Development of an ANT+ Wireless Sensor Network Based System for Lactate Monitoring in Saliva

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***Abstract*—In this paper, the implementation of a wireless sensor network system is proposed and described in details. The system uses a micromachined sensor that enables continuous, real time and location independent measurements of lactate concentration in saliva. ANT wireless protocol was used to provide the wireless connection between the sensor node and the receiver. ANT protocol is introduced due to its characteristics of flexibility, reliability and particularly its low power consumption which is suitable for sensor application as in wireless body area networks. Therefore, current consumption and coverage area have been addressed to evaluate the protocol and system performance.**

***Index Terms*—ANT protocol, healthcare, wireless body area network, remote monitoring, vital signs.**

I. Introduction

Wireless monitoring of human vital signs is one of the current needs that are required in different applications especially in healthcare and sport medicine systems. The importance of these systems comes from the fact that it provides a remote monitoring of different physiological parameters without the need of professionals and complicated equipments reducing by that the cost that is usually required to do such medical tests [1], [2], [3]. The solution of such important systems achieved by integrating two important technologies: sensor technology and wireless technology. The sensor technology enables the development of small medical sensors which are able to provide real time measurements of many vital signs like blood pressure, heart rate, lactate and other important medical and sport parameters [4]. While different wireless protocols have been and still developing to provide the connection between the sensors and the different wireless devices forming by that an entire health care system that can be used for remote monitoring. One important part in these systems is wireless body area network WBAN. WBAN can be achieved by using small scale personal area technologies like Bluetooth, ZigBee, and other wireless sensor network together with reliable sensors to provide health care monitoring applications [2]. But implementing such systems is not easy because of the challenges that may be presented as in providing reliable communication by eliminating the interference with other wireless devices, low cost, flexibility and also the low power consumption [1].

Some Existing medical systems use the short range IEEE 802.15.4 (ZigBee) protocol due to its low transmission power and good range that it can provide comparing to the classic Bluetooth protocol which lasts only for days [1]. On other hand, Bluetooth have been used due to its compatibility with most of new devices like PCs and cell phones which are always around the human body eliminating by that the need to build new compatible devices. Of course the development did not stop at this level, many attempts and improvements are introduced to such protocol and others have been appeared as in Bluetooth LE and ANT protocol in order to overcome the difficulties and the different challenges in building these systems.

A WBAN system for healthcare and sport medicine applications will be presented in this paper. ANT+ protocol is used to build a wireless sensor network for lactate monitoring in saliva using a miniaturised lactate sensor. The data is transmitted and received by ANT based modules using 2.4 GHz ISM Band.

The reset of this paper is organized as follows: section 2 illustrates system architecture and the implementation of the transmitter and the receiver nodes. Also ANT wireless network and settings are explained in this section. To evaluate the system, current measurements and ANT range tests are discussed in section 3. In section 4, an overview of the popular protocols is introduced by providing a technical comparison between them. Finally, Section 5 concludes the paper.

II. System Implementation

The system presented in this paper can be divided into two major parts: transmitter node which represents the sensor node and the receiver node. ANT wireless protocol is used to provide the wireless connection between the transmitter node and any device that is compatible with ANT protocol and able to receive ANT data packets if the wireless settings are met. In this work a windows based application is created to handle the received data. Figure 1 shows the main parts of the system.

A. Transmitter Node

The used sensor in this system is a miniaturised sensor for continuous lactate measurement in saliva. The size of the chip

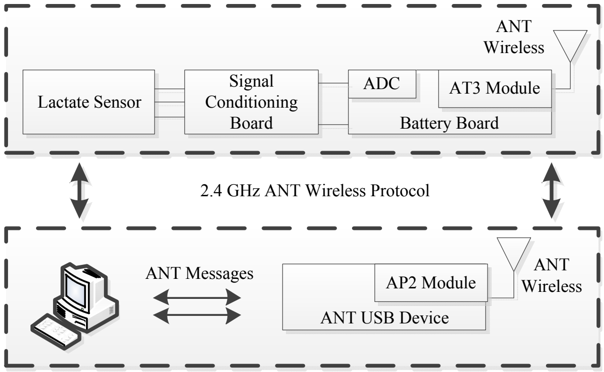

Fig. 1. System Block Design

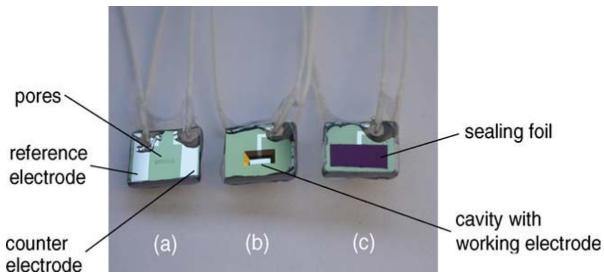

Fig. 2. Photograph of the packaged lactate chip. The size of the chip is 5.5mm×6.4mm×0.7 mm: (a) front side showing the pores, the reference and counter electrode; (b) back side with cavity and working electrode; (c) back side covered with sealing foil after filling.

is 5.5mm×6.4mm×0.7mm and it uses three electrode set-ups to provide amperometric readout for the lactate concentration. In order to connect the sensor electrically, isolated wires are glued onto the three electrodes using an electrically conductive adhesive [5]. Figure 2 shows a photograph of the lactate sensor with the three electrodes.

A signal conditioning circuit is used to modify the electrical output signal of the sensor to a suitable level that is applicable for further processing. Then an analogue to digital conversion stage is employed to convert the analogue signal into digital ones. The used ADC is integrated with the transmitter module which eliminates the need of building an isolated ADC. The converter has a resolution of 10-bits and voltage reference of 3 V is used due to the output range of the amplification stage. Sampling rate of 4 Hz is convenient according to the recommendation of the sensor's designer [5], [7].

ANT AT3 module is used to provide the wireless communication as a transmitter in order to send the signal wirelessly after digitizing it using the integrated ADC converter. The module is based on the chipset combining MSP430f22x2/4, the ultra low power microcontroller (MCU) from Texas Instrument, and nRF24L01, the ultra low power radio chip from Nordic Semiconductor [7]. In addition to that, AT3 module supports SensRcore platform which can be configured using script file, and it can be mounted easily on the battery board using the module socket on both AT3 module and battery board [8], [9]. This allows AT3 module to get the

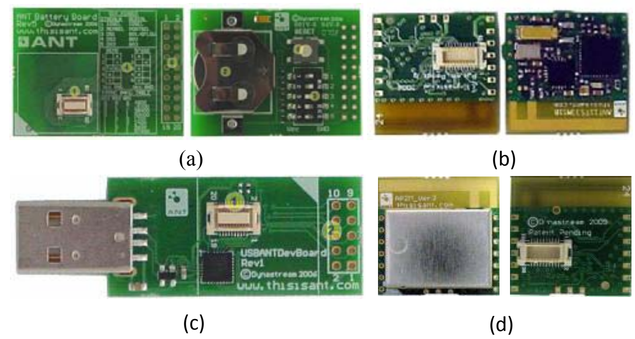

Fig. 3. Photograph of wireless components: (a) Battery board; (b) AP3 module; (c) ANT USB; (d) AP2 module

access to the I/O ports on the battery board which means handling the analogue sensor signal [10], [7]. Figure 3 shows a photograph of the ANT AT3 module and buttery board.

B. Receiver Node

To handle the received messages, ANT AP2 module is connected to a computer via ANT USB interface. The computer works as a host to the ANT module which will pass all the received data to the computer. Since AP2 module doesn't support SensRcore platform, channel configurations should be done programmatically by sending command messages to the module via the USB interface [10], [11]. Figure 3 shows ANT AP2 module and the USB board.

C. ANT Wireless Network

The implemented network is a simple broadcast network. It uses an independent unidirectional channel to establish the connection between the nodes. The transmitter is configured as a master node while the receiver is configured as a slave node. Both nodes should have the same channel configuration including Channel ID, channel period and same working frequency from the available operating frequency with the base of 2.4 GHz. On other hand, a managed network type is used by setting a managed network key on both nodes and 25 seconds of high priority search mode is used in the slave device as a default value for search time out [12], [13].

By opening the channel on the master node, it will start sending its channel ID along with the data on a specific time slots at specific rate according to the chosen channel period. On other hand, the slave device will start searching for the master device that has similar channel ID or any subset of channel ID's fields. Once the slave device found a matching master, it will start receiving data on the configured channel period. Figure 4 illustrates search mechanism between the master and the slave. If the slave didn't find any matching master channel ID, the channel on slave device will be closed according to user defined search time out [12], [6].

III. System Evaluation

ANT uses adaptive isochronous scheme to ensure coexistence with other 2.4 GHz radios especially if there are several ANT nodes working in the same area and it achieves that in time domain by using TDMA [14], [15].

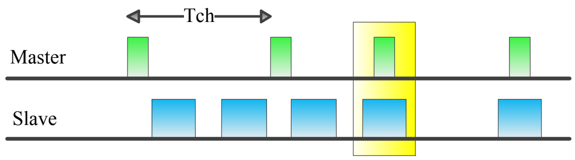

Fig. 4. ANT search mechanism

This techniques relies on transmitting data in a very short time slot allowing single channel to be divided into hundred of time slots. So if an interference occurs between an ANT node that transmit at a specific time slot and other ANT nodes working in the same band, the ANT node will adapt its time slot and start transmitting at new ones [14]. But in spite of that, the working environment and the existence of other wireless devices that work on the same band of 2.4 GHz or closer frequencies may cause interferences with ANT nodes and that means reducing the performance of ANT protocol. Therefore, to evaluate the system, several statistics have been recorded to measure the coverage area using a transmission power of 0dbm, these statistics include: number of received packets, number of lost packets, distance, number of times the receiver enter search mode and its duration in seconds. The tests have been done in lab environment which includes several reflectors and power supplies. Table 1 lists the results of different cases.

As we can see from the table, the results differ from place to place and it highly depends on the environment and other available signals in the surrounded working area. For example, in the case of distance of 4.5 m, the receiver went into searching mode 4 times: first one for 2 s, then 9, 9 and 5 s for the second, third and fourth duration respectively.

Table I. DATA PACKET STATISTICS

Case	Range (m)	Received Packets	Lost Packets	Entering Search Mode (Times)	Duration of Searching (s)
1	2.5	861	104	0	0
2	4.5	748	59	4	[2]-[9]-[9]-[5]
3	6.5	0	0	Closed	-

In all cases the transmitted packets are of type of broadcasted packets which means no acknowledgement and that will cause loosing packets even when the receiver goes into search mode. On other hand, if we took case 3, we can find that the receiver couldn't find the transmitter and the channel is closed. While in the first case where there was a free space between the nodes, the receiver didn't enter the search mode after synchronizing. These results indicate that ANT protocol is more effective in free areas and at short ranges, in addition to that, the coexistence procedure of ANT protocol allows using multiple sensors around the human body without any interference between the nodes which may be helpful in wireless body area network applications.

A. Current measurements

Average and peak values of the current were measured for AT3 module during the transmission. Table 2 lists the current

Table II. CURRENT MEASURMENTS

Symbol	Description	Current	Value	Unit
TX_UNI	Master channel, TX only	I_av	46	µA
		I_peak	~8	mA
TX_UNI_ADC	Master channel, TX only with ADC	I_av	0.89	mA
		I_peak	~8	mA
TX_UNI_ADC_LED	Master channel, TX only with ADC and LED is enabled	I_av	0.91	mA
		I_peak	~10.5	mA

value of different cases. Common settings were used by applying a message rate of 4 Hz and using A/D sampling rate of 4Hz for some cases. In addition to that, a transmission power of 0 dBm and broadcast unidirectional channel type were also used for all cases.

The time duration of the current's peak value is almost the same for all cases and it is around 300 µs. On other hand, it is obvious that using the ADC increased the current consumption from 46 µA to around 0.89 mA which is a noticeable increasing, while the peak value remained almost the same for both cases because it represents the current value of the transmission. Also, we can notice that the average current value of the amplification circuit is higher than the rest of measurements. These measurements showed that most of the current consumption is hardware related, while the wireless part consumes the least ones.

IV. TECHNICAL COMPARISON OF ANT, ZIGBEE AND BLUETOOTH

The classic Bluetooth is designed for rapid transfer in order to send large files as in cell phones and portable computer. On other hand, the ZigBee has a smaller protocol stack compared to Bluetooth ones and it's able to address more nodes than Bluetooth does.

Table III. COMPARISON BETWEEN DIFFERENT PROTOCOLS

	ANT	ZigBee	Bluetooth
Standard	Proprietary	IEEE 802.15.4	IEEE 802.15.2
Application	PANs and WSN	PANs and WSN	PANs
Host Resources (Kbyte)	2	100	250
Buttery Life	3+ years with cell-coin buttery	4 to 6 months	1 to 7 days
Max Network Size (Nodes)	2^32	2^64	7
Over the Air Transmission rate Kbps	1000	250	1000
Range	1 to 30 meter	1 to 100+	1 to 10+
Supported Network	Peer to Peer, Star and Mesh	Peer to Peer, Star and Mesh	Peer to Peer and Star
Success Metrics	Ultra Low Power	Power	Power
Min. Node Configuration	Transmitter only or Transceiver	Transceiver	Transceiver

ZigBee consumes less power compared to Bluetooth and it may last for months, while Bluetooth protocol just for days. ZigBee uses the standard IEEE 802.15.4 and Bluetooth uses the standard IEEE 802.15.1.

Compared to Bluetooth and ZigBee, ANT provides ultra low power wireless communication protocol that may works with Buttery cell-coin for years according to application's complexity. In addition to that the protocol stack is smaller than the rest but it's not standard. Table 5.8 gives a brief comparison of ZigBee, Bluetooth and ANT [14].

Other protocols are also exist and it may be quite competitor to ANT protocol especially in power consumption issues as in Bluetooth LE, which provides data transmission with low power consumption that enables building sensor application based on coin battery with a transmitting range of 100m..

V. CONCLUSION

ANT + wireless network system has been designed for lactate monitoring in saliva. System evaluation showed the efficiency of ANT protocol at short ranges and its low power consumption comparing to the hardware parts. This makes ANT protocol suitable for battery based application which is mostly required in WBAN systems. Using TDMA with a 2.4 GHz protocol may not be enough to avoid the interference in crowded areas, but it is suitable to build a network of ANT based sensor nodes with minimum interfering between each other in more free areas. Also, the existence of some ANT compatible devices as in cell phones, facilitate the interfacing between ANT protocol and other wireless protocols to create remote monitoring systems. There are still challenges to overcome and improvements to be done when security issues, co-existence and data types are studied. Of course, it is not easy to achieve that quickly but the importance of building such systems on life's quality requires lot of efforts and many attempts should be done until reaching the goal that will help a lot of people to survive an independent life.

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REFERENCES

[1] M. R. Yuce, Implementation of wireless body area networks for healthcare systems, Sensors and Actuators, A 162 (2010) 116–129.

[2] H. Alemdar, C. Ersoy, Wireless sensor networks for healthcare: A survey, Computer Networks 54 (2010) 2688–2710.

[3] S. Sneha, U. Varshney, Enabling ubiquitous patient monitoring: Model, decision protocols, opportunities and challenges, Decision Support Systems 46 (2009) 606–619.

[4] N. Ullah, P. Khan, K. S. Kwak, A Very Low Power MAC (VLPM) Protocol for Wireless Body Area Networks, Sensors (Basel). 2011, 11(4): 3717–3737.

[5] C.G.J. Schabmueller, D. Loppow, G. Piechotta, B. Schütze, J. Albers, R. Hintsche, Micromachined sensor for lactate monitoring in saliva, Biosensors and Bioelectronics 21 (2006) 1770–1776.

[6] ANT Channel Search and Background Scanning Channel, Dynastream Innovations Inc., 2009.

[7] AT3 RF Transceiver Module, Dynastream Innovations Inc., 2009.

[8] SensRcore™ Messaging and Usage, Dynastream Innovations Inc., 2007.

[9] ANT SensRcore™ Mode, Dynastream Innovations Inc., 2008.

[10] ANT User Manual Development Kit, Dynastream Innovations Inc., 2009.

[11] AP2 RF Transceiver Module, Dynastream Innovations Inc., 2010.

[12] ANT Message Protocol and Usage, Dynastream Innovations Inc., 2009.

[13] Network types. [Online]. Available: http://www.thisant.com/technology/network-types.

[14] ANT™ Protocol Brief Technical Description, ANT Dynastream (June) (2007).

[15] ANT Basics. [Online]. Available: http://www.thisisant.com/pages/support/presentations, Sep 2010.