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# 14

# Ad-hoc Networks As an Enabler of Brain Spectroscopy

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## 1. Introduction

The purpose of this chapter is to show the feasibility of using ad-hoc networks as an enabler of brain spectroscopy. Ad-hoc networks have many applications. The application which this chapter explains provides full mobility in everyday environment using a near-infrared light sensor designed to monitor brain function in humans. Multiple wireless networks employing several different protocols are used for data carriage and provide new freedom to conduct tests in real environment outside a lab. An Ad-hoc network (Bluetooth) is one of the wireless networks used to support the application. The value of this application is to measure the changes in the concentration of oxyhemoglobin (HbO2) and deoxyhemoglobin (Hb) in tissues in the real-life environment. This might lead to better understanding of tissue pathologies. This type of application was not available before.

A fully mobile functional brain spectroscopy system has been developed to allow the possibility of testing subjects to be monitored in their real environment. To test this hypothesis, communication software was developed to allow for the collection of physiological data from a mobile near-infrared sensor via a mobile telephone that has a Bluetooth support. The developed application is used to track the changes in the concentrations of HbO2 and Hb during various activities and send the data to a computer at a remote monitoring site.

The specific aims of this application have been to build a fully mobile system to monitor the concentrations of HbO2 and Hb in near real time, to monitor the concentrations of HbO2 and Hb during smoking, as well as to analyze the gathered data, and to try to understand the correlation between HbO2 and Hb during smoking. Performance and data accuracy were the key for this application to provide the sought value.

Java portability allows the developed application to run on a wide range of operating systems and devices. Java Standard Edition (J2SE) was used for server code; Java Micro Edition (J2ME) was used to run code in the phone; C language was used to build the Bluetooth code and the protocol in the sensor; and Eclipse was used as the integrated development environments (IDE) to build and debug the application.

Java has native network support. It is possible to create applications to support different kinds of networks and protocols. Java has native libraries that support wired and wireless communications. It supports Bluetooth, WiFi, and more. Several popular network protocols and standards are also supported. By default, Java libraries support Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and binary stream communications.

In this application a reliable network is required. To meet part of reliability requirements, TCP protocol was fond to be the best supported protocol in the mobile device used in this system. TCP protocol is a reliable protocol used in communication when a reliable connection is required (Comer, 1997). It allows two hosts to communicate and exchange data streams and guarantees the data delivery (Stevens, 1994). Data packets are delivered in the same order they were sent. In contrast, UDP does not provide guaranteed delivery and does not guarantee packet ordering (Comer, 2007). Selecting which protocol to choose for a particular application mainly depends on the application requirements. These protocols have proven their value and made their way into Bluetooth and GSM networks. Bluetooth networks support both TCP and UDP communications (Bray & Sturman, 2002). Applications running on the Bluetooth networks can use any of these protocols to send and receive data. The most common way to send TCP and UDP packets over Bluetooth is using Bluetooth Radio Frequency Communications (RFCOMM) (Ganguli, 2002). RFCOMM is a transport protocol that provides RS-232 serial port emulation. Bluetooth Serial Port Profile (SPP) is based on this protocol (Huang, 2007; Bluetooth Core Specifications Version 2.1. 2007).

GSM networks are similar to Bluetooth networks and wired local area networks. They support TCP and UDP communication protocols (Delord et al., 1998; Eberspächer et al., 2001; Chakravorty et al., 2003). Since wireless networks support the same communication protocol as wired local area networks, applications running on wireless networks can communicate and exchange data with the applications running on wired local area networks.

Application level protocols are created to support specific applications. These protocols can run on top of either TCP or UDP protocols. KREIOS protocol and LayerPro protocol in this application are examples of such protocols. It contributes to the overall reliability of the application. KREIOS is a packet-oriented protocol created to support data exchange between the sensor used in this application and any other application running in another device (Arquatis GmbH, 2007). LayerPro is a protocol created in this research based on KERIOS protocol to allow global communication between the sensor, the PDA, and the server over Bluetooth and GSM networks.

The wireless sensor used in this application implemented KREIOS protocol, which was created by (Muhlemann, 2006) and implemented by Arquatis GmbH, Rieden Switzerland (Arquatis GmbH, 2007) in the wireless sensor. The KREIOS is a packet-oriented protocol between two devices: one acts as a master and the second one acts as a slave; both communicate through a request and response transaction. In this application, the master is the PDA and the slave is the sensor.

Several methods have been devised for imaging the human brain, in particular Electroencephalography (EEG), Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), Near-infrared Spectroscopy (NIRS), and Diffuse Optical Tomography (DOT). These methods vary in their strengths (Strangman et al., 2002). In recent years, researchers have started using NIRS and DOT, either alone or in combination with other methods, to image brain functions. The non-invasive nature of the NIRS is appealing to researchers to measure changes in HbO2 and Hb during brain function activities (Izzetoglu et al., 2003).

Functional Optical Brain Spectroscopy using Near-infrared Light (fNIRS) has been introduced as a new method to conduct functional brain analysis. fNIRS is a method that uses the reflection of infrared light to observe changes in the concentration of HbO2 and Hb

in the blood, and can provide a similar result to fMRI (Villringer & Chance, 1997). fNIRS takes advantage of the absorption and scattering of near-infrared light to provide information about brain activities (Gratton et al., 1997). For a long time, it was thought that it was only possible to collect information from the superficial layers of tissue (e.g., microscopy) due to light scattering. However, about 25 years ago, it was discovered that functional information could be obtained from brain tissue using light shone at the scalp and detected from the scalp (Jobsis, 1977). This discovery motivated the development of diffuse optics as a method for brain monitoring. This method has different names: Near-infrared Spectroscopy (NIRS), Diffuse Optical Tomography, and/or Near-infrared Imaging (NIRI). Today, several types of NIRS devices have been built to image brain functions. These devices differ in their capabilities, designs, and costs (Strangman et al., 2002; Bozkurt et al., 2005).

The NIRS devices can be classified into three main types: Continuous Wave Spectroscopy (CWS), Time-resolved Spectroscopy (TRS), and Frequency Domain Spectroscopy (FDS). The CWS device consists of a continuous light source, which transmits light waves with constant amplitude, and a detector that locates the attenuated incident light after it passes through the tissues. The TRS device transmits short incidents of light pulses into tissues and measures the light after it passes through the tissues. On the other hand, the FDS device transmits a sinusoidally modulated light wave into the tissue (Strangman et al., 2002).

Each of these types of NIRS devices has limitations and strengths (Hong et al., 1998). CWS has the advantage of low cost; however, with CWS it is difficult to distinguish contributions of absorption and scattering to light attenuation. FDS, on the other hand, is known for its good spatial resolution, penetration depth, and accurate separation of absorption and scattering effects. Nevertheless, FDS is significantly more expensive than CWS. As for TRS, although theoretically, it can provide a better spatial resolution than FDS, it has a lower signal-to-noise ratio. Since TRS requires short pulsed lasers and photon counting detection, it is the most expensive type of the NIRS instrumentation. Despite the advancements in NIRS technology, NIRS still has limitations, such as the short path length and the artifacts' movements during measurements.

Absorption and scattering are the main physical processes affecting the transmission of light photons in tissues. Light photon absorption and scattering causes the light intensity to decrease. Both absorption and scattering are wavelength dependent. The amount of absorbed light photons is also impacted by the concentration of blood HbO2 and Hb in tissues which vary in time, reflecting physiological changes in tissues' optical properties (Villringer & Chance, 1997).

When light photons travel through tissues, they are scattered several times before finally reaching the receiver. Scattering increases light optical path length, causing photons to spend more time in tissues which in turn affects the tissues' absorption characteristics.

Despite the fact that both absorption and scattering play a major role in light transmission, scattering is more dominant than absorption. When light travels through tissues and blood, photon absorption leads to a loss of energy to tissues and blood chromophores, or induces either fluorescence (or delayed fluorescence), or phosphorescence. The main substances of biological tissues that contribute to light photon absorption in the near-infrared light are water, fat, and hemoglobin. While water and fat remain fairly constant over a short period of time, the concentrations of oxygenated and deoxygenated hemoglobin change according to the function and metabolism of the tissues. Thus, the corresponding changes in absorption can provide clinically useful physiological information (Villringer & Chance, 1997).

Near-infrared light, in the range of 700-900 nm, can travel relatively deep into body tissues. It is also worth mentioning that such light can easily travel through soft tissues and bones, such as those of neonates and infants. Therefore, it is suitable to use near-infrared devices to monitor brain activities or other oxygen-dependent organs in this category of humans (Germon et al., 1998).

NIRS relies on a simple principle: light in the range of near-infrared light emitted on the organ of interest passes through the different layers above the organ. When it passes through the tissues, light photons go through physical interactions, such as scattering and absorption that leads to a loss of energy in the emitted light. When the remaining light exits the organ, it is measured by a detector.

In neuroimaging applications, the light is injected through the scalp, so the photons pass through several layers of tissue surrounding the brain, such as the scalp, skull, Cerebrospinal Fluid (CSF) and meninges. Then, the NIR light reaches the brain and the blood vessels, and backscattered light gets detected by a set of detectors. The light in this case follows the so-called banana-shaped path due to scattering effects caused by the tissues. Due to the fact that water and lipids are relatively transparent to near-infrared light and the optical properties of the layers surrounding the brain and blood are fixed within a given period of time, it was found that light is mainly absorbed by oxygenated and deoxygenated hemoglobin. Here, it must be noted that the scattering of the near-infrared light in the human tissues is much larger than its absorption, while absorption of this kind of light is much larger in the blood. This leads to the belief that the optical properties of the blood, which in fact change based on the amount of oxygen in the blood, can play a vital role in determining the amount of backscattered light from the brain. The amount of blood volume and blood oxygen concentration can be an indicator of hemodynamic activities that are related to brain functions. Analyzing the amount of backscattered light during the oxygenation and deoxygenation process of the blood flow in the brain can lead to a better understanding of the brain function (Benni et al., 1995).

NIRS measures the optical properties of HbO2 and Hb in near-infrared light. The effects of the changes in concentration levels of HbO2 and Hb in the blood stream on light absorption can be described by the Beer-Lambert's Law. A Modified Beer-Lambert Law can be used to predict the amount of blood chromophoers (HbO2 and Hb) in tissues (Bozkurt et al., 2005).

## 2. Brain spectroscopy

Functional brain imaging using fMRI and Positron Imaging Tomography (PET) have increased our understanding of the neural circuits that support cognitive and emotional processes (Cabeza & Nyberg, 2000; Davidson & Sutton, 1995). However, these methods are expensive, uncomfortable, and might have side effects such as exposure to radioactive materials (with PET) or loud noises (with fMRI) (Hong et al., 1998; Chance et al.,1993). Such disadvantages make these imaging methods inappropriate for many uses that require the monitoring of brain activities under daily, real-life conditions.

Functional Optical Brain Spectroscopy Using Near-infrared Light (fNIRS) is another method to conduct functional brain analysis. fNIRS is a non-invasive method that uses infrared light reflection to gather changes in the concentration of HbO2 and Hb in the blood(Jobsis, 1977). The main advantages of fNIRS are: ability to measure concentration of chemical substance; device's low cost; device's low power requirements; non-invasiveness nature, and device's portability. Low cost and portability have made it possible to use fNIRS to monitor patients

in their homes for an extended period of time, allowing health care providers to monitor slowly developing diseases in patients. The non-invasive nature of fNIRS has also made it possible to perform as many tests as needed without worrying about side effects (Boas et al., 2002).

Blood carries oxygen and nutrients to tissues. Also, it carries carbon dioxide and other products of metabolism away from tissues, so the body can eliminate them. Red blood cells contain hemoglobin, which is the main oxygen transporter. When the red blood cells pass through the lungs, they collect oxygen where it becomes bound with the hemoglobin. Furthermore, red blood cells release carbon dioxide to the lungs. Blood vessels form a comprehensive network inside the body where they deliver blood to different tissues and organs. Arteries, arterioles, and capillaries deliver oxygenated blood to tissues whereas veins and venules collect deoxygenated blood from them (Boas et al., 2002).

The human brain is protected by several layers. These layers provide a safe and secure environment for the brain. Near-infrared light, used to measure changes in the blood oxygenation, has to pass through all the protective layers: scalp, periosteum, skull, and the meninges (Fig. 1). The meninges contain three layers: dura mater, arachnoid mater, and pia mater (Porth, 2005).

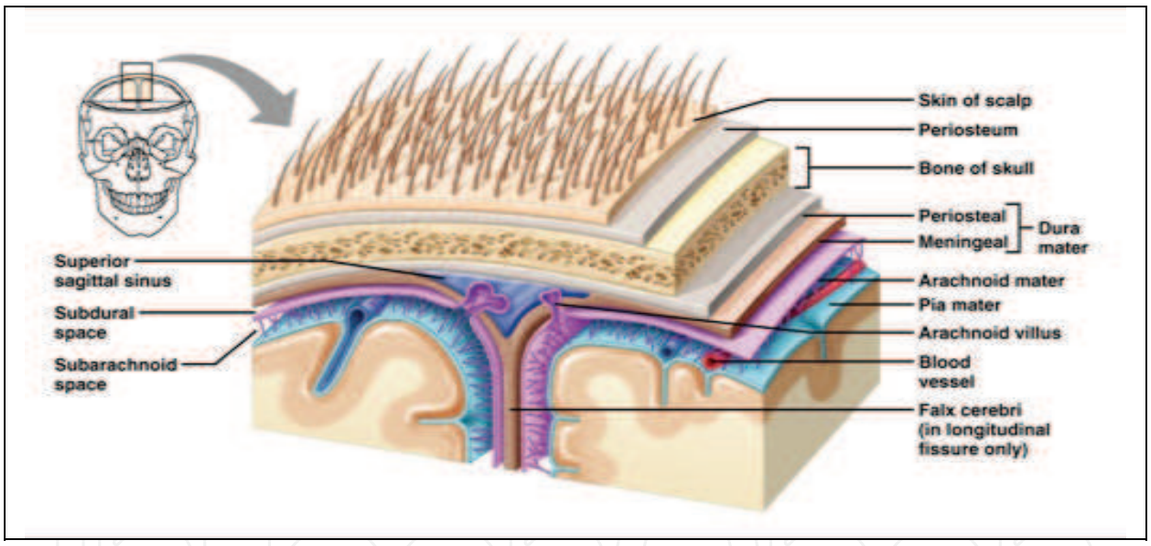



Fig. 1. The Brain's Protective Layers [18]

## 3. System design

The system developed for this application consists of three main hardware components. The first component is a Bluetooth wireless sensor (built by Arquatis GmbH, Rieden, Switzerland), which is the data acquisition device (Muhlemann, 2006; Muhlemann et al., 2006). The second component is a PDA and is the main controller for the measurement process and the data communication bridge between the sensor and the central computer. The third component is a central computer (Server, or Host Computer, or PC) that stores the data for later analysis. See Fig. 2 for a full display of the system's architecture.

Two different ranges of communication are used in the developed system. First, the communication between the sensor and the PDA is carried over a Bluetooth network. The

signal range between the PDA and the sensor is approximately 10 m (short range). This short range is enough to perform bedside monitoring without the need to carry the PDA. The other range of communication occurs between the PDA and the central computer and is carried over the GSM network (wide range). The range of the GSM is very wide indeed since the system employs the mobile phone network with a roaming feature. Technically, it is possible to monitor a test subject wearing the sensor in any part of the world as long as they are within the range of a GSM network with roaming capabilities.
The PDA and the sensor are light weight devices that make it possible to carry them easily. The sensor has a set of programs developed in the C language required to enable the data acquisition and data transmission. The PDA runs the Java ME program that performs the data transmission between the sensor and the host PC. The host PC works as a server and a database server as well. Additionally, the PC is configured with a public IP address to make it accessible through the Internet and to the GSM network. The communication between the PDA and the sensor is bidirectional and the communication between the PDA and the PC is unidirectional – from the PDA to the server.
The combination of these communication technologies allowed the creation of a fully mobile system for Functional Optical Brain Spectroscopy using Near-infrared Light (fNIRS) technology extending the range and the mobility of an existing solution (78; 79; Muhlemann et al., 2006; Trajkovic, 2006).

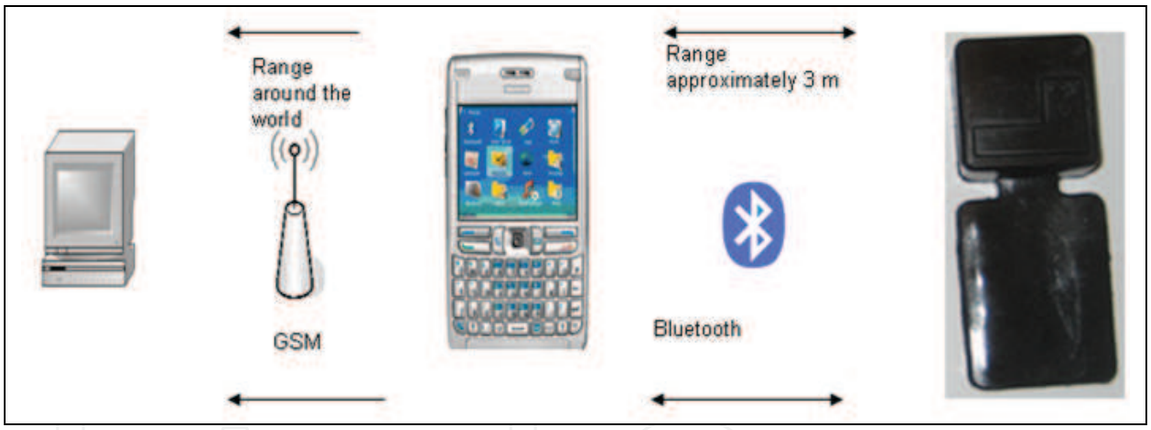



Fig. 2. System Architecture

## 4. Protocols and algorithms

Initially the system used HTTP protocol as a data encapsulation protocol. HTTP protocol is designed to be a request-response protocol to transmit text based data. This makes it not suitable for binary transmission without adding performance overhead.
This application required continuous fast binary data upload. After reviewing existing upload protocols and approaches, we came to conclusion that a new protocol is needed to be created. Performance and native binary upload were key requirements for the protocol. Based on the requirements the protocol was designed and extended KERIOS protocol. The protocol achieved the requirement through minimizing the control data and the number of the overall transactions. Moreover the protocol packet was designed to hold binary data which reduced the data representation overhead.

The protocol (see Fig. 3) for this application was created to encapsulate only the acquired data and send it to the server; it is based on KERIOS protocol. The extension was necessary to ensure data integrity and improve KERIOS protocol parsing. LayerPro carries only the KERIOS data packet and adds 3 extra bytes as a sequence number. The sequence number ensures that the packets are continuous and no packet loss will occur during transmission. Moreover LayerPro has a fixed length; it has 35 bytes, while KERIOS has a variable length. These modifications made LayerPro packet parsing easier and faster on the server. This protocol is stateless and supports limited transactions, of which it allows three: open, close, and send.

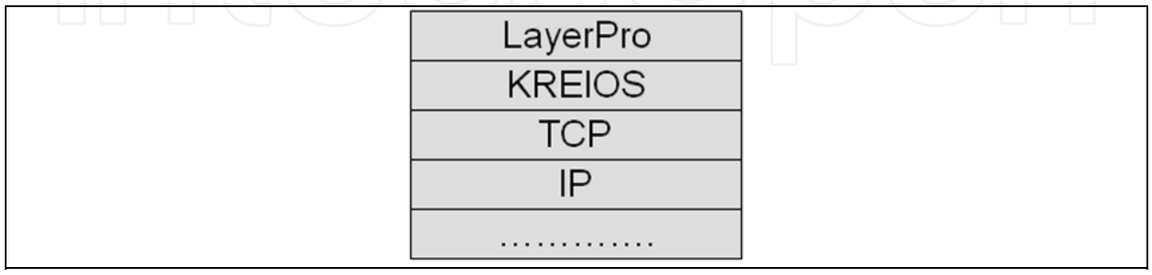



Fig. 3. Protocol Stack

LayerPro protocol has two parts: head and tail (see Fig. 4). The head contains 3 bytes representing the transmission sequence number and 1 byte describing the packet type (Data or Control). There are four possible values for the packet type field: 0-data; 1-open; 2; send; 3-close. The tail contains the actual binary data. In this protocol, the fixed length is used to determine the end of the packet.

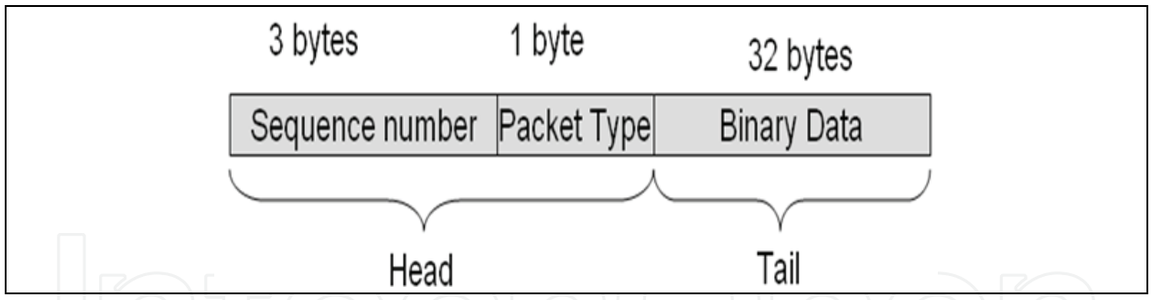



Fig. 4. LayerPro Packet Format

To start the data streaming, the source system sends an open transaction packet. This transaction packet indicates to the destination system (server) the beginning of a transmission. The sequence number value in the packet head is “00 00 00”; the packet type field contains the open command, and no data in the packet tail. The open transaction packet is followed by a send transaction packet that contains the acquired data from the source (sensor) in the tail, the send command in the packet type and a sequence number in the sequence number field. The close transaction packet indicates to the destination (server) the end of transmission. The packet type field has a close command; the sequence number value in the packet head in this transaction is the last data sequence number with no data in the packet tail. Fig 5 demonstrates these transactions and flow between the source system (PDA) and the destination system (server).

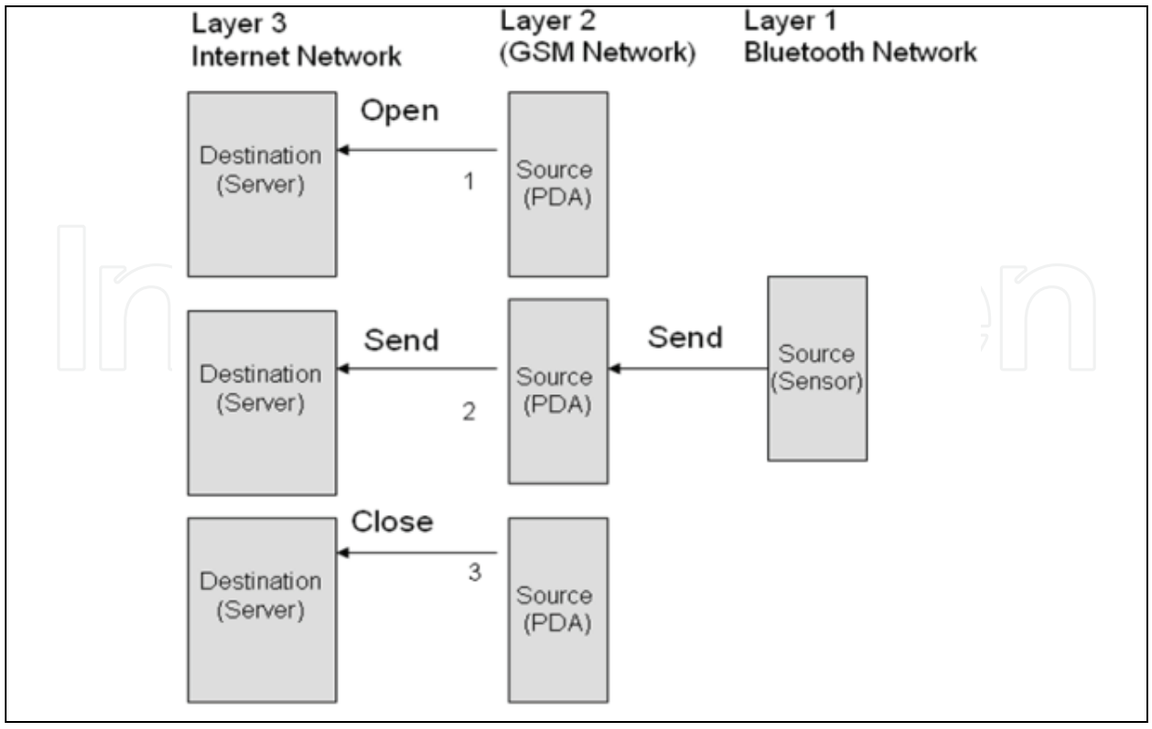



Fig. 5. Layer Pro Transactions

## 5. Network integration

To validate the protocol's basic functionality more than 100 tests were performed. They were designed to monitor brain functions during smoking outside the lab environment to collect changes in oxygenation concentration levels in the brain during breath holding and finally to measure the changes in oxygenation concentration levels in dogs' brains when presented with their favorite toys.

The tests were focused on performance, data integrity, availability and the effectiveness of the developed protocol. The system worked in all cases, but different amounts of delay were experienced in the data transmission. The delays vary between 1 to 5 seconds. The delay is impacted by the networks' speed during the time when the experiments were performed.

The protocol design allowed the sending of one packet at a time. This approach reduced the overall packet size which made it possible to send the data with a very short delay (1 second) most of the time. Whereas the packet size was very small (36 bytes) due to the protocol design, the network bandwidth requirements became very small. Therefore, the system required only a few resources to transmit the data to the server which made it possible to transmit the data without data lost despite unpredictable changes in the networks load.

To compare LayerPro performance versus HTTP protocol performance, two version of the system were implemented. The first version implemented LayerPro protocol and the second version implemented HTTP protocol. The results demonstrate that LayerPro protocol provides better near-real-time binary data transmission than the HTTP protocol. Table 1 shows a sample result compares LayerPro protocol and the HTTP protocol.

| Layer Pro Average Delay | HTTP Average Delay |
|---|---|
| 1 Second | 8 Second |
| 1 Second | 5 Second |
| 1 Second | 5 Second |
| 1 Second | 7 Second |
| 1 Second | 5 Second |
| 1 Second | 5 Second |
| 1 Second | 5 Second |

Table 1. LayerPro Protocol versus HTTP Protocol

The system was tested in two different locations to ensure that the protocol can support true mobility. The test subject was wearing the sensor and carrying the PDA while he was moving around between two cities (Toronto: big city has 5 million people and Markham: small city has 0.5 million people). The tests were performed over several days and different times. The combination of location, date and time were necessary to investigate the effect of the mobile network and the internet load on the quality of the transmitted data during low usage and peak usage of the heterogonous networks. Moreover the location, time and date combination were used to validate how well the protocol can handle the communication during different networks load.

Fig. 6 shows a direct comparison between LayerPro and HTTP protocol. From the figure we can see that LayerPro protocol provides better near-real-time binary data transmission than the HTTP protocol. The figure also shows that the network load effect is minimal on LayerPro protocol.

In biomedical applications data integrity is very important. Even one packet dropping sometimes means losing valuable information. Tests also showed that all data packet were streaming correctly and in a timely manner.

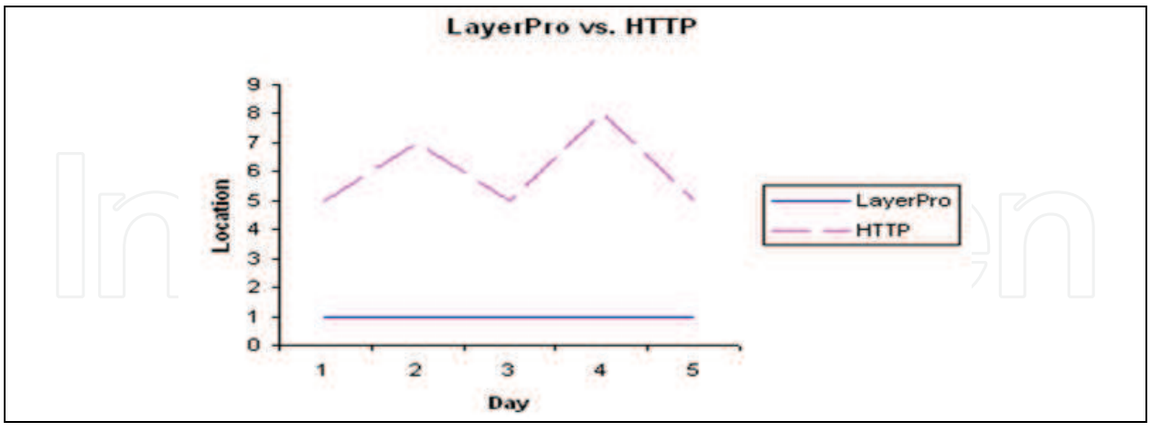



Fig. 6. Averafe delay LayerPro vs. HTTP

## 6. Ad-hoc networks embedding in medical sensors

The application software architecture (Fig. 7) has three major layers: a data acquisition layer (DAL), a control layer (CL), and a data storage layer (DSL). The DAL software component in the sensor controls data acquisition and packet transmission. It is composed of a set of

programs that implements the data communication protocol, the RFCOMM Bluetooth protocol, and the sensor's low-level controls. The second layer (CL) resides on the PDA and acts as the central control unit for the application. The majority of the system components reside in this layer. The third layer (DSL) is mainly used to accept connections from the PDA and stores the received data packets in the server for later analysis. The PDA creates a persistent connection with the sensor and with the PC during the duration of the measurements. The system is designed to support a wide range of measurements and acquisition activities. Several types of tests can be performed using the system without the need to modify the programs. Most of the components are designed to be configuration-driven. The system architecture provides high interoperability between heterogeneous hardware and software.

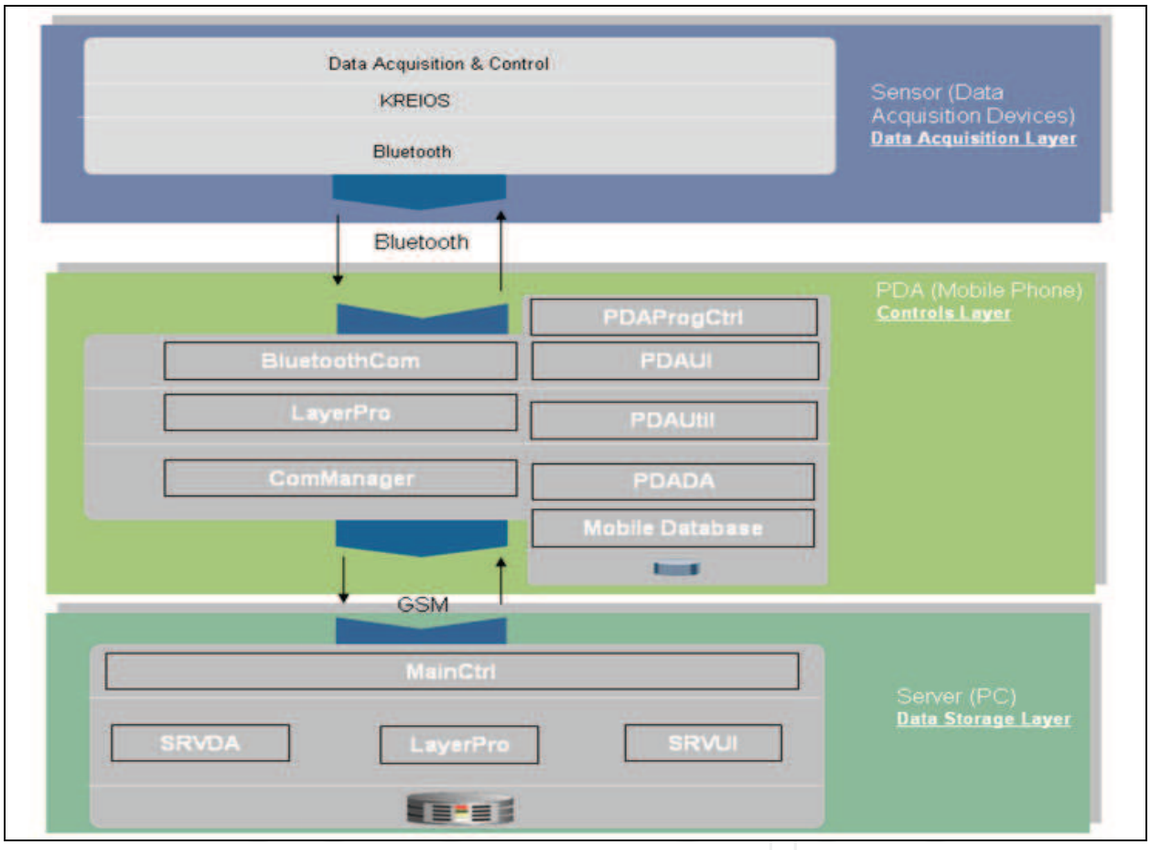



Fig. 7. The Application Software Architecture

All user interactions (Fig. 8) in the system are initiated by the User Interface Component (PDAUI) that is controlled by the program control component (PDAProgCtrl). Program control calls the LayerPro component to create command and data packets. All commands are encapsulated by a LayerPro packet before they are sent to and received from the sensor; this is performed by the LayerPro component. A LayerPro packet is sent and received over the air using the Bluetooth communication component. When data is collected from the sensor it is sent to the server using the communication manager component (ComManager); then a local copy of the packet will be saved to the mobile local file system using the Mobile Database Access Component (PDADA).

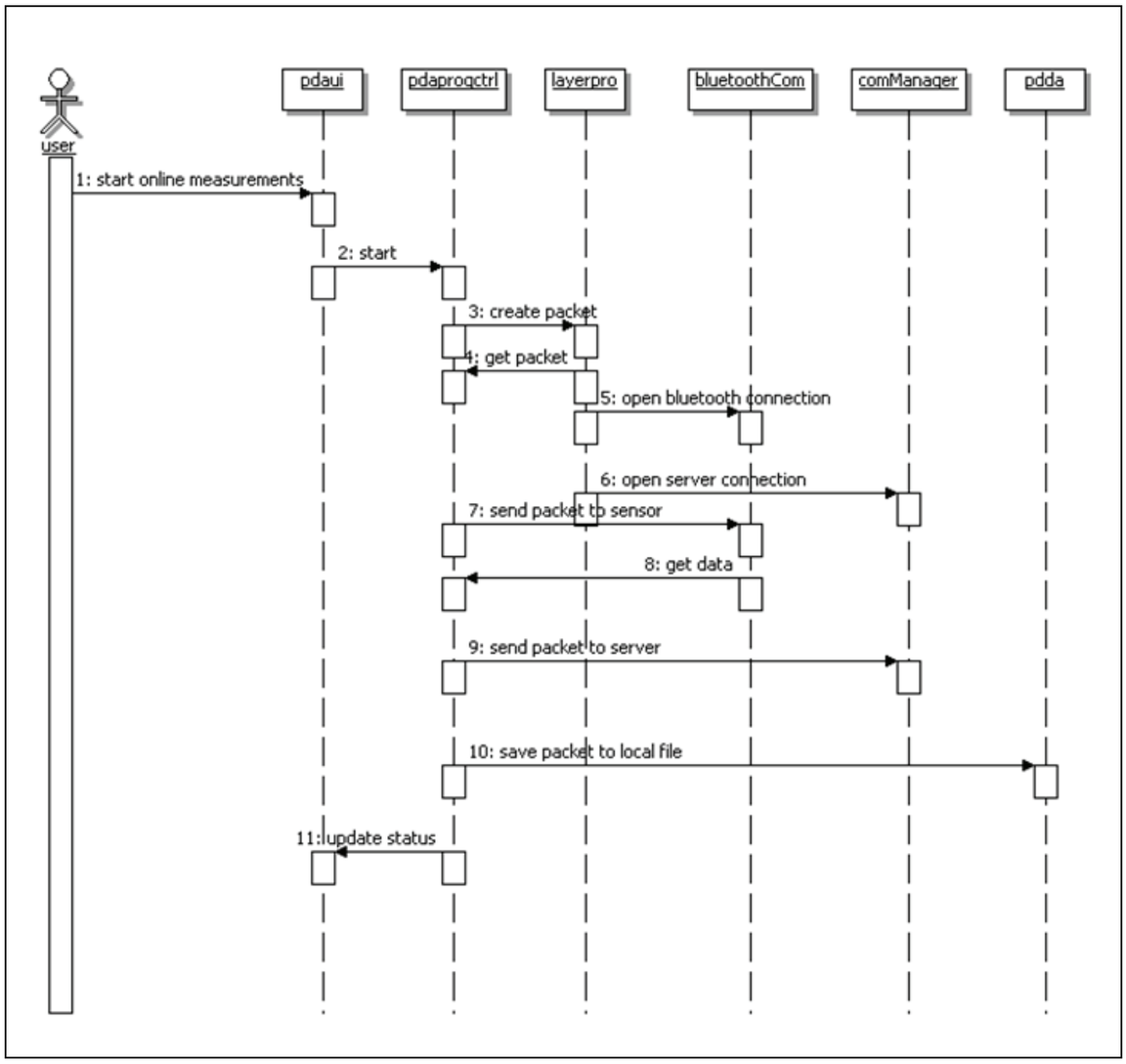



Fig. 8. The application overall interactions

## 7. Case studies summary

The system was designed to support a wide range of measurement activities. We wished to ensure that a variety of data be available for testing. In order to achieve this goal we performed tests on both humans and trained dogs with tests being conducted both inside and outside a lab environment. HbO2 and Hb changes in brain and tissue were collected for both species in different circumstances. In total, three major types of biomedical experiments were conducted using our system.

The first experiment was a breath holding experiment. The test was used as a validation experiment in order to ensure that our system worked correctly and could collect biological data.

The second experiment was related to smoking and was conducted entirely outside the lab. This experiment was performed to understand the effect of smoking on the brain in a real

environment away from the distractions and unrealities of a rigid laboratory environment—an environment where smoking actually takes place.

The third experiment was conducted to monitor a trained canine's brain activities. The experiment was conducted in order to determine if it was possible to monitor the brain activity of animals. We found the second and third tests to be particularly compelling. Smoking is an addictive behavior that occurs in the real world. In order to understand the factors that cause this behavior more accurately, we believed that any measurement must occur in the true circumstances of the activity. The third experiment involving trained canines was motivated by both the need for data outside the human realm and because we believed it could be possible to determine elements of mental activity within working animals—specifically canines--that directly relate to the activity that the animal is about to engage in. This is significant because it implies a certain level of predictability. Whether this is actually feasible is beyond the scope of this application; however, Helton et. al. have run a similar test in a lab environment without the benefit of our system (Helton et al., 2007) However, if testing is ever to be done in a real world setting, there must be a mechanism for allowing it.

## 8. Case studies 1

To validate that the system was functioning as expected, a breath holding experiment was performed on humans. The result was compared with a lab method (Zhang et al., 2005). Test subjects were asked to rest for 20 seconds, then to hold their breath for 20 seconds, and thereafter exhale and breathe normally for 20 seconds. The trial for each test subject lasted for 120 seconds. The rest duration between trials for each test subject was approximately 2 days.

We performed 15 breath holding trials. We asked three different test subjects (two males and one female) to hold their breath. The first test subject was a 23-year-old healthy female, non-smoker; the second test subject was a 46-year-old healthy male, non-smoker; and the third test subject was a 36-year-old healthy male smoker. During the lab trials, the test subjects were asked to wear the sensor on their forehead near the hair line and lay down on their backs on the test bed; they were asked not to move and not to speak. Instructions to inhale and exhale were communicated to them by the person running the trials. In the outside trials, the test subjects were asked to wear the sensor on their foreheads and sit on a chair in the open and they were asked not to move or speak while performing the breath holding trial.

After analyzing the collected data using our system, we can see that each breath holding trial had a measured impact on the HbO2 and Hb concentration. The result was compared to a result obtained from a similar experiment using fMRI (Zhang et al., 2005). This experiment proved that the system can provide results similar to the ones previously obtained by other test methods (Zhang et al., 2005). Clearly the system worked as expected.

Fig. 9 shows an example of data obtained during a breath holding trial. The graph shows that HbO2 increases during the breath holding. The arrow indicates when the increase happens due to breath holding. The brain compensates for the lack of oxygen by increasing the blood flow (Zhang et al., 2005). Then the HbO2 level goes down after breathing was resumed.

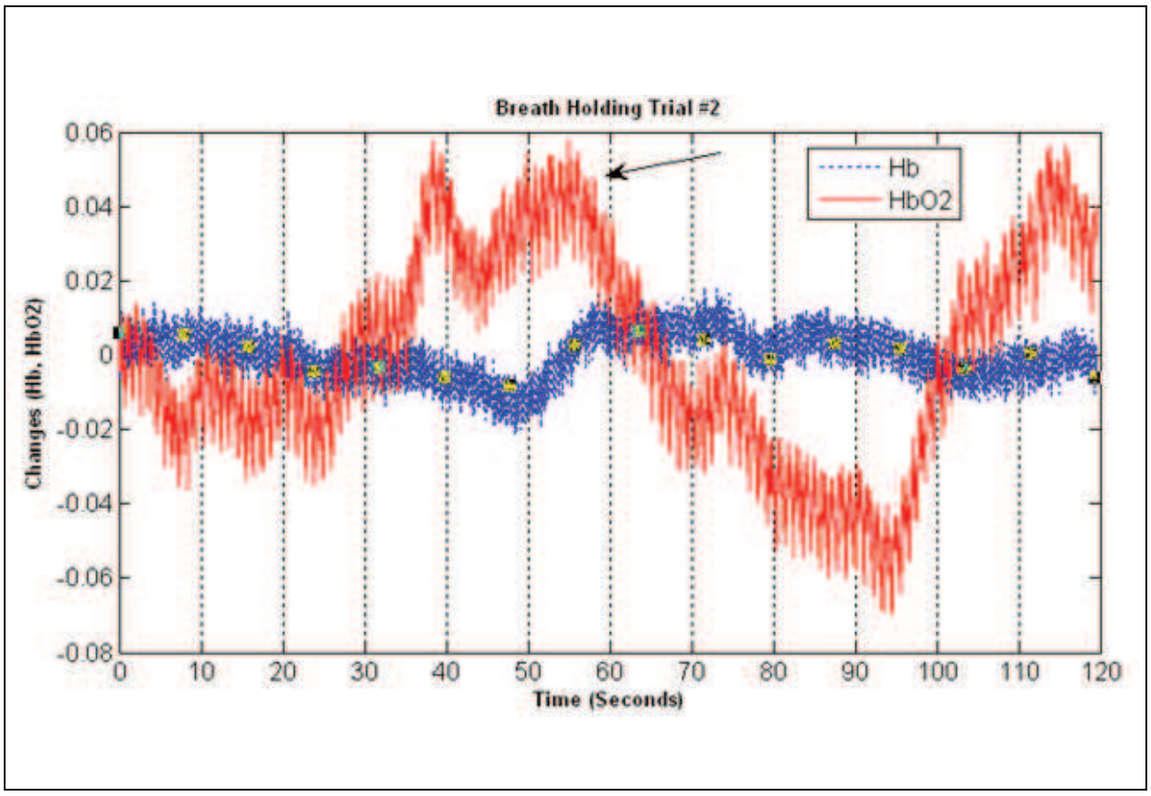



Fig. 9. Sample breath holding trails result

## 9. Case studies 2

There is an agreement among scientists that cigarette smoking causes lung cancer, heart diseases, and other serious illnesses (Carmines, 2002; Giessing et al., 2006). Almost five million Canadians smoke 15 times or more per day (Flight, 2007; Health Canada, 2007). The chemical substances, including nicotine, found in cigarettes Hoffmann et al., 2001; Baker et al., 2004; Rodgman et al., 2000; Frederick et al., 2007)entering the human body during smoking can cause several physiological changes. Few studies have applied fMRI to detect the oxygen level changes in the human brain under the effect of direct nicotine administration. The results have proven that nicotine can impact the level of oxygen in the hemoglobin in the brain Giessing et al., 2006; Siafaka et al., 2007). It is important to emphasize, however, that all these studies have tested the impact of the nicotine on the oxygen level in the brain using direct nicotine administration rather than actual smoking.

To understand the real effect that cigarettes (nicotine and other chemicals) have on the brain, as opposed to direct administration of nicotine, smoke testing must be performed in a natural way rather than in a controlled environment. One contribution of the developed system is to address this need. In fact, there are pragmatic health and safety reasons why this method is superior to in-lab testing. Because test subjects can be tested independently of the environment, no collateral damage from smoking need be accidentally inflicted on auxiliary participants in the test. Thus this method is safer, does not require special lab modifications and is as effective as other methods.

In total, six smoking trials were conducted. The experiment's purpose was to examine the relationship between smoking and HbO2 and Hb changes in the brain. Five healthy human males and one healthy human female participated in the experiment. The test subjects' ages ranged from 30 to 40 years old. All the test subjects were active smokers for a period of more than 2 years. During the trials, the test subjects were asked to wear the sensor on their foreheads and sit on a chair in the open where they were asked not to move more than they had to in order to smoke and not to speak. The sensor was fixed with a bandage on the test subject's head to improve the sensor's stability on the head and minimize the effect of the test subject's movement during the smoking process. Instructions as to when to smoke were communicated to the subjects by the person running the trials. Each trial lasted for 15 minutes, which included a five-minute baseline, five minutes of smoking, and a five-minute recovery after smoking.

Baseline data was recorded for 5 minutes before the test subject started smoking. The test subject was asked to smoke for 5 minutes. The test subject inhaled every 20 seconds for the duration of the test. After the 5-minute smoking period, the test subject was asked to keep wearing the sensor for another 5 minutes. The data collection continued during the 5-minute waiting period after the smoking was complete. The recovery period allowed us to capture any delayed after-effect changes that occurred due to smoking.

When we analyzed the data, we observed HbO2 and Hb changes during the baseline, the smoking, and the recovery periods. Fig. 10 illustrates the results from a smoking experiment. The graph shows that during the baseline duration, changes in HbO2 and HHb reflected normal physiological states. Sharper changes in HbO2 and Hb were appeared during smoking. These changes were similar to changes that occur during functional brain activities. Usually, such changes occurred due to the increase in the blood flow (Toronov et al., 2001).

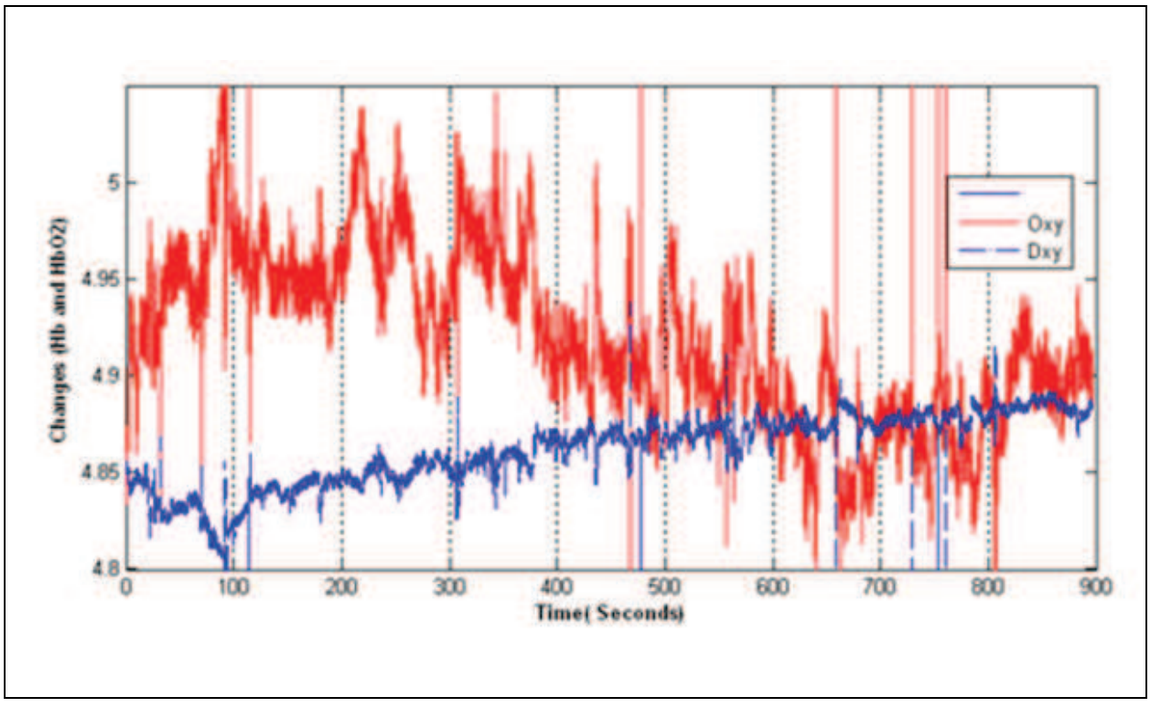



Fig. 10. Sample smoking trial result

## 10. References


Lima, P.; Bonarini, A. & Mataric, M. (2004). *Name of Book in Italics,* Publisher, ISBN, Place of Publication

Li, B.; Xu, Y. & Choi, J. (1996). Title of conference paper, *Proceedings of xxx xxx*, pp. 14-17, ISBN, conference location, month and year, Publisher, City

Siegwart, R. (2001). Name of paper. *Name of Journal in Italics,* Vol., No., (month and year of the edition) page numbers (first-last), ISSN

Arai, T. & Kragic, D. (1999). Name of paper, In: *Name of Book in Italics,* Name(s) of Editor(s), (Ed.), page numbers (first-last), Publisher, ISBN, Place of publication

Arai, T. & Kragic, D. (1999). Name of paper, In: *Name of Book in Italics,* Name(s) of Editor(s), (Ed.), page numbers (first-last), Publisher, ISBN, Place of publication

[67] Comer, D. (1997). In Stevens D. L. (Ed.), Internetworking with TCP (Windows sockets version. ed.). Prentice Hall, Upper Saddle River, N.J.

[68] Stevens, W. R. (1994-). Addison-Wesley Pub. Co., TCP. Reading, Mass.

[69] Comer, D. (2007). *The internet book: Everything You Need To Know about Computer Networking and how the Internet Works*, Pearson Prentice Hall, 0132335530, Upper Saddle River, NJ.

[70] Bray, J. & Sturman, C. F. (2002). *Bluetooth: Connect Without Cables*, Prentice Hall, 0130661066, Upper Saddle River, NJ., U.S.A.

[71] Ganguli, M. (2002). *Getting started with Bluetooth,* Premier Press, 1931841837, Cincinnati, Ohio, U.S.A.

[72] Huang, A. S. (2007). In Rudolph L. (Ed.), Bluetooth essentials for programmers. New York, NY: Cambridge University Press.Muller, N.J. (2001).

[73] Bluetooth Core Specifications Version 2.1. 2007. Available at <http://www.bluetooth.com/NR/rdonlyres/F8E8276A-3898-4EC6-B7DA-E5535258B056/6545/Core_V21__EDR.zip>.

[74] Delord, X.; Perret, S. & Duda, A. (1998). Efficient Mobile Access to the WWW over GSM, *Proceedings of the 8th ACM SIGOPS European Workshop on Support For Composing Distributed Applications*, pp. 1-6, Sintra, Portugal, September 1998, ACM, New York, U.S.A.

[75]. Eberspächer, J.; Vögel, H.J. & Bettstetter, C. (2001). *GSM: Switching, Services and Protocols*, John Wiley & Sons, 047149903X, Toronto, Canada.

[76] Chakravorty, R.; Clark, A. & Pratt, I. (2003). GPRSWeb: Optimizing the Web for GPRS Links, *Proceedings of the 1st International Conference on Mobile Systems, Applications and Services*, pp.317-30, San Francisco, California, U.S.A, May 2003, ACM, New York, USA.

[78] Arquatis GmbH, Rieden, Switzerland. Developed in cooperation with the Biomedical Optics Research Laboratory at the Clinic of Neonatology(2007) <http://www.arquatis.com>: product name nScan W1200.

[79] Muhlemann, T.L. (2006). New Wireless Probes for Near In-frared Spectroscopy. Master Thesis, Swiss Federal Institute of Technology, Zurich.

[80] Muhlemann, T.L.; Haensse, D. and Wolf, M. (2006). A Wireless Near-Infrared Imaging Device. The 34th Annual Meeting of the International Society on Oxygen Transfer

to Tissue. (Louisville, Kentucky, August 12-17), available at <http://louisville.edu/conference/isott06/WebProgram.pdf>.

[81] Trajkovic, I. (2006). Examination of the Brain with Light: Integration of a Wireless Sensor into a Graphical User Interface based on Java. Semester Thesis, Swiss Federal Institute of Technology, Zurich.

[82] Strangman, G.; Boas, D.A. & Sutton, J.P.(2002). Non-Invasive Neuroimaging Using Near-infrared Light. *Biological psychiatry*, 52, 7, (October 2002) 679-693, 0006-3223.

[83] Izzetoglu, K.; Yurtsever, G.; Bozkurt, A.& and Bunce, S. (2003). Functional Brain Monitoring via NIR Based Optical Spectroscopy, *Proceedings of the 29th IEEE Annual Conference-Bioengineering Conference,* pp.335-336, 0-7803-7767-2, Newark, N.J., USA, March 2003).

[84] Villringer, A. & Chance, B. (1997). Non-invasive optical spectroscopy and imaging of human brain function. *Trends in Neuroscience*, 20, 10, (October 1997), 435-42, 0166-2236.

[85] Gratton, E.; Fantini, S.; Franceschini, M.A.; Gratton, G. & Fabiani, M. (1997). Measurements of scattering and absorption changes in muscle and brain. *Philosophical Transactions: Biological Sciences*, 352,1354, (June 1997), 727-735, 0962-8436.

[20] Jobsis, F.F. (1977). Noninvasive infrared monitoring of cerebral and myocardial oxygen sufficiency and circulatory parameters. *Science*, 198, 4323, (December 1977)1264-1267, 0036-8075.

[86] Bozkurt, A.; Rosen, A.; Rosen, H. & Onaral, B. (2005). A portable near infrared spectroscopy system for bedside monitoring of newborn brain. Biomedical Engineering Online, 4, 1, (April 2005),
< http://www.biomedical-engineering-online.com/content/4/1/29 > 1475-925X.

[87] Hong, L.; Worden, K.; Li, C.; Murray, T.; Ovetsky, Y.; Pidikiti, D. & Thomas, R. (1998). A novel method for fast imaging of brain function, non-invasively, with light. *Optics Express*, 2, 10, (May 1998) 411-423, 1094-4087.

[88] Germon, T.J.; Evans, P.D.; Manara, A.R.; Barnett, N.J.; Wall, P.& Nelson, R.J. (1998). Sensitivity of near infrared spectroscopy to cerebral and extra-cerebral oxygenation changes is determined by emitter-detector separation. *Journal of Clinical Monitoring and Computing*, 14, 5, (July 1998) 353-360, 1387-1307.

[89] Benni, P.B.; Bo , C.; Amory, D. & Li, J.K. (1995). A novel near-infrared spectroscopy (NIRS) system for measuring regional oxygen saturation., Proceedings of the 1995 IEEE 21st Annual Northeast, pp. 105-107, 0-7803-2692-X, May 1995, IEEE.

[16] Cabeza, R. & Nyberg, L. (2000). Imaging cognition II: an empirical review of 275 PET and fMRI Studies. *Journal of Cognitive Neuroscience*, 12,.1 (January 2000), 1-47, 0898-929X.

[17] Davidson, R. J. & Sutton, S. K. (1995). Affective neuroscience: the emergence of a discipline. *Current Opinion in Neurobiology*, 5, 2 (April 1995), 217-224, 0959-4388.

[19] Chance, B.; Zhuang, Z.; UnAh, C.; Alter, C.; & Lipton, L. (1993). Cognition-activated Low-frequency Modulation of Light Absorption in Human Brain, *Proceedings of the National Academy of Sciences*, 3770-3774,, 90, 8, (April 1993),.

[21] Boas, D.A.; Franceschini, M.A.; Dunn, A.K. & Strangman, G. (2002). Non-invasive imaging of cerebral activation with diffuse optical tomography, In: In *Vivo Optical Imaging of Brain Function*, R. Frostig, (ed.), 193-221, CRC Press, 0849323894, Boca Raton, Florida.

[94] Porth, C. (2005). *Pathophysiology: Concepts of Altered Health States*, Lippincott Williams & Wilkins, 0781749883, Philadelphia.

[97] Helton, W.S.; Hollander, T.D.; Warm,J.S.; Tripp, L.D.; Parsons, K.; Matthews, G.; Dember, W.N.; Parasuraman, R.; & Hancock, P.A.(2007). The abbreviated vigilance task and cerebral hemodyamics. *J. of Clinical and Experimental Neuropsychology*, 29, 5, (July 2007) 545-552, 1380-3395.

[98] Zhang, X.; Toronov, V.; Webb, A. (2005). Methodology development for simultaneous diffuse optical tomography and magnetic resonance imaging in functional human brain mapping, *Proceedings of SPIE*, 453-463, San Jose, CA, USA, April 2005, International Society for Optical Engineering, Bellingham, WA, USA.

[99] Carmines, E.L. (2002). Evaluation of the potential effects of ingredients added to cigarettes. Part 1: Cigarette design, testing approach, and review of results. *Food and Chemical Toxicology,* 40,1,(January 2002), 77-91, 0278-6915.

[100] Giessing, C.; Thiel, CM.; Rösler., F & Fink GR. (2006). The modulatory effects of nicotine on parietal cortex activity in a cued target detection task depend on cue reliability. *Neuroscience* 137,3, ( February 2006) 853-864, 0306-4522.

[101] Flight, J. (2007). Canadian Addiction Survey (CAS): A national survey of Canadians' use of alcohol and other drugs: substance use by youths. Health Canada, Ottawa.

[102] Health Canada (2007). Canadian Tobacco Use Monitoring Survey. Health Canada, Ottawa.

[103] Hoffmann, D.; Hoffmann, I.; & El-Bayoumy, K. (2001). The less harmful cigarette: A controversial issue. A tribute to Ernst L. Wynder. *Chemical Research in Toxicology* 14,7, (July 2001) 767- 790, 0893-228X.

[104] Baker, R.R.; Massey, E.D. & Smith, G. (2004). An overview of the effects of tobacco ingredients on smoke chemistry and toxicity. *Food and Chemical Toxicology,* 42 Suppl: 1, (March 2004) 53-83, 0278-6915.

[105] Rodgman, A.; Smith, C.J. & Perfetti, T.A. (2000). The composition of cigarette smoke: a retrospective, with emphasis on polycyclic components. *Human and Experimental Toxicology*, 19,10,( October 2000) 573-595, 0960-3271.

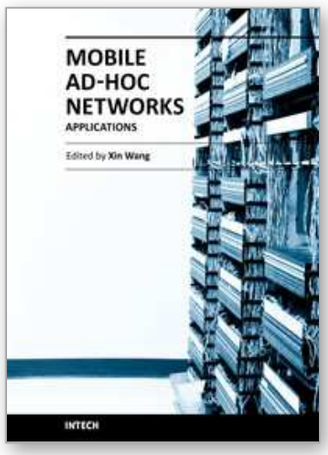
[106] Frederick, B.; Lindsey, KP.; Nickerson, LD.; Ryan, ET. & Lukas SE. (2007). An MR-compatible device for delivering smoked marijuana during functional imaging. *Pharmacology, Biochemistry, and Behavior,* 87,1,(May 2007) 81-89, 0091-3057.

[107] Siafaka, A.; Angelopoulos, E.; Kritikos, K.; Poriazi, M.; Basios, N.; Gerovasili, V.; Andreou, A.; Roussos, C.& Nanas, S.(2007). Acute effects of smoking on skeletal muscle microcirculation monitored by near-infrared spectroscopy. *Chest Journal,* 131,5,(May 2007) 1479-1485, 0012-3692.

[108] Toronov, V.; Webb, A.; Choi, JH.; Wolf, M.; Michalos, A.; Gratton, E.& Hueber, D.. (2001). Investigation of human brain hemodynamics by simultaneous near-infrared spectroscopy and functional magnetic resonance imaging. *Medical Physics,* 28, 4, (April 2001) 521-527, 0094-2405.

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