Envisioning 6G Terahertz Communication for IoBNT Disease Detection Systems

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Abstract

The utilization of nanoscale devices within the human body opens up novel prospects within the domain of healthcare. One of the prospective applications that might arise in the 6G mobile network is the Internet of Bio-Nanothings (IoBNT), which envisions the interaction between biological cells or nanodevices and the Internet. In this paper, we propose a future detection system that diagnoses disease biomarkers online via intrabody terahertz communication channel and machine learning techniques. Moreover, we are discussing the mechanisms of biomarker detection, the data transmission interface, path loss and machine learning techniques for biomarker detection.

Ⅰ. Introduction

The upcoming 6G networking is expected to enable advanced health monitoring technologies, where nanoscale networking has emerged as a potentially promising communication paradigm. Nano-scale communication plays a crucial role in enabling various important applications in the fields of health care and environment. These applications include targeted drug delivery (TDD), internet-of-nano-things (IoNT), early detection of viruses, and environment monitoring [1]. As an example, precautionary measures can be especially crucial in safeguarding the health of the elderly, who may possess a diminished capacity for self-healing. It is anticipated that the IoBNT could enable hourly or even daily preventive monitoring, as opposed to the conventional method of health monitoring [2]. Terahertz (THz) communication systems are extensively used in various aspects for 6G, such as THz antenna design, THz Tx and Rx implementation, channel models, and path-loss. Graphene-based nanoscale antennas that facilitate intra-body communication connections exhibit efficacy within the frequency range of 0.1 THz to 1 THz However, when the signal propagates through the medium, these high electromagnetic (EM) frequencies result in substantial path losses, which drastically reduces the range of communication between nanodevices. In communication theory, intra-body connection attenuation and noise have been researched to accurately simulate the signal to noise ratio (SNR) metric. Several studies on THz signal path loss in blood and tissue reveal that communication within a few millimeters is possible [3]. Further, Molecular communication (MC) is of the utmost importance at the infinitesimal level in IoBNT systems. In MC is based on transmission of information molecules between biological cells, tissues and organisms. The MC channel consists of three elementary processes: transmission, propagation and reception.

Ⅱ. IoBNT System Model

Figure 1 shows the envisioned disease detection system. The proposed system is designed to perform three functions: First, the mobile nanomachine with sensing capabilities will detect cancer biomarker emitted by disease cell in the blood vessel. Second, upon successful detection, the mobile nanomachine sends sensed data to the outside world via a Bio-cyber interface (BC). Finally, the medical personnel receive this data and evaluate the cancer cell information using machine learning algorithms. It is important to note that the diffusion can be utilized to model the propagation mechanism of mobile nanomachines (MNs) and biomarkers within the blood vessels.

A system for the detection of comprehensive biomarkers utilizing mobile nano sensors was proposed in reference [4]. It is postulated that in a particular location within the blood vessel, proteins are secreted as a result of the existence of cancer cells. These proteins function as biomarkers for the cancer. After being released, the biomarkers travel through the blood vessel propelled by the circulation of blood and the process of diffusion. We inject a mobile nanomachine at a targeted location within the bloodstream. Biomarkers have varying degrees of activation potential in each MNs. In addition, MNs have the capability to measure the concentration of biomarkers. The MNs transmits the collected information to the bio-cyber interface

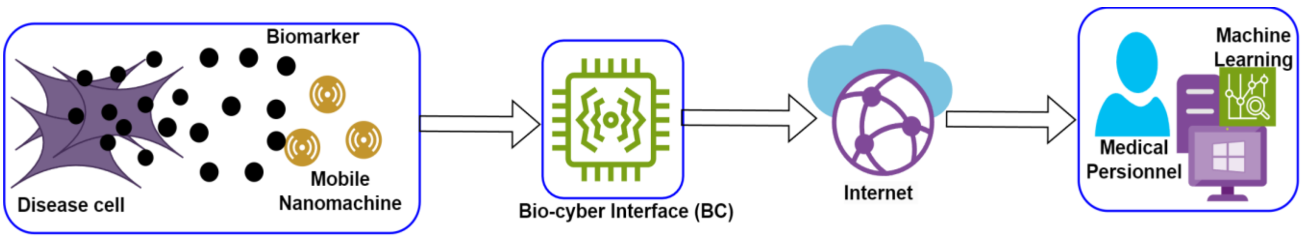

Figure.1. IoBNT Disease Detection System.

using a THz signal. The Bio-cyber interface (BC) is located on the patient's wrist skin or body part. The BC interface interprets the information represented by MN and transmits the results to the doctor via the surrounding gateway (or access point) and Internet network through wireless communication. In particular to note, "BC interfacing refers to a series of sequential operations designed to transform biochemical signals obtained from intra-body nanonetworks into electrical signals suitable for transmission over the Internet's cyber domain, and conversely". However, designing and modeling the BC interface is important but challenging to implement IoBNT.

Moreover, as computing algorithms, particularly machine learning (ML), continue to advance, more accurate signal modeling will become possible, leading to enhanced signal understanding. Machine learning (ML) has been widely used in cancer detection, leveraging its ability to analyze large datasets, identify patterns, and make predictions. Various ML algorithms have been applied to different types of cancer detection tasks. In [5], four ML classifiers (Random Forest, K-nearest neighbour(KNN), support vector machine (SVM), and convolutional neural network (CNN)) were used to detect breast cancer through combined biomarkers. Moreover, several ensembles of different ML-based classifiers were also tested for the classification of breast cancer [6].

The communication between the mobile nanomachine (MNs) and the bio-cyber interface. The system model for the communication link, which implies three layers of tissue blood vessel, tissue, and skin, is illustrated in Figure 2. As a consequence, nanosensors are required to transmit their data across all three layers. They accomplish this by utilizing sub-THz frequencies between 0.1 and 1 THz. The Intra-body connection attenuation and noise, including signal to noise ratio (SNR), are investigated from the standpoint of communication theory. Numerous studies examining the path loss of THz signals through blood and tissue have demonstrated that communication is feasible within a few millimeters [3]. The simple architecture, however making a compact antenna structure that can be transfused into the body is difficult. Nanotechnology helps make graphene and its derivatives.

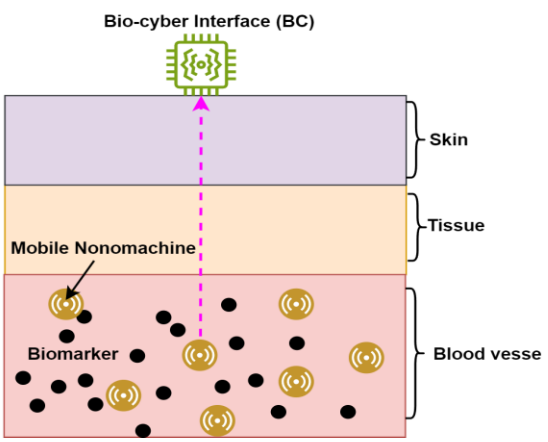

Figure. 2. Information transmission system via blood vessels, tissue, and skin.

Ⅲ. Conclusion

In this paper, we envisioned disease detection IoBNT system using the mobile nanomachine injected inside blood vessels based on disease detection using terahertz (THz) communication principles. The MN detects the presence of an abnormality by identifying biomarkers released by cancer cells. The output will be sent to the outside-world environment and further analyzed with machine learning techniques. The report of the diagnosis will be communicated to both the patient and the physicians. This concept aligns with the advancement of 6G communication technology, which envisions a future where everything would be interconnected.

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