological cell

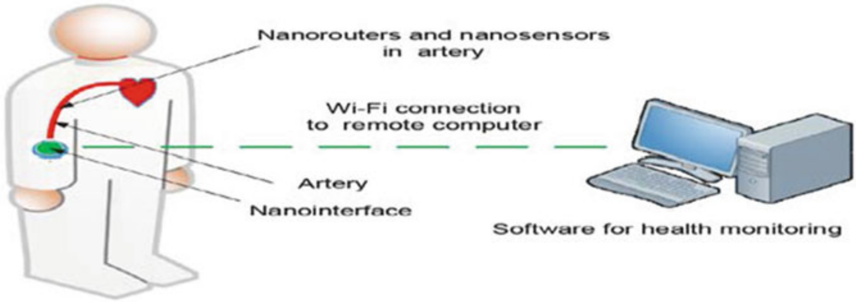

Fig. 4 Framework for observing wellbeing using WNSN and WBAN

- C-health—represents classical healthcare.
- E-health—electronic healthcare, which is also known as a subset of the c-health model using ICT.
- M-health—mobile healthcare, which makes use of mobile devices, and is also known as the subset of e-health.
- S-health—smart healthcare, helps in maintaining records, delivery data, and permissive prevention of health hazards.

As in [6] the author's main focus is to set a standard example of an IoBNT which has an extraordinary ability to set up the elimination of bio-nano devices from the internet source when it is required. This model imitates the apoptotic flagging pathways in living beings, where specific molecules are sent to cells to start their self-obliteration from the framework. Figures 5 and 6 represent the architectural model of the IoBNT. The main goal of the author is to focus on allowing the communication interface between the nanotransmitter and the other nanodevice by providing a deterministic model. The major work expressed here concerns the self-annihilation which explains the sending of the death command through the nanotransmitter, which has the capability to execute the received death command by using natural cells.

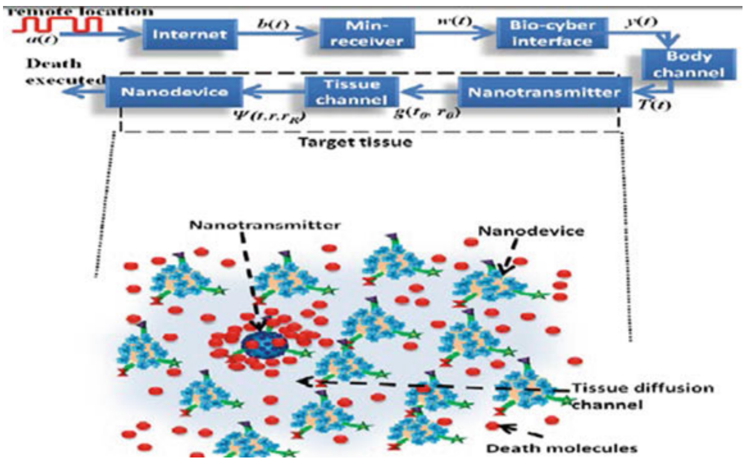

Fig. 5 Block diagram of diffusion-based IoBNT

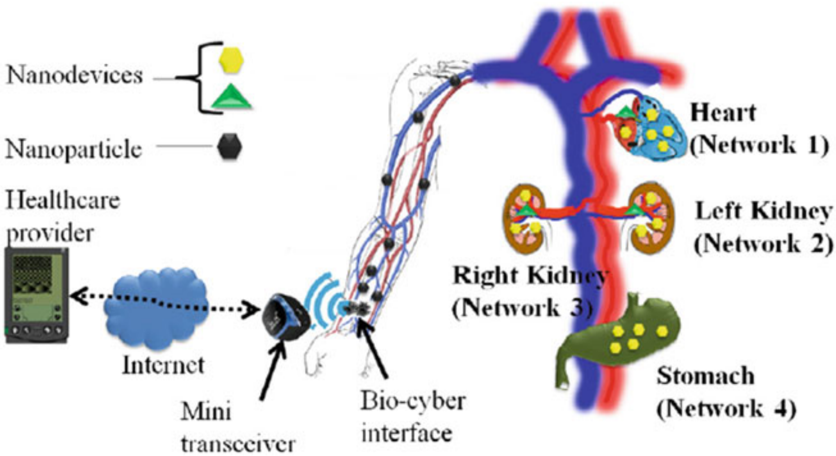

Fig. 6 Network architecture for the IoBNT

The paper entitled [7] the authors portray challenges, solutions, and applications in accordance with the IoNT which involves data collection, system architecture, routing technology, middleware, system management, data analysis, energy conversion, and other challenges, such as security and privacy. The main realization according to the author is the data collection regarding the IoNT, which in turn relates information from the nanosensors and their environmental condition according to which the system can handle the further process. The system architecture makes use of the data that has been collected by the device, which may not be so easy to process so the solution described by the author is to make use of *micro gateways.* Once the system architecture has completed the process, the next step is the routing technology. Routing technique is extremely important while the data is being transferred or received. This is made possible by the nanocommunication system which involves molecular and electromagnetic communication.

The paper entitled [8] depicts healthcare applications which incorporate different requirements, opportunities, and challenges. The author also introduces the basic classification of requirements relating to the generic application functionalities supported by the IoNT and also informs implementation and performance evaluation issues, particularly those which relate to deployment, communication, and coexistence with other networking paradigm. This paper describes the innovative smart technologies which were not previously feasible but are now easily accessible using wireless communication with high-end facilities. A body area network is used and this supports the near real-time sensing and also provides the reporting on the patient's various health conditions. This can be operated using mobile health (*M-health*) and also by the many health monitoring systems which provide for the monitoring of the health status of patients with the help of smartphones. The major aim of this paper is to convey the importance of the nanoscale in accordance with healthcare applications, such as diagnosing, treating, and monitoring, with the focus mainly on treating patients at the molecular level. The main advantage of the nanonetwork discussed by the author is that it has an ability to detect the availability of any imbalance regarding molecules, chemicals, or any kind of virus, and send an alert.

The paper entitled [9] depicts the current promises, future aspects and numerous applications in the area of the IoNT and also gives an extensive review of the IoT, IoE and IoNT, revealing the extreme extension of the IoT by implementing the IoNT. The main perspective is to focus on further studies which will mainly focus on industrial and biomedical areas. The author describes technologies which support the IoT mostly by the physical objects linked to the internet by the different methods of short-range wireless technologies such as ZigBee, RFID, sensor networks and also through location-based technologies. This paper focuses on describing the difference between these three techniques, which are an extension of one another which helps in the future technologies. The main concept which is been portrayed here is the improvement of the technology in terms of communication, such as person-to-person communication, person-to-machine, and now with the help of the IoNT, machine-to-machine communication within the body is possible.

The paper entitled [10] the paper emblematic the advancement of a novel radio channel demonstrate within the human skin at the terahertz, which will empower the association among potential nano-machines working in the bury cell regions of the human skin. The communication media used here is body-centric wireless communication (BCWC) which has been widely contemplated in the past at a range of frequencies. Since nanoscale technologies has attractive future potential to open up a large number of opportunities for making use of the latest nanomaterials, such as carbon tubes and graphene etc. As mentioned earlier, the main purpose of the author is to come up with unique idea of a channel model for use the skin, which considers all of the previously mentioned parameters and also undergoes blind testing for the analytical results which is carried out on the previous works done with the help of simulated data. The potential of the model suggested by author can also be evaluated by comparing it with measures of skin samples using THZ time-domain spectroscopy (THz-TDS).

3 Conclusion

This paper present a review on the IONT for healthcare applications. As per the requirement of new generation nanotechnology the communication between nanosensors and nanodevices within the human body is made possible by adopting the IOT technology such as molecular communication, electromagnetic communication, layer models, non-layer models, telemedicine, and embedded computing using biological cells. The paper also describes the major studies and novel thoughts of many author conveying the idea that the internet of nanothings looks as if it will be extremely helpful in the future, especially in the field of biomedicine, where the IoNT allows nanosensors to communicate with themselves and interface with the outer world according to human requirements.

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