WLAN Interface for a Wireless EEG System

E. Velarde-Reyes and F. Martin-Gonzalez
Cuban Neuroscience Center, Havana, Cuba

Keywords: WLAN, Interface, Wireless, EEG, Holter.

Abstract: A WLAN interface for a Wireless EEG System is presented in this paper. Selection of broadcasting band, available hardware, and connection algorithm to use are discussed before making a choice. Two alternatives were explored: Wireless EEG Device (Holter) and its Server communicate with each other within the same physical network, and from a complex network like the Internet. Results of experimental tests carried out on the prototype demonstrate the functionality of the implemented interface.

1 INTRODUCTION

Electroencephalography (EEG) studies are increasingly important in numerous applications, from clinical diagnosis of different brain pathologies to research on cognitive processes and to the development of brain-computer interfaces and neurofeedback. In some of these applications long-lasting recordings are required and desk electroencephalographs with personal computer (PC) wired interfaces as USB, are not the best solution since they restrict patient movements. Such is the case of study and diagnosis of epilepsy whose studies can last up to three continuous days. This has brought attention to the need of developing wireless interfaces in order to add telemetry capability to EEG recorders.

Other requirement for EEG long-lasting recordings is the portability of the recorder. Portable devices with telemetry capability and possibility to record medical data in an ambulatory way may receive the generic name of Holter monitors. Holter monitor, the PC where the doctors process EEG studies (Server) and the possible communications infrastructure conform a Wireless EEG System (WES).

Moreover, WLAN is the protocol commonly used in PC-based wireless networks. Some hospitals use this telecommunication technology in automation of processes. Doctors can immediately access medical records and patients' special medication by means of this technology (Goldman, 2008). If our WES supports WLAN, we can guarantee monitoring of patients at all times and in all places in the hospital, by adapting into existing WLANs or installing new ones. This makes WLAN a very convenient option.

The aim of this paper is to describe the design and implementation of a WLAN interface for a Wireless EEG System.

2 DESIGNING THE WLAN INTERFACE

2.1 Broadcasting Band

In order to ensure its compatibility with installed systems, broadcasting band of our WES must be recognized as a license-free band in the majority of countries around the world. Therefore, we selected the frequency band between 2400–2483.5 MHz. This band is frequently used by numerous devices such as microwave ovens, wireless phones, RFID units, and wireless local area networks (WLANs), causing a potential source of strong interference between devices within a domestic or hospital environment. There exist various techniques for decreasing the interference impact. The advantages of the selected broadcasting band include the short length of antennas, the existence of relatively cheap radio frequency transceivers and certified modules that work in the band, the universal acceptance of the band, and the better propagation characteristics over other world-wide accepted bands such as 5727–5875 MHz.

Velarde-Reyes E. and Martin-Gonzalez F..
WLAN Interface for a Wireless EEG System.
DOI: 10.5220/0005067900890093
In *Proceedings of the 2nd International Congress on Neurotechnology, Electronics and Informatics* (NEUROTECHNIX-2014), pages 89-93
ISBN: 978-989-758-056-7

2.2 Bit Rate Demands of the WES

In EEG recording is recommended a sampling rate of at least 200 Hz and a resolution of 12 bits. Even so, higher sampling rates and resolutions are preferable.

An EEG Holter monitor which could record data of 40 channels in simultaneous mode using a sampling rate of 400 Hz and coding the samples with 24 bits needs a data throughput of 384 kbps. That data throughput is achievable in any WLAN network as discussed later on.

2.3 WLAN Standard

One of the fundamental advantages of WLAN over other standards is the ability to connect to a local area network (LAN) using a wireless Access Point (AP), which allows patient monitoring in a most extense area and the development of future applications of telemedicine.

WLAN or IEEE 802.11 is a family of specifications. Among them, IEEE 802.11b and IEEE 802.11g are the most ubiquitous, and is very convenient that our WLAN interface supports them both. Both specifications of the WLAN work in the 2400–2483.5 MHz band and implement modulation techniques against interferences, as DSSS, FHSS and OFDM (Proakis, 2008). Also, WLAN allows retransmission in case of occurring errors in transmission or reception and supports throughputs from 1 to 54 Mbps in the case of IEEE 802.11b and IEEE 802.11g specifications.

2.4 WLAN Interface Implementation

Our WLAN Interface must be integrated, in its more simplified form by: one antenna for the transmission and reception of RF signals, one RF transceiver and one base band modulator with an 802.11 MAC Layer implementation.

In the short term, among the options to develop a WLAN Interface using integrated circuits and to acquire a certified WLAN integrated module, the most economic one is the second. There exist WLAN integrated modules having a firmware/hardware implementation of a TCP/IP (transmission control protocol/internet protocol) stack, that results essential for an adequate communication into a LAN network.

In summary it is very important that the selected WLAN integrated module has the following characteristics: low power consumption (Holter monitor necessarily works with battery) and a proper implementation of a TCP/IP stack.

3 WES MERGED IN THE COMMUNICATIONS INFRASTRUCTURE

Our Wireless EEG System could face two situations using WLAN standard:

1. The Server is in the same physical network.
2. The Server is in an infrastructure network.

Our WES must be authenticated and associated in a WLAN for transmitting data, it is an unavoidable requirement. The WLAN can be an infrastructure or ad hoc network. In the first case, authentication and association processes are executed by Holter monitor and an AP, while in the second case the processes are executed by Holter monitor and a WLAN module embedded in a PC. Authentication and association are indispensable conditions for a successful data interchange, but it is also necessary to know the destination and source internet protocol (IP) addresses and to possess a suitable TCP/IP stack. Moreover, source and destination devices must implement a network layer protocol for IP address dynamic assignation (e.g., Dynamic Host Configuration Protocol, DHCP). Since WLAN is a network-oriented standard, it would be convenient for our WES to include some protocols of the transport layer (e.g., TCP and UDP). There are some IEEE 802.11 embedded modules that, besides physically implementing the communication, incorporate a complete stack of TCP/IP protocols.

In accordance with the type of situation, our Wireless EEG System must employ a different technique or algorithm in order to connect to its server.

3.1 The Server Is in the Same Physical Network

In the case that Server is in the same physical network of the Holter monitor (Client from now on), it is appropriate that they implement a connection algorithm that resolves the Server's IP address and enables medical data transmission through a transport layer protocol. This algorithm must ensure connectivity and good performance in any network topology. It is convenient that it be simple, with low program processing times, and therefore easy for programmable devices to implement.

We propose a new version of algorithm presented in Velarde-Reyes et al (2008). This algorithm (Figure 1) ensures a fast and reliable data interchange and has four stages: annunciation, acceptation, TCP connection establishment and reconnection. In the annunciation stage, the Client must begin the communication as soon as it has been authenticated and associated in a WLAN. Communication is initiated by the transmission of a command sequence that travels within UDP datagrams addressed to the broadcast address and to a specific registered port. Commands consist in annunciation's indicatives that will reach all hosts inside the same physical network. Inside annunciation's indicatives are the Client IP address and the registered port opened by the Client. Annunciation's indicatives are repetitively transmitted until the Client receives the Server's acceptation commands. The application running on the Server opens its specific registered port and receives the annunciation's indicatives. As soon as the Server obtains that information, it permits data transmission to the Client. This new stage is known as acceptation, and it is executed by the Server in automatic or manual (by the Server's user) form. The Server can simultaneously allow various Clients to pass to the next stage: Acceptation.

Acceptation is accomplished by sending commands to the Client IP address. These commands travel in UDP datagrams and consist in acceptation's indicatives that contain the Server IP address and the TCP port opened for the next connection.

After the acceptation stage is TCP connection establishment. In this stage, the Server opens the TCP registered port indicated in the acceptation command. Then it starts a passive opening and waits for a TCP connection establishment. After the TCP connection establishment stage, the Server send to Client a TCP Connection Established Indicator ("Go") every 3 seconds announcing that it is prepared to receive all the data sent by the Client. Client must response to that indicator with a "Go" ack in case that it is not transmitting medical data.

If Client could not receive "Go" Indicators, it will initiate the reconnection stage, establishing again a TCP Connection with previous Server. Also, if Server could not receive data or "Go" acks, it will initiate too the reconnection stage, waiting for a TCP connection establishment by its open TCP port.

3.2 The Server Is in an Infrastructure Network

In this section we named Infrastructure Network to the networks that connect different network devices which are located in different physical networks. In this case, data travels through different network nodes (switches, routers, bridges, or others). A group of interconnected LANs and WANs (wide area networks) that conforms to the Internet infrastructure are examples of an Infrastructure Network.

Our Client could not connect to its Server in this kind of network using the algorithm proposed in the previous section. The difficulty is that the broadcast UDP messages cannot travel out of its physical networks because most routers in their default state do not have that configuration. Therefore, it is indispensable to use a new connection mode in order to establish a TCP connection between our Client and its Server when they are in different physical networks.

The new proposed connection mode is by means of the use of the Domain Name System (DNS) protocol services. DNS is a mechanism that implements a machine name hierarchy for computers, services, or any resource connected to any network. It associates several information with domain names assigned to each of the resources in the network. Its most important function is to translate domain names meaningfully to humans into the numerical addresses associated with networking equipment (or any resource) for the purpose of locating and addressing these devices worldwide.

DNS uses a hierarchical naming scheme known as domain names. A domain name consists of a sequence of subnames separated by a delimiter character, the period. Thus, the domain name electron.cneuro.edu contains three subnames: electron, cneuro, and edu. Any subname in a domain name is also called a domain. In the above example the lowest level domain is electron.cneuro.edu, (the domain name for the Electronic Design Department at the Cuban Neuroscience Center), the second level domain is cneuro.edu (the domain name for the Cuban Neuroscience Center), and the top level domain is edu (the domain name for educational institutions). DNS protocol makes it possible to assign domain names to users or groups (e.g., Internet users) in a meaningful way, independent of each user's physical location. Because of this, Internet contact information can remain consistent and constant even if the current Internet routing arrangements change.

Using the DNS protocol, our Client can establish a TCP connection with its Server if the Server has a domain name (e.g., epilepticserver.electron.edu.cu). It will not matter if the Server IP address is unknown

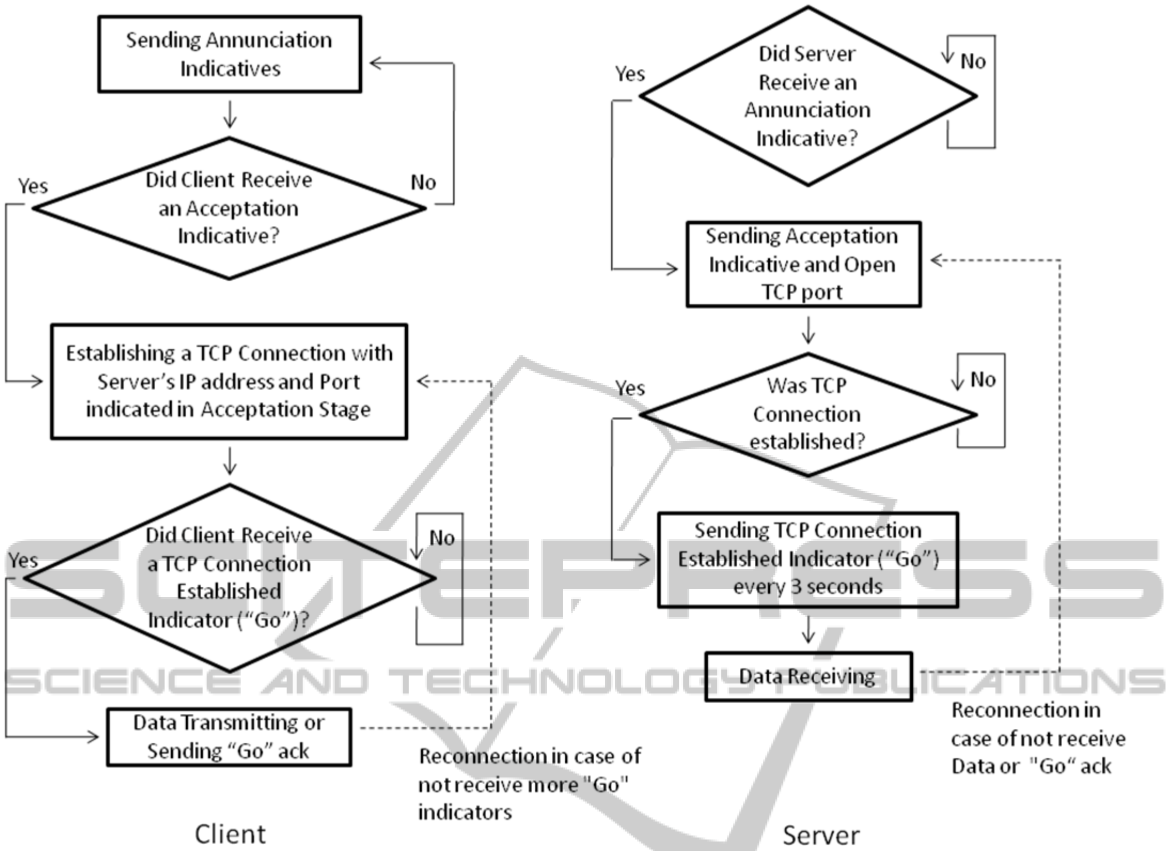

Figure 1: Connection Algorithm.

to it. To use the DNS protocol our Client must implement a complete stack of TCP/IP protocols.

4 INTERFACE VALIDATION

For validating the wireless communication interface we built a prototype integrated by an OWS451 module from ConnectBlue and a microcontroller. The broadcasting power selected for the module was +17 dBm. The microcontroller was used for executing the tasks assigned to the Client in the connection algorithm. A PC was used as Server.

Two experiments were selected for modelling the two principal scenarios that could face a WES in its same physical network. They were:

- Experiment 1 consisted of broadcasting data inside a room from a fixed position using multipath trajectories. This situation modelled a hospital room scenario due to the geometry of the room and the materials of the walls and furniture (Schäfer et al, 2005).
- Experiment 2 consisted of broadcasting data inside a corridor using line of sight (LOS) trajectories. The corridor selected is similar to other modern hospital corridors, with similar dimensions and materials (Schäfer et al, 2005).

In both experiments the Packet Error Rate (PER) was measured and the faults in the connection algorithm were counted. In Velarde-Reyes et al (2008) are depicted in detail the two experiments.

4.1 Considerations about the Experimental Results

The experimental results show that the proposed connection algorithm guarantees the WES communication and it works satisfactorily in multi-path and LOS trajectories.

5 CONCLUSIONS

The main result of this work was the description of the design and implementation of a WLAN interface for a Wireless EEG System.

REFERENCES

Goldman, J., 2008. Wireless Hospital: Orlando Regional Healthcare. In *Wi-Fi Planet*, March 13, 2008, accessed 30 April 2014, <http://www.wi-fiplanet.com/columns/article.php/3734011> .

Proakis, J., 2008. *Digital Communications*, Mc Graw - Hill. New York, 5^{nd} edition.

Velarde-Reyes, E., Marante-Rizo, F., Morgalo-Santos, B, Garrote-Jorge, J., and Martin-Gonzalez, F., 2010. Wireless communication interface for EEG/PSG Holter monitor. In *Journal of Medical Engineering & Technology*, vol. 34, pp. 172-177, April 2010.

Schäfer, T., Maurer, J., Hagen, J., and Wiesbeck, W.. 2005. Experimental Characterization of Radio Wave Propagation in Hospitals. In *IEEE Transactions on Electromagnetic Compatibility, vol. 47, pp. 304-311, May 2005.*