A Group Monitoring Wireless System

for Health Care Monitoring

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Abstract - Body Area Network (BAN) is a sensor network technology for monitoring and logging vital signs of a person, such as cardiac frequency and blood pressure. The main goal of BAN is to make remote monitoring possible. In this paper a group monitoring approach is presented. The work differs from others because the idea is to monitor a group of patients in a hospital or clinic at the same time while having only one receiver for up to 32 people. There is no need to have a transmitter/receiver pair for each patient, making the system affordable. The solution presented also involves wireless transmission, i.e., the captured signs are transferred from the patient device to a host in a wireless fashion. Practical experiments are presented to demonstrate the feasibility of the system.

Keywords: Health Care Monitoring, BAN, Wireless Sensor Network, RF.

1 Introduction

With the advance of technology it became possible to bring together two distinct areas, medicine and engineering, in benefit of human being. Among the projects and research done until now, there is the possibility of monitoring vital signs of a being, the study is known as Body Area Network – BAN.

BAN is a base technology for permanent monitoring and logging of vital signs. It is a proven method of supervising the health status of patients suffering from chronic diseases, such as Diabetes and Asthma. Another prominent area of application for long-term logging of patient data is cardiology, where 24-hour-ECGs are required for therapy control and as early indicators for impending heart attacks. Blood pressure is yet another vital sign that can be monitored.

The basic concept of BAN is the fusion of both ideas: a set of mobile and compact units which enable the transfer of vital parameters between the patient’s location and the clinic or the doctor in charge. The vital signs data flow passes a chain of BAN modules from each sensor to a main body station, which consolidates the data streams of all sensor modules attached. It then transmits the data to a server which can further analyze the data and alarm the doctors if necessary.

Considerable attention is spent on a high level of security for the new BAN transmission protocol. Appropriate encryption mechanisms are foreseen to be integrated in BAN communication. Finally, it must be guaranteed that patient data are only derived from each patient’s dedicated BAN system and cannot be mixed up with data from other patients or BAN systems at the same location. BAN is not only appropriate for communication in hospital and at home but has further applications. Potential areas of use are sleep laboratories, monitoring of new-borns or wireless hearing aids.

This work presents a new health care monitoring approach. The idea is to monitor a group of at most 32 people, simultaneously, using only one receiver instead of a transmitter/receiver pair for each patient, considerably reducing cost. The system is implemented over two distinct, but interconnected, modules. The first module is responsible for monitoring cardiac information and transmitting it in a wireless fashion to the second module. The second module receives the information, discovers from which of the 32 devices it came and analyzes the information to find out if it is on an acceptable range, for instance, the system may check if the cardiac frequency and blood pressure are on a compatible range to that specific patient. The system also maintains a complete log for each of the 32 patients in the group.

The rest of this paper is described as follows, section II presents some of the related work, section III brings the methods used to build up the modules, section IV shows some of the practical experiments and, finally, section V concludes the work.

2 Related Work

This section presents some of the related work. They deal with different ways to bring together biomedical engineering and computer networks. The goal in common is to perform personal monitoring in a remote environment.

In [1] the authors present a platform design for health care monitoring applications. They use general characteristics of medical monitoring applications and physical movement monitoring as the pilot application. Furthermore, they
elaborate several design techniques that can be tightly coupled with real-time signal processing, and may enhance the system performance. Finally, they present preliminary results on the movement monitoring application and demonstrate feasibility of the proposed techniques.

The author of [2] proposes an implementation of a personal sensor network for health care monitoring. It comprises several smart sensor nodes and a control node organized into a Bluetooth piconet. Remote users can access the network, query and control sensors via GPRS network using methods provided by the control node.

A wearable system for detecting accelerations of a user’s head while standing still is presented in [3]. The prototype, a headset, weights 195 grams including a 9V NiMH battery. The goal is to detect faint accelerations in both the front to back and right to left directions. The work is very interesting and is showed feasible through several practical experimentations. The authors discovered that the total length of a 2-dimensional acceleration pattern trace and a high frequency spectrum of right/left acceleration are related to the physical condition of the user.

In [4], a sensor network is built-in and a wireless interface is used for monitoring patients. Captured data is wirelessly transmitted to a computer and further analyzed by professionals. The goal is to capture and transmit information about only one patient. Our work differs from this because the system is able to capture information about up to thirty two individuals; besides the remote device wore by the patient is designed to consume very low energy, a small internal battery of 1,5V/500uAh is enough to make it work.

In [5], the wireless distributed data acquisition system for prolonged, patient monitoring is presented. It is based on mobile client devices and gateways that communicate using a 900MHz wireless link. The mobile gateway, implemented on a PDA (Personal Digital Assistant), is responsible for collecting data from sensors during periodical visits. Captured data is processed and synchronized with the existing records on the server. This is actually our next step in the project, to make it possible to transmit several patients’ data from a remote location through a VPN (Virtual Private Network) to a server, which will not only receive data but also set an alarm in case it receives critical data.

Finally, in [6] the authors present a Wireless Health Advanced Mobile Bio-diagnostic System abbreviated as WHAM-BioS. The research proposes a novel clustered sensor network (CSN) architecture for long-term periodical telecare applications. Most network functions are concentrated in a special purpose device called the human body gateway (HBG). The sensor nodes focus on detecting and reporting their detection results to their HBG. Power consumption is also a worry. The contention free environment reduces the power consumption in data retransmission and a power saving mechanism is proposed to reduce consumption in idle listening.

3 Methods

The system presented is composed by two distinct, interconnected, blocks. A brace is responsible for monitoring the vital signs, such as cardiac frequency and blood pressure, and for sending this information to the remote block, the first block. The remote block packs the data and sends it to the base block, the second block. The base block receives and unpacks the data, discovers from which patient the data belongs and finally displays it all on a computer’s monitor.

Communication between the two blocks is performed through an RF circuit, operating at 858MHz. Communication between the base block and the computer is made through an USB connection. Figure 1 presents an overview of the process.

![Figure 1 – Interconnection between modules.](image)

3.1 The Brace

A totally new brace was developed during this project. The brace may be fixed in any place of the body, preferentially in the members, allowing monitoring the blood pressure. The purpose of the new brace is to behave as a low power consumption device, having an internal sealed battery of 1,5V/500uAh.

The brace monitors the cardiac activity through two electrodes, positioned at the patient’s internal side. Each heartbeat produces an electrical signal captured by the electrodes. The blood pressure is obtained over the maximum amplitude and the cardiac frequency is the time between two consecutive beats [7].

The internal brace circuit produces an RF burst of 5KHz for every beat. The burst duration time is equal to the blood pressure from the patient monitored. It means, low pressure produces a burst with the same amplitude but low duration,
and high pressure produces bursts with the same amplitude and high duration. A burst of 5KHz is showed on Figure 2.

Figure 2 – Burst for every heartbeat.

3.2 The Remote Module

The remote module is fixed in any location of the patient’s body. It receives the brace signal, decodes information and stores it. It only sends the stored information when requested by the base module.

The distance between the brace and the remote module must be at most ninety centimeters. This is necessary because every brace produces the same signal sample of 5KHz, thus, if the distance is not respected, one remote module may receive signals from several braces. Figure 3 shows the spectral receive radius from the remote module.

Figure 3 – Spectral signal strength from the brace to the remote module.

The brace signal captured by a RLC (Resistor, Coil and Capacitor) circuit, goes to a gain and filter stage. In the third step a trigger level is used to obtain the blood pressure. The information then goes to a controller that stores it and waits a signal from the base module to transmit. Figure 4 depicts a block diagram of the remote module.

Moreover, the controller monitors power consumption and the RF transceiver. The main tasks of the controller are monitoring the cardiac brace signal, decoding pressure and frequency from the signal, configuring the RF transceiver, controlling communication with the base module, using a specific protocol.

A commercial RF transceiver [8] is used in this project. The data transmitted has specific address for each patient, allowing up to thirty two different patients. The controller block also turns on and off the RF transceiver. This solution increases the autonomy, diminishing power consumption. Finally, the distance transmission between the remote and the base modules can reach up to one hundred meters in outdoor places.

3.3 The Base Module

The base module is responsible for receiving the data from each remote module, interpreting it, connecting the data with its respective patient and plotting the information in the computer program. An alarm is set if any data reaches a dangerous threshold.

The communication with the remote modules is controlled using a token scheme. Every remote module has a time slot to transmit the information to the base. The base module groups the information requested from the remote modules and sends it to the computer software that further analyses the data, displays it to a user and sets an alarm if it is the case.

At each three transmissions, the base module also verifies which of the remote modules are still active or disable and sends this information to the computer program that alerts the user about active remote modules that are not monitoring. Figure 5 depicts the algorithm for the base module.

Figure 4 – Remote module block diagram.

Figure 5 – The base module algorithm.
Communication between the remote modules and the base module uses FSK (Frequency Shift Keying) modulation and data transmitted uses a protocol to prevent errors. In Table 1 the protocol developed to control the communication is presented.

<table>
<thead>
<tr>
<th>Data</th>
<th>Transmitter</th>
<th>Receiver</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xAA</td>
<td>Base</td>
<td>Remote</td>
<td>Synchronizes transmitter and receiver modules.</td>
</tr>
<tr>
<td>‘a’</td>
<td>Base</td>
<td>Remote</td>
<td>First character. To recognize communication start.</td>
</tr>
<tr>
<td>‘b’</td>
<td>Base</td>
<td>Remote</td>
<td>Second character. To indicate that the first character is not burst.</td>
</tr>
<tr>
<td>Address</td>
<td>Base</td>
<td>Remote</td>
<td>Remote module address that will have permission to send information.</td>
</tr>
<tr>
<td>0xAA</td>
<td>Remote</td>
<td>Base</td>
<td>Synchronizes transmitter and receiver modules.</td>
</tr>
<tr>
<td>‘cd’</td>
<td>Remote</td>
<td>Base</td>
<td>First character to recognize communication start.</td>
</tr>
<tr>
<td>Data</td>
<td>Remote</td>
<td>Base</td>
<td>Send data string with cardiac frequency and blood pressure.</td>
</tr>
<tr>
<td>‘dc’</td>
<td>Remote</td>
<td>Base</td>
<td>End of transmission.</td>
</tr>
</tbody>
</table>

Table 1 – Remote/Base module communication Protocol.

4 Experimental Results

A broad range of analysis was done over the equipment developed. These experiments have the purpose to verify some of the equipment characteristics. Tests were performed to analyze the main requisites: power consumption, transmission distance and transmission time.

4.1 Power Consumption

Power consumption tests were performed with the intent to analyze current consumption and expected running time of the equipment, i.e., the autonomy of the remote modules. The power consumption has great changes in three situations: reception, transmission and stand-by. Because it, the tests cover all of the situations.

Power consumption tests were performed on the brace and the remote modules. There is no need to worry about power consumption on the base module since it is powered up by the computer’s USB connection.

1. Brace

When the brace is connected on the person, it is in transmission mode. Otherwise, if the brace does not receive any vital sign in three seconds, it goes to stand-by mode automatically.

To analyze the brace current consumption three tests were performed. These tests cover the situations in which the brace is used full time and in maximum distance, half-time period in maximum distance and when the brace is not used, i.e., it is kept in stand-by mode.

In the tests, the brace was monitor from the time it was started until the time it did not transmit more data. The power consumption value was then estimated. In Table 2 the minimum, average and maximum time values obtained are presented. Through these values the current consumption was estimated over the average value.

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (h)</th>
<th>Average (h)</th>
<th>Maximum (h)</th>
<th>Consumption (uA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% on transmit mode</td>
<td>383</td>
<td>437</td>
<td>456</td>
<td>458</td>
</tr>
<tr>
<td>50% on transmit mode</td>
<td>457</td>
<td>753</td>
<td>812</td>
<td>266</td>
</tr>
<tr>
<td>100% on stand-by</td>
<td>1015</td>
<td>1042</td>
<td>1057</td>
<td>192</td>
</tr>
</tbody>
</table>

Table 2 – Brace autonomy and current consumption (estimated).

2. Remote Module

The remote module was analyzed in all possible situations: transmission, reception and stand-by. Consumption tests were performed on laboratory, current drained by the equipment was measured directly. Thirty samples were performed for each mode. Table 3 shows the values obtained, minimum, average and maximum values.

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (mA)</th>
<th>Average (mA)</th>
<th>Maximum (mA)</th>
<th>Consumption (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission</td>
<td>3,2</td>
<td>4,1</td>
<td>5,1</td>
<td>13,53</td>
</tr>
<tr>
<td>Reception</td>
<td>7,6</td>
<td>8,1</td>
<td>8,5</td>
<td>26,73</td>
</tr>
<tr>
<td>Stand-by</td>
<td>0,06</td>
<td>0,08</td>
<td>0,15</td>
<td>0,264</td>
</tr>
</tbody>
</table>

Table 3 – Remote Module current consumption.

4.2 Distance Transmission

The system has two sets of wireless communications. First, the communication between the brace and the remote module and second the communication between the remote modules and the base module. All distance transmissions were analyzed at indoor and outdoor environment.

1. Brace/Remote Module

The objective of the transmission test between the brace and the remote module was to find the maximum distance reached without any burst loss. Since the transmission distance between these modules is small, there is no difference between indoor and outdoor environments. Thirty samples were carried through the modules and the maximum distance obtained was 110 (one hundred and ten) centimeters in the best case, the brace and the remote module were
2. Remote/Base modules

The communication between the remote modules and the base module is more critical. This is because the two modules do not recognize transmissions loss. This test also evaluated the maximum distance between modules without any data loss or corruption.

For this test, the modules communicate for five minutes with previously knew data strings and at the end, the data received and waited were compared for errors. Again, thirty samples were carried out. Table 4 shows minimum, average and maximum distances for indoor and outdoor environment.

<table>
<thead>
<tr>
<th>Place</th>
<th>Minimum (m)</th>
<th>Average (m)</th>
<th>Maximum (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor</td>
<td>53</td>
<td>62</td>
<td>67</td>
</tr>
<tr>
<td>Outdoor</td>
<td>92</td>
<td>101</td>
<td>110</td>
</tr>
</tbody>
</table>

Table 4 – Communication distance between remote and base modules.

4.3 Transmission Time

Transmission time is as critical as distance transmission. If the time is long between samples, doctors do not have any way to evaluate the patient and discover before hand any problem.

Data packets are small, 16 bytes, but the system was developed with a time frame scheme. The base module controls whenever any remote module can send information. Because of it the transmission time grows up as the number of user’s increases. In Table 5 is presented the transmission time for one, two, eight and thirty-two users.

<table>
<thead>
<tr>
<th>Users</th>
<th>Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53</td>
</tr>
<tr>
<td>2</td>
<td>106</td>
</tr>
<tr>
<td>8</td>
<td>416</td>
</tr>
<tr>
<td>32</td>
<td>1507</td>
</tr>
</tbody>
</table>

Table 5 – Transmission time vs. users connected.

5. Conclusions

The main goal of BAN is to make remote monitoring possible. In this paper a group monitoring approach was presented. This work differs from others because the idea is to monitor a group of patients in a hospital or clinic at the same time while having only one receiver for up to 32 individuals. There is no need to have a transmitter/receiver pair for each patient, making the system affordable. The solution presented also involves wireless transmission, i.e., the captured signs are transferred from the patient device to a host in a wireless fashion.

The results obtained showed that the remote modules, the ones connected to the patient, consume very low power. The average distance to successfully communicate the remote module with the base module is of 62 meters indoor and 101 meters outdoor. The transmission time, i.e., the time to transmit data from the remote module to the base module, varies from 53 milliseconds when there is only 1 patient and goes up to 1507 milliseconds when there are 32 patients.

Future work includes studies to make the solution feasible in a remote environment, such as the patient’s home. In this case, the plan is to have the remote module and the base module communicating in a regular way, but the base module would also be connected to the Internet and would transmit the captured data in real time to a clinic or monitoring software in a hospital server.

6. References