

Live Substance in Cyberspace - Biodriver System

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Abstract— The internet of bio-nanothings has become an important research topic last years, because of the broad opportunities for the new applications that it provides. The key problem which should be solved is a creation of its-bio interface for integration of the living substance into the cyberspace. This paper formulates the general conjugation principle of a living substance with an info-communication system, and develops an integrated system enabling quantitative and qualitative measurements of the certain processes occurring in living organism with a feedback. The study reveals the design of an integrated system and the way of interaction between components can be organized. Further, the paper reviews the medical health status indicators that can be used in an integrated system for analyzing the processes occurring in the body. Then, the possible applications as well as the open research problems are presented.

Keywords— Internet of Things, it-bio interface, Internet of bio-nanothings, body area networks, health status monitoring

I. INTRODUCTION

Development of IT industry will inevitably affect the human lifestyle. It is worth noting that this strong influence is especially felt in the last few decades. The widespread adoption of the Internet and mobile telecommunication devices has led to a substantial dependence of the business. In some countries, the Internet is recognized on legal grounds as the inalienable right of citizens. We can assume that in the future the impact of infocommunications on a human society will be increasing and finally the reality and the cyberspace will merge into a common entity. Before it will be implemented, there is still a long way to go and the introduction of the Internet of Things concept can be considered as the first step on this path. This article focuses on one of the lines of the Internet of Things concept - the integration of the living matter into the cyber-space.

The paper is organized in following way: section 2 provides a brief overview of developments relating to Internet of the bio-nanothings and links to some of the works; in 3 section there is our formulated idea of the harmonic integration, which defines the general principle of the integration of the living matter in the cyberspace; sections 4,5,6 are devoted to describing the system of Biodriver; section 7 reviews the medical health indicators, which can be used to analyse processes in the body; in section 8 there are applications that

can be implemented on the basis of Biodriver; section 9 is the conclusion.

II. INTERNET OF BIO-NANOTHINGS

The development of the nanotechnologies, and the Internet of Things concept has led to the emergence of a new term – the "Internet nanothings." This term is used to refer networks in which the nodes are microscopic in size and that enables to interact with the processes occurring at the nanoscale [1]. Nodes in such networks are based on the use of the unique properties of innovative materials. One of the most striking examples of such materials is graphene. Experimental production of graphene and its unique properties were a powerful motivation to improve electronic components. It gives an opportunity to create the miniature electronic devices (nanomachines) which have a significant computing power. The topic of creating the nanomachines is not limited with the only use of electronic components. The issues of creating the nanonetworks with the biological components, the biological nanonetworks, are actively explored. In works [2] and [3] some aspects of the transmission of information by bacteria are considered. Meanwhile bacteria play a role of courier, carrying messages between two points. In [4] the possibility of using calcium metabolism between cells to transmit the information is examined. Attention was drawn to the idea of its using to create the biological neurons of the nanonetworks [5].

Research in the use of the biological components to create a communications network is not limited with the mentioned ones above. In general, based on an analysis of the literature on this subject, we can say that the construction of a communication network through the use of living organisms is possible.

III. THE IDEA OF HARMONIC INTEGRATION

We should highlight that one of the most important problems in the IT-Bio is the connection of the biological nanonetworks and the traditional communications networks. Let us ask a question: are the biological nanonetworks suitable for the transmission of the "traditional" types of the traffic (video, images, audio, etc.)? The ability of a network to transmit a particular type of the traffic is primarily characterized by a delay in the transmission of messages, jitter, bandwidth and losses. Perhaps in the future we will be able to achieve transmission parameters in the biological networks,

that are similar to the transmission parameters of traditional networks, but available research indicates that nowadays the transmission parameters in biological networks are far from the traditional networks. In our opinion, the current situation of biological networks is characterized by the following theses:

- the nowadays transmission parameters in the biological nanonetworks cannot be considered suitable for transmission of "traditional" types of information;
- functionality of a multicellular organism significantly exceeds the capabilities of its functionally differentiated structural components (organs and systems, tissues, cells) and/or microorganisms interacting with it in a parasitic, symbiotic or commensalistic way, it is achieved through evolutionary interaction between the cells (organismic level of organization of a living system) or microorganisms (micro-biome) that are part of a multicellular organism;
- communication networks and modes of information transmission that exist in a multicellular organism, are the product of a long, natural optimization process and are quite effective for solving the information exchange between the cells.

Based on this theses, the idea of harmonic integration is formulated, the essence of which is that connection of biological nanonetworks with traditional communications networks should be based on the use of ways of information exchange that is natural for biological nanonetworks and the natural type of the information. A schematic example of the connection of organisms to traditional networks based on the idea of harmonic integration is illustrated in Figure 1. Simply speaking, it is necessary to understand the language, in which biological organisms interact, and to use this language to connect them to traditional communications networks.

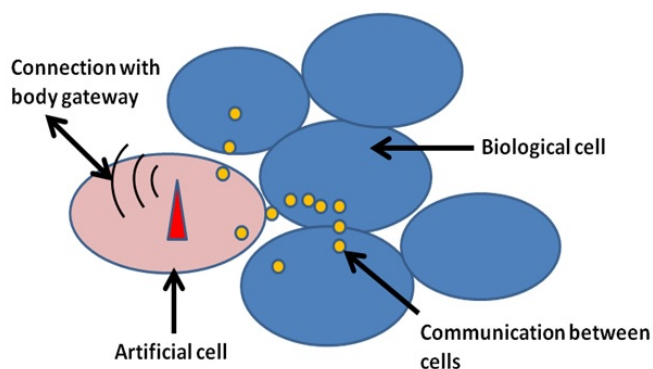


Figure 1. Connecting biological nanonetworks with traditional communication networks based on the idea of a harmonic integration

IV. BIODRIVER PROJECT

Existing research results in the field of Internet nanothings have brought us to the idea of creating a hybrid bioelectronic system in which the electronic computer centre takes part in the management of processes in the living matter. We called this project as Biodriver. The main elements of the system Biodriver are sensors, actuators, body-gateway and Computing Centre (Figure 2).

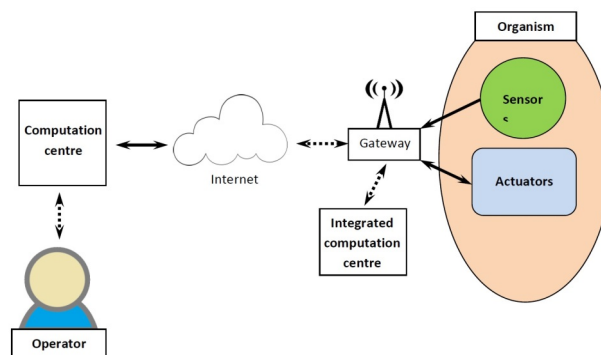


Figure 2. Block diagram of the system Biodriver

Sensors are necessary for registration and measurement of parameters that characterize the functional state of the controlled body. The role of the actuators is to exert influence on the body to affect the processes occurring in it. Work cycle of Biodriver system shown in Figure 3.

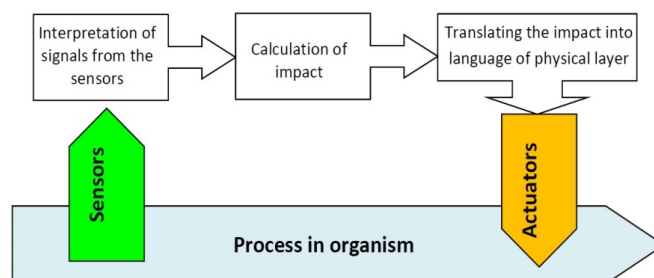


Figure 3. Work cycle of Biodriver system

V. CONNECTION BETWEEN BODY-GATEWAY AND ARTIFICIAL NANOMACHINES

Ensuring interaction of artificial nanomachines with the body-gateway is an important task, the solution of which depends directly on the system performance. Models of interaction of artificial nanomachines and body-gateway, should consider the following requirements:

- harmlessness to the body (exchange of data should not harm the body);
- error-protection (errors in transmission can lead to serious negative consequences);
- low delay (high delay in the information transmission will reduce the efficiency of the system);
- low power transceiver of nanomachines;
- a communication session should be initiated by the body-gateway;
- transceiver of nanomachine should have a very small size.

Data transmission between the body-gateway and the nanomachines initiates a gateway because of the need to reduce energy consumption of nanomachines. Session between the gateway and the nanomachines (sensor, actuator) is shown in Figure 4.

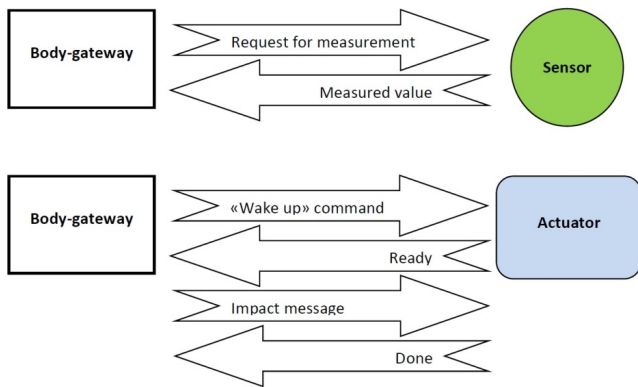


Figure 4. The sessions between body-gateway and nanomachines

One of the most promising methods for the data transfer between the nanomachines and body-gateway is to use electromagnetic wireless link operating in the radio frequency THz range [6], [7]. The main advantages of this method include the small-sized antenna required for emitting and receiving a signal. In addition to the preliminary estimates, the radiation in the THz range has no negative effect on living organisms. The main drawback is high signal loss while distribution in space that significantly limits the transmission distance; it is estimated that transmission range is limited to several meters.

We cannot exclude the possibility of using other means of communication between nanomachines and body-gateway. The channel may be based on the use of chemical, acoustic, electrical or other communication. However, the works that are devoted to the study of this question are unknown to the authors.

VI. CONNECTION BETWEEN BODY-GATEWAY AND COMPUTER CENTER

There are three options for interaction of body gateway with computer centre. The first option is to use only remote data centre. If system of the Biodriver is used to coordinate different organisms, which are aimed at achieving a common goal, to adequately calculate the impact on each individual body. A preliminary collection of data from all the organisms can be required. In this case, a local computer centre is not suitable for this task. The data from body gateway should be transferred to a remote computer centre, where information from all organisms will be consolidated, controlled and involved in the achievement of a common goal. Due to this fact it is necessary to solve the problem of optimal data collection from body gateways and the data relay to a remote data centre. It is difficult to offer a universal solution to this problem, each situation should be considered individually. Depending on the restrictions that are imposed on this process, the most appropriate option for the data collection from the body gateways can be implemented. There is a variety of opportunities for that - from the use of existing communications infrastructure (e.g., mobile network) to specific solutions, such as unmanned aerial vehicles [8].

The advantages of this option are:

- a virtually eliminated risk of intentional destruction, distortion or blocking of information while transferring the data between the computer centre and the body gateway;
- a performance of the system does not depend on the availability and quality of Internet access or other intermediate networks that are required for communication with a remote data centre.

Disadvantages of the second option are:

- an energy consumption of the body gateway is higher in comparison with the first option;
- the body gateway is larger than in the first option;
- a performance of the data centre is comparatively high;
- an ability to reflect external factors in the calculation of the impact on the body is significantly limited.

The third interaction option is combined. It is a synthesis of the previous two options. Combined option involves the pre-emptive use of the remote data centre, but at the same time there is also a local (integrated with the body gateway) simplified version of the computer centre, which carries out primary data processing functions as information protection, and has a basic set of functions that enables to exert the necessary impact on the body if the situation is critical and requires immediate response, but communication with the computer centre is missing.

Advantages of the combined method:

- due to pre-processing it is possible to reduce the amount of data that is transmitted to a remote computer centre, so that it reduces the network load;
- enable to promptly affect the body in a critical situation;
- comparing with the first method, a smaller dependence of the system on the intermediate networks that are required to communicate with a remote computing centre.

Disadvantages:

- a preliminary information processing adds a time delay in the cycle of the system;
- a size and power consumption of the body gateway are worse than the second method.

VII. MEDICAL INDICATORS OF HEALTH STATUS

Special attention should be paid to the task of collecting information about the processes in the body: in what points and how to collect this information? Are the cells, being placed for example, in hand, able to give information about the processes in the foot?

The organization complexity of the structural elements and the high specialization and differentiation of cellular elements of human, like any other highly organized multicellular organism involves assessment of the functional state of a biological object, including a real-time work, but at the microorganism level. Despite the fact that homeostasis of microorganism involves many regulatory systems (nervous, endocrine and humoral) and the importance of mechanisms (genetic, immunologic, and detoxification) is stressed, physiologists have distinguished three basic systems: neurohumoral regulation, connecting the nervous system and

body fluids (blood, lymph, interstitial fluid), and immunity. Though there are thousands of instrumental and laboratory values (parameters) of various body systems, about two hundred of them, that have clinical significance, are used in routine clinical practice, no more than fifty and about ten of them have integral value, characterizing the qualitative state of a biological object and the status of vital functions - the degree of health risk (Table 1).

The monitoring of vital functions or other vital signs or metabolism of a living organism is badly needed in various sectors: Experimental Medicine and Biology (to track the dynamics of the structures in a real time and / or at a distance), medicine extreme conditions (for the control of the certain categories of drivers and drivers working in high-pressure conditions, low oxygen partial pressure, emergency workers, law enforcement officers, military personnel) and sports medicine (to monitor the parameters of vital functions), real-time control of patients with chronic diseases (in violation of rhythm and conduction, epilepsy, diabetes), as well as for effective control of keeping the regime of patients with various physical or mental dependences (alcoholism, bulimia, drug abuse) and the effectiveness of control in the work associated with exposure to occupational hazards (monitoring of intake of toxic substances).

TABLE 1. INTEGRAL INDICATORS OF VITAL FUNCTIONS OF THE HUMAN BODY

Physiological Properties of the Organism	Research Method	Invasiveness with Respect to the Biological Object
electrophysiological activity myocardial	electrocardiography	skin contact electrode
electrophysiological brain activity	electroencephalography	contact skin electrodes
	electrocardiography	invasive electrodes placed on the cerebral cortex
blood circulation in the tissues	laser Doppler flowmetry	a fiber optic probe pin and a photo detector
peripheral circulation pulse wave	pulsometry	contact sensor
blood pressure in the central and peripheral vessels	tonometry	pin circular sensor that is placed around the limb
oxygen saturation of arterial blood (oxygenation, oxygen saturation)	oximetry (non-invasive Medical spectrophotometry)	contact optical emitter of different spectral composition and recorder

Based on the accumulated experience of several authors, thanatogenesis affects the circulatory system in extreme

situations in varying degrees. The most integral indicators for measuring vital signs are heart rate and blood oxygenation (oxygen saturation). Application of non-invasive hemodynamic monitoring to wounded and sick men is safe and inexpensive and provides accurate correlation with the state of the whole organism [9], [10], [11]. In medicine of the extreme conditions replicated devices are used in order to monitor the vital functions of the body, which are important for portability, functionality, reliability, ease of use.

VIII. APPLICATION OF THE BIODRIVER SYSTEM

The range of areas where the Biodriver system can be applied is extensive. The primary area of application is monitoring and control of processes of the human body. There are several areas, the most important of which are the medical applications. Implementation of the system Biodriver into medical practice will:

- timely provide self- and mutual prehospital help;
- realize real-time monitoring of the total number of the living subjects in the situations with an extremely high life risk (fighting, fires of high level of complexity, geoclimatic and man-made disasters);
- quickly assess the necessity of strength and the means for medical care and / or evacuation of the wounded and sick;
- carry out the primary processing of information and the health of the controlled man and implement decision support by a specialist;
- conduct a detailed medical history.

Another area where the possibility of Biodriver can be demanded is the entertainment industry, in particular the establishment of computer peripherals for PC gaming. Biodriver system can be used to create additional effects on the player, thus it will make the feelings during the gameplay more exciting and realistic. The functionality of the system Biodriver can also be claimed for the monitoring the group of people with high-risk health problems, for example, inmates of correctional institutions, psychiatric patients, patients of drug treatment clinics. In addition to monitoring and management of processes in the human body, the system Biodriver can be used for other purposes, involving the integration of cyberspace and living matter, the list of which is limited only by the imagination of researchers.

IX. CONCLUSION

The development of nanomachines that enables to connect the living matter to electronic computer systems and networks, opens up new opportunities to create vast amounts of applications to make life more comfortable and safe, as well as for new levels of quality of medical care. The project Biodriver was precisely initiated to achieve these humanitarian goals.

This article provides general information about the project, as well as theses that define the vector for the further research on this topic. We present the general scheme of interaction between system elements of Biodriver, some aspects of their operation are reviewed. Subject of research is at the

crossroads of several scientific areas: tele-communications, electrical engineering, medicine, biology and others. Due to this fact, experts of these areas were involved in the project.

Implement of research project requires from participants to look at the object of study from a different angle, which leads to appearance of the new problems in different fields of science, that earlier did not get into the field of researchers view. The main tasks that should be solved on the way to implement the system of Biodriver, include the following:

- development of a universal basic model of artificial nanomachines and its further use to create sensors and actuators;
- development of the body gateway;
- development of the effective ways to transmit information from the artificial nanomachines to the body gateway;
- a study of the data transfer between the body gateway and the Computing Centre;
- an analysis of the system security against the external Biodriver intentional and unintentional impacts;
- development of the algorithms for error protection during data transfer between the Biodriver system elements;
- development of the routing protocols in networks of the nanomachines;
- a search for effective ways to power the nanomachines and the body gateway;
- a study of the impact of prolonged high-frequency radiation (THz) on the living cells;
- a feasibility study of nanonetworks to improve methods of collecting information about the state of the organism.

According to some of these problems interim results are obtained, which will be presented in the subsequent publications.

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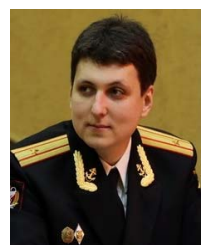
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