WIRELESS LOCAL AREA NETWORK FOR LOW SPECTRUM SIGNAL: APPLICATION AT THE MEDICINE AREA WITH A WIFI DEMONSTRATOR

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Abstract:

Current technology offers many possibilities for the transfer of data via the wireless local area networks such as: the WLAN, the UWB… Communication protocols can also arise, and develop to networks, the most widespread being WiFi which is based on the standards 802.11a/b/g. All these networks are generally created to connect between them a small number of near computer systems with reduced mobility or no mobility at all, which exchange files which could be bulky. That's why those systems need a large bandwidth. There are also many fields where lots of information needs to be exchange. The wires quickly become an issue, especially when the systems are often moved around, or if they are mobile. In addition, most of the time, the spectrum of the signals to be transmitted is very reduced. It is the case of the collection of the physiological signals. It appeared interesting to us to use a base of WiFi communication which we adapted in order to make of medical telemetry. In this article, we will develop these aspects and we will show one of our demonstrator.

Keywords: Wireless network, WiFi, medicine, telemetry, physiological signals

Introduction

In the medical field, the collection of the physiological signals (electric or not) is often used to either determine a pathology or its evolution, or to have the value of a parameter and to start an alarm in the event of an abnormal evolution: for example in the cases of the epilepsy, apnea of the sleep, or cardiac insufficiency. The signals necessary to the doctors are generally electric and they are taken on the surface of the human or animal body: for example, the Electrocardiogram (EKG), the Electroencephalogram (EEG) and Electromyogram (EMG). Usually, the signals are collected and recorded what allows direct and differed analyses. The recording and measuring equipment is made up of sensors, amplifiers, converters analogical/numerical and a microcomputer equipped with software intended to control the unit. The recordings are carried out either in a clinical way over one period of limited time; or in over several hours, even several days. Whatever the time necessary to these recordings, the wires connecting the sensors to the acquisition system are very often an issue and source of many artefacts which can be badly interpreted. They become crippling, when the patients involved are children (new born), people suffering of desynchronization and especially when the examination is done over several days. Taking into account what precedes, it would be judicious to be freed from wires connecting the sensors to the acquisition system, in another word making telemetry. Today, there are many systems of telemetry, but they are not as much used as they should, because the frequencies of transmission are low and the artefacts are frequent, what's more the wire connections still exist between the subject and the amplifier-transmitters. To our knowledge, the only systems which remain used today are intended for animals. They function around 450kHz and are limited to 3 recording channels and 8 animals at the same time. According to those facts, it seemed interesting to us to study and carry out a wireless acquisition system. The continuation of this article aims at exposing the wireless networks, the choices which we made and the demonstrator who results from this.

Wireless network Many articles describe in details the telecommunications and the various characteristics of the wireless networks [1], [2], [3], [4]. The most widespread are the WLAN[1], HiperLAN[2] and more recently the UWB[3]. The fundamental differences between these networks involve in the frequencies of transmission, the number of channels and the maximum bite rate. Their principle consists of peripherals and frames which forward at their own frequency either by an access point (infrastructure mode) or directly of peripheral to peripheral (*ad hoc* mode). To avoid the collisions, a listening of the channel is carried out before the sending of a frame (CSMA/CA[4]).

[1] Wireless Local Area Network
[2] High performances Local Area Network
[3] Ultra Wide Band
[4] Carry Sense Multiple Acces/ Collision Avoidance

These networks use rather complex modules, based on physical layers and software layers. Some of them (WiFi), uses the technique of the bite-rate's dynamic variation, so that it is possible to adapt the power of emission and the bite rate according to the quality and to the occupation of the channel of propagation. Thus, the errors of transmission are reduced and the loss of information is rare. The following chart gives some characteristics of the most used wireless networks in France, Bluetooth and WiFi through the standards 802.11 a/b/g.

Network	Maximum coverage	Data Rates	Frequency	Mobility
Bluetooth	10m	750kb/s	2.4 GHz	very low
IEEE 802.11 a/b/g	300m	54/11/54Mb/s	5/2.4/2.4 GHz	Medium

Table 1: some characteristics of two main wireless' technologies in France

With that we can add that Bluetooth is limited to 8 peripherals, whereas a WiFi network offers much more possibilities in terms of peripherals and bite rate. Consequently, we made our feasibility study on the WiFi networks, although they are very large consumers of energy.

The WiFi networks

They depend on the standard 802.11 which makes possible to have variations of bite rate according to the environmental quality, allowing to keep the communication between the communicating entities even in the most critical cases (disturbed transmission channel, reflexion, fading). For such robustness and an optimal bite rate, the communicating systems use techniques of communication and digital modulations. However, it is the channel of propagation limits the capacity of communication, in accordance with the equation of Shannon:

$$C=Bw\log_2(1+S/N) \quad \textbf{Equation 1}$$

Where C is the Capacity (in Bits/Second), Bw is the Bandwidth, and S/N is the Signal-To-Noise ratio of the link.

Techniques of communication and modulation

There are techniques of spreading out of spectrum which transform a signal with narrow band into a signal with wide band without losing power. Thus, the transmitted signal can be collected despite of the presence of noise or other signals interfering in narrow band. It is the case of the communication technique FHSS (Frequency Hopping Spread Spectrum), which rests on the jumps of frequencies (Figure 1).

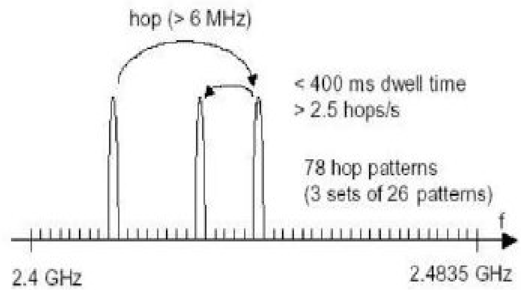

Figure 1: FHSS technique

This technique is restrictive, since in practice because of the covering of the spectra, only 15 networks are available gathering a maximum of 48 stations. The band-width available for each channel is 1MHz and offers a bite rate from 1 to 2 Mbps. To increase the number of communicating entities, the standard proposes the communication technique DSSS (Direct Sequence Spread Spectrum) (Figure 2). This technique uses a scrambling between the data and a random pseudo succession which has very robust mathematical characteristics in term of correlation, which allows the receiver to better detect the signal and to maintain the communication, even in the presence of noise and of interferences in narrow band. This technique generally uses the random pseudo code of Barker. If a proper code is used it becomes technique CCK (complentary code keying). Whatever the random pseudo continuation used, the flow can vary from 11Mbps to 54 Mbps for each station (12 maximum).

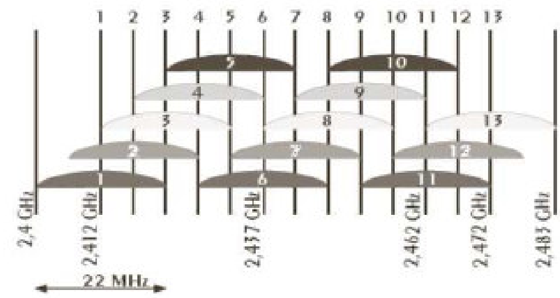

Figure 2:Channel of DSSS technologie

In theory, in France 13 channels are available. Taking into account coverings between the channels, only three channels are usable simultaneously. The third communication technique available is the OFDM (Orthogonal Frequency Division Multiplexing) which is also a digital technique of modulation. This technique cures the fading problem of the transmission channel because it uses a frequential multiplexing with the carrying orthogonal which allows it occupy all the band of transmission in an optimal way. It is based on the redundancy of data, which avoids the retransmission of information in the case of an erroneous reception. The successive frames are separated by bursts, so the multi way is better managed. On the other hand, the transmitter and the receiver must be synchronized. To increase the bite rate of the transmission channel, it is enough to increase the spectral effectiveness. The standard stipulates the recourse to the usual numerical modulations in telecommunication, such as: the ASK, the PSK, the QPSK, the QAM or the ODFM are their constellations.

So, our study showed that we could treat 12 or 15 patients at the same time, each equipped with 40 sensors.

Field of application of the wireless networks

The field of application is mainly the data-processing field, where each peripheral is not very mobile and can exchange a great number of information requiring a large bandwidth. However, there are also many fields where lots of information needs to be exchange. The wires quickly become an issue, especially when the systems are often moved around, or if they are mobile. In addition, most of the time, the spectrum of the signals to be transmitted is very reduced. It is the case of the collection of the physiological signals. It appeared interesting to us to use a base of WiFi communication which we adapted in order to make of medical telemetry. Here is the reason why we made the feasibility study which is developed in the following paragraph.

Our application

The objective of the project is the creation of a complete system of bidirectional telemetry for medical applications for both human and animal making possible to free it from physical connections, which are sources of artefacts and errors in the analysis of the data. This system makes it possible to optimize and increase the number of medical explorations in residence, especially neurophysiological ones, which is a major stake in the cut of public health costs. The medical fields are those of EEG, polysomnography, electrocardiography, concerning epileptic pathologies, sleep and automobile vigilance, cardiac as well as monitoring in real time in the intensive care units. The bidirectional parameter of the system will not only make it possible to receive the biological signals but also to act on the human body widening the field with multiple neurological pathologies: treatment by major cerebral stimulation of the Parkinson's disease, the compulsive obsessional troubles, the essential tremor. The whole of the technical parameters of the telemetric system (filter, gain, a number of channels) will be programmable and modifiable according to the medical needs. The studies made for the animal applications will be closer to the real conditions of evolution of the animals, by removing the wire connections, with an increase in the number of parameters studied by animal and in the number of animals. The finality of the product implies technological innovations for the transmission of the data with in its industrial version an extreme miniaturization.

Feasibility study

We have then validated this theoretical study by a transmission/bidirectional reception of a cerebral electric signal (EEG) by using a traditional commercial system WiFi and suitable medical material (Figure 3).

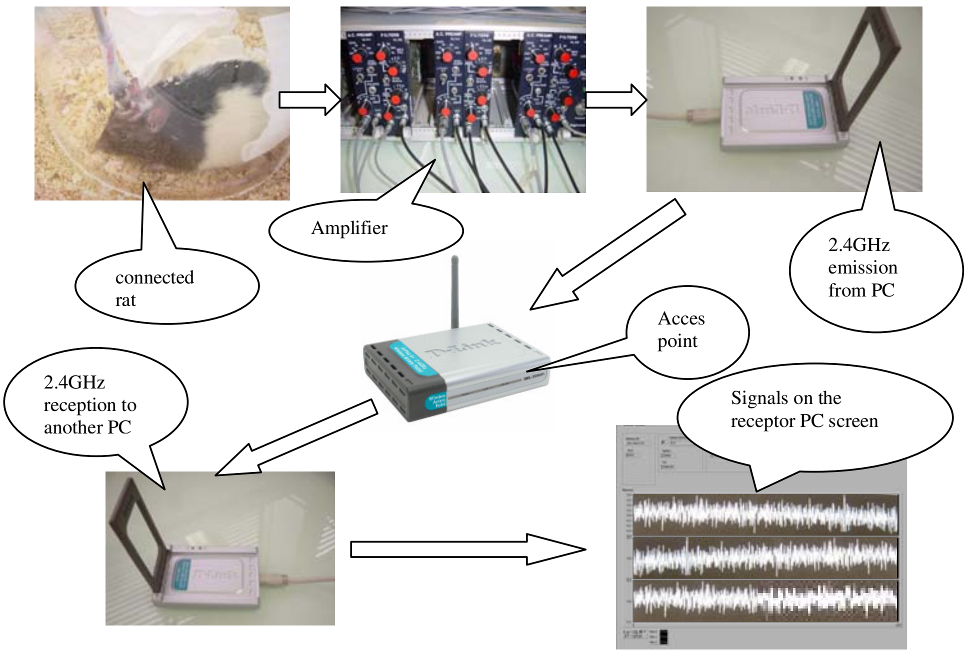

Figure 3: Animal telemetry with standard material

This stage passed, we had to develop our own system of acquisition and our own frame in order to create a demonstrator, and then prototypes. The main characteristics of the specifications that we fixed ourselves for the demonstrator are as follows:

number of sensor	3
kind of signal	EEG, EMG, EKG, temperature
scale of amplitude	µV to 0.1V
sampling	up to 10kHz (programmable)
low pass filter	0.4Hz
high pass filter	by software
ADC	10 bits
input impedance	up to GΩ
Gain	programmable
stimulation	programmable
carrier	2.4 GHz
bite rate	54 Mbps

Table 2: Principal characteristics of the demonstrator

We adopted the following structure for our system (Figure 4).
A sensor is used as reference; the two others are connected to the entries of an instrumentation differential amplifier. The gain is adapted automatically according to the amplitude of the signals collected. The microprocessor converts the analogical signal and carries out the frame according to the model describes hereafter. The latter is transferred to the module RF which formats all part RF and transmits the signals. The following diagram gives a representation of a data frame [5]:

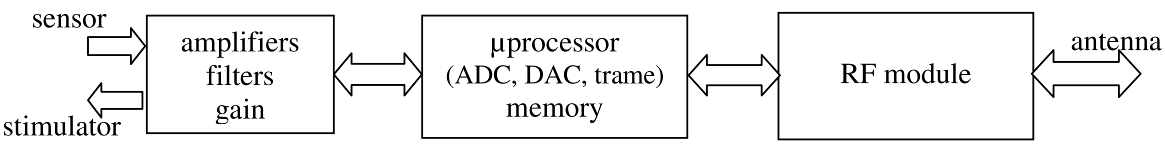

Figure 4: synoptic of the demonstrator

IDGR	ENSENS	G_0	G_1	…	G_n	F_0	F_1	…	F_n	t_0	t_1	data 0	data 1	…	data n

Figure 5: Example of frame

with:

- IDGR, the identifier of the group of module,
- ENSENS, activation of the selected sensors
- Gi, profit of sensor i, variable according to the number of selected sensors,
- Fi, the sampling rate of sensor i, variable according to the number of selected sensors,
- t_0, the time of the beginning of acquisition,
- t_1, the time of end of acquisition,
- Data i, the data collected on sensor i, with t_0, t_0+1/fi, … to t_1.

The identification of the module is made by the MAC address of chip RF. This identifier allows physical detection and the recognition of each system. With the level of the checkpoint, when a data frame is detected following a sending by the module, the identifiers are compared with those which are already saved in the data base to recognize the module which emits this frame.
Parameter ENSENS contains the list of the activated sensors.
Each Gi value corresponds to the profit of amplifier i of activated sensor i. It is programmable at the time of the sending of an order frame.
The Fi values indicate the frequency of acquisition of the signal collected on sensor i.
In parallel, we can acquire signals with the different frequential contents, therefore of different nature. The values t_0, t_1 allow synchronization, at the checkpoint, of the data gathered on each sensor for frames of successive data. Thanks to this technique the receiver can readjust the signal in the event of a loss of data during the transmission of a frame.

Data i contain the data collected of sensor i between time t_0 and t_1. The presence of those parameters enables us to carry out adaptations of impedances and gains. The demonstrator can also receive the order to stimulate an area of the body. Information forwards then contrary to what is described above.

The demonstrator

According to the design presented, we realized a demonstrator whose photography is given on Figure 6. We can mainly the module RF.

Figure 6: The demonstrator in its case

Then we carried out several tests of transmission to check the quality and the continuity of the signals collected. Figure 7shows an example of capture of an EKG collected using our demonstrator.

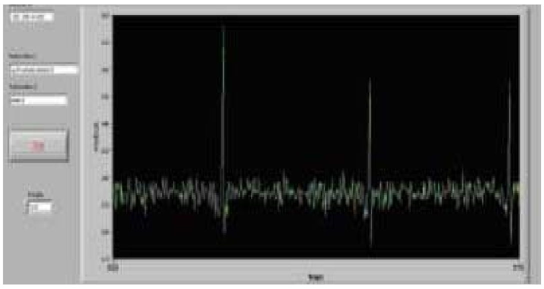

Figure 7: Capture of one EKG using the demonstrator

Conclusion

We showed the feasibility to transmit weak spectrum signals by using the wireless networks of WiFi type. Today we still have to miniaturize the system by making new prototypes and carrying out tests with several receiver/transmitter functioning at the same time.

A study is also undertaken on the management of energy, because modules RF available on the market consume approximately 500mA, which limits a lot the duration of analysis of a wandering system.

Our system can be used in many fields of industry, but currently we focus on the medical applications.

Also, there is currently no system of this type on the market in the field of the EEG in particular and the biological field more generally. The collection of the biological signals (cerebral electrogenesis of surface or in the major cerebral structures) does not require the development of particular transducer, but in the long term it is possible to imagine an application of this system to non electric biological signals by developing specific transducers.

The applications concerned are related in particular to electroencephalography: recording of long duration and in residence of patients epileptics, in particular at mentally handicapped, prone subjects reached disorders of the rate/rhythm day before-sleep, infants and premature. Activity EEG could also be raised on animals free of their movement, and it is also possible to consider the recording and the control of the unit, multi-unit activity or of field of potentials in underlying structures. This last development is to be integrated in the possibility of installing sensors in-depth and the transmitter-receiver into subcutaneous under the scalp of the patient. In fact, our system will be able to make possible to collect and transmit any electric biological signal (electrocardiogram, electromyogram, EEG, cellular electric activity…).

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