Five-Point Acceleration Sensing Wireless Body Area Network - Design and Practical Experiences

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Abstract

An implementation of an unobtrusive five-point acceleration sensing wireless body area network (WBAN) with mobile device data logging capabilities is presented, along with practical experiences on performance. Results show good communications performance in laboratory conditions. Field test performance is weaker and the reasons for this are discussed.

1. Introduction

In related work, wearable sensor data loggers have been demonstrated [1]. To the best of our knowledge, this is the first report on practical experiences of implementing a WBAN and testing it in sports data logging.

2. Wireless Body Area Network

The WBAN implementation presented in this paper is based mainly on our generic device platform called SoapBox (Sensing, Operating and Activating Peripheral Box) [2]. It is a small, matchbox size device with sensing and communications capabilities, thus it is unobtrusive for measuring user activity. Its *basic board* holds a real-time clock circuit, which provides timing reference precise enough for implementing a TDMA based MAC protocol. Microchip PIC16LF877 is used as a microcontroller. RS-232 is used for serial communications with external devices. A single channel, 1 mW license free radio (RF Monolithics TR1001) is used for networking devices, providing 10 kbps bidirectional, half duplex wireless communications.

The standard sensor board of SoapBox ver. 1.0 includes five different types of sensors. Only the 3-axis acceleration sensor (two +/-2g Analog Devices ADXL202JE) is utilized in the WBAN arrangement. In one node, a +/-10g derivative of the sensor is used.

2.1 Network Topology

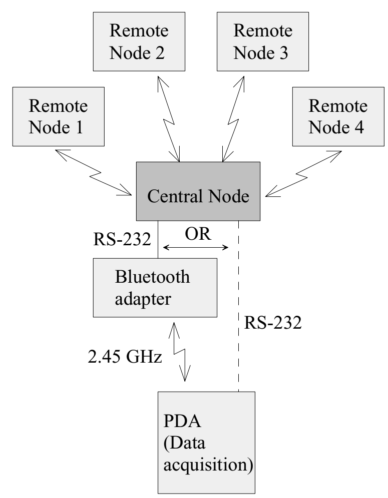

Figure 1. The overall network topology.

The overall WBAN topology is shown in Fig. 1. All the nodes measure three-dimensional acceleration: *remote nodes* at 41.25 Hz and the *central node* at 33.00 Hz sampling rate. The central node receives acceleration data from all the remote nodes, and forwards both its own and the received data to the data acquisition PDA. A Bluetooth connection (F2M01 serial-to-Bluetooth adapter) with up to 100m range is used for this data link. As an option, a wired RS-232 link can be used.

2.2 Communication Protocol

The most efficient way to transfer data within the single channel is TDMA protocol. When the central node

Proceedings of the Eighth International Symposium on Wearable Computers (ISWC'04)
1530-0811/04 $ 20.00 IEEE

is powered up, it sends synchronization message to the remotes. The remote nodes then time their actions, especially sending data, depending on an individually allocated slot. In this approach, the system must work for the required time solely with the initial synchronization. Timing drift is compensated by individually fine-tuning each remote node. 5 ms margins are reserved to allow some timing drift, to increase robustness, and to leave time for CRC checking in central node. To reduce the proportion of header data, five (remote nodes) or four (central node) acceleration samples are buffered into memory before sending. The frame length is 121.2 ms.

3. WBAN Performance

3.1 Laboratory tests

We measured that the system maintains synchronization properly for approximately 125 minutes.

The first laboratory tests were carried out with stationary devices. Other than temperature, also multipath fading inside the metal covered refrigerator could explain the difference in cold temperature tests (see Table 1). We also studied the electromagnetic interference (EMI) between central node and an independent Bluetooth adapter sending dummy data. The average results from several repeated measurements show that data communication performance deteriorates slightly because of Bluetooth interference, making a close proximity class 1 Bluetooth device problematic as a companion data link.

Table 1. Performance in laboratory conditions

Test description (RS-232 used as central node - PDA data link)	lost central data	lost remote slots, average
30 min. on the table	0%	0.40%
1 hour on the table	0%	0.68%
30 min. in refrigerator,	0%	1.03%
15 minutes on the sitting user	0%	3.09%
Bluetooth EMI test, Bluetooth switched off	0%	0.31%
Bluetooth EMI test, Bluetooth active	0%	0.69%

Attaching nodes to a person increased data losses. Losses from right hand were about two times higher than losses from other remote nodes, probably because the user was working with the right hand. This was confirmed by swapping left and right hand nodes.

We also studied the proximity detuning effect on the helical antennas used. We found that the wrist straps alone shifted the resonance by 4.5 MHz. Adding the body effect, the resonance was even 12 MHz lower, the return loss being 25.5 dB higher at the operating frequency. Ankle node situation was better. The additional effect of clothing was not studied.

3.2 Field tests

In the field study (see Table 2), the remote nodes were attached into test person's wrists and ankles, while the central node was attached to the hip. In indoor tests, the users were actively moving: walking, running, using bike trainer, jumping indoors. In outdoor tests, the users were cross-country and downhill skiing.

Table 2. Performance in field tests

Test description	lost central data	lost remote slots, average
10-15 min. indoors, RS-232	0%	10.58 %
10-15 min. indoors, Bluetooth	1.93 %	21.46 %
10-15 min. outdoors, RS-232	2.09 %	13.66 %
10-15 min. outdoors, Bluetooth	3.84 %	52.51 %

Tests show significant losses in communication, compared to the lab test where the user was sitting and working with computer. Additionally, we observed that losses from hands were about 1.7 times higher than from legs, and that data losses from the nodes located on the same side of the body as the central node were lower than losses from the nodes on the other side by factor of 1.4.

Measured performance outdoors was worse than indoors due to damage in Bluetooth adapter and accidental disconnection of the serial cable. It is unclear how much data loss was caused by these events.

4. Conclusion

Our WBAN tests show good communication performance in laboratory conditions. Statistics of our tests suggest that reflections and/or RF-signal path cut-off caused by human body and its movements have significant effect on network performance. Taking proximity detuning effects into account in antenna design and tuning is of utmost significance.

References

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