Bio-Optical Communication: a case-study of Out-to-In Body Interface

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Abstract

Internet of bio nano things (IoBNT) is a recent concept which foresees the possibility to interconnect biological or artificial nano devices to the Internet. This would enable the inner part of the human body as part of the global network. One of the major challenge to provide this inter-connectivity is how to move the information from outside to inside the body. This paper proposes a bio-optical communication (BOC) as a potential solution. The paper proposes to use a visible light communication (VLC) LED-based lamp to send a message to the human brain using the eye retina as a relay node. In fact, the eye and the brain can be seen as a natural VLC receiver. We aim to demonstrate that a VLC signal with specific configuration parameters (frequency, etc.) can be successfully demodulated at the brain level and to provide analytically the channel capacity of the communication link.

Introduction

Molecular communications (MC), and more generally, Internet of bio nano things (IoBNT), have raised the interest of the scientific community in the last ten years [1]. The concept of human body as part of the global Network is a fascinating concept which can bring many benefits, from smart drugs to bio nano machines to cure the body from inside. The body owns already mechanisms to communicate, from microsystems, e.g., cell to cell, to macro-systems, e.g., endocrine or nervous system. The human nervous system (HNS) can be considered a ‘wired’ communication channel throughout the entire body. One of the major challenge in the field of IoBNT is how to move information from out to in the body, to interconnect inside (bio) nano devices to outside world [2]. The latest advances in nanotechnologies foresee the possibility to use HNS as a communication channel between two implanted devices [3]. In [4] a brain-to-brain interface is proposed. The interface is composed by a electroencephalography (EEG) to record brain signals and transcranial magnetic stimulation (TMS) to deliver information non-invasively to the other brain.

Our Contribution

In this paper, we propose the use of VLC [5] as a mechanism to provide information from outside to inside the human body. We want to study the possibility to use the HNS (from the retina to the brain) as a communication link without interfering with the usual activities of the brain neurons. Figure 1 shows the overall system architecture, and an example of communication system that uses HNS to carry information from out to in the body. In this particular case, human eye are used as bio-sensors for the communication system, while VLC provides the transmission. Referring to Figure, the proposed system consists of three channels: a free-space propagation channel between the LED lamp and the human eye, a HNS channel between the eye and the brain, and a channel from brain to sensor of the electroencephalogram (EEG) used to collect and analyse the brain signals.

The results of Hermann’s measurement campaign [6] led us to explore the possibility to carry external information from eye to brain. In fact, in [6], human subjects did not perceive flickering light above 30 Hz, while the EEG sensor received a valid signal until a frequency of 80 Hz. The frequency band from 30 to 80 Hz can be thus used to communicate data without disturbing the human senses. Sense-based communication approach can be generalized in the future: human senses, e.g., hearing, tasting or smelling, can be used to carry digital data from outside to inside the body.

Expected Results

We expect to provide a theoretical characterization of the channels depicted in Figure. In particular, we expect to analytically derive the channel capacity of the eye-to-brain channel, as well as the brain-to-EEG channel. An experimental test of the proposed system is under construction. We aim to provide the characterization of all the telecommunication blocks depicted in Figure and to prove the validity of the approach by sending a VLC signal and to correctly reconstruct it from EEG equipment. We also expect to study the main parameters for a reliable communication from outside to inside the body, i.e., frequency of the light and other modulation parameters.

Potential Applications

Apart from the already mentioned out-to-in body communication link, BOC can be used for several other applications. An EEG detector, integrated into the cranium, could receive data from outside (by a simple light), interpret it and relay or apply the information to other part of the body by means of molecular or nanoscale communications. As another example, BOC could be used as a method to detect which part of the environment the look of a person is directed. Assuming to be in a museum, the lamp illuminating a work could be VLC modulated with a specific code [7]. Once the eye of the person looks at the work, the EEG sensor can demodulate the VLC code and thus know which is the work and the location of the person. Moreover, BOC could be used to support augmented reality (AR) since it provides simpler eye-tracking compared to other technology.

Conclusions and Future Works

This paper aims to propose a possible approach to use human nervous system as a telecommunication channel to carry information in Internet of Bio-Nano Things Networks. We aim to demonstrate that a VLC lamp can be used to communicate a message to the human brain, using the retina as a relay node. We aimed to provide theoretically the channel capacity of the eye-to-brain link as well as from brain to EEG sensor. In addition, an experimental test is set to validate the possibility to send a known signal from VLC lamp and to recover it at brain level, by using an EEG to analyse the received signal. We are aware that this is a very first result, which just provide a feasibility study. Many additional work has to be done to implement a communication scheme from VLC lamp to the human nervous system. Once this channel is definitely validated, one future work should surely be to investigate how much it is secure [8] or how to make it secure.

References