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High reliability body sensor network using gesture triggered burst transmission

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Abstract

Body Sensor Networks (BSN) is a developing area of research that allows wireless sensors to collect important parameters and monitor the human body. The wrist movement of a test subject running at moderate speed was monitored using accelerometer sensors. The sensor nodes were programmed to follow a gesture transmission technique to collect acceleration data and to predict the best limb position for communications while the athlete is moving. This paper reports a high reliability wireless network to acquire 50Hz movement acceleration during running. This reduces transmission power and increases the reliability. A result of 30% data loss was reduced to around 1% compared to continuous communications. This technology is important for a wide range of monitoring applications including measuring movement symmetry, physiology and athlete rehabilitation.

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Keywords: Body sensor networks; network reliability; gesture identification; acceleration measurements; sport applications.

1. Introduction

“Sports bands” worn on the wrist are now a popular accessory for amateur and professional athletes. They are used to monitor and interpret movement (accelerometers and gyroscopes) and position (GPS, magnetometers). Some parameters such as heart rate, expired breath, and foot impact require an array of various sensors distributed across the body (e.g. chest, shoe). The use of a hub in such a wireless sensor network (WSN) is invaluable for both data synchronization and data storage. The hub can also be used for off-body communications to a coach or way-point in a long distance race. In non-sporting activities, the general health and well-being of a person requires 24/7

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monitoring and so very high data transfer requirements with cloud storage now a realistic option. These advances have been made possible by improved battery technology, low-power wireless transmission, advanced sensor technology and highly functional microcontrollers [1]. Within the vast number of applications in which WSN can make a significant contribution, one field in particular involves accelerometer use on the human body [1-3].

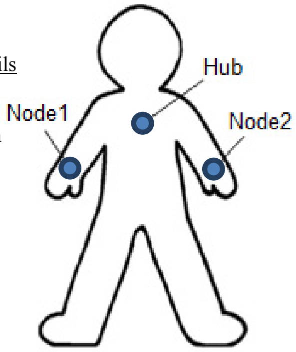
These sensor nodes collect relevant information, transmit the data and perform computational operations. An example of real-time physical monitoring networks is presented in [4], in which the system classifies the body activity by recognizing the angles calculated from the acceleration segments. Another body network uses a unique method for measuring the angular motion of an arm swing in golf by placing a local acceleration sensor at the grip [5].

Careful consideration of important characteristics of body sensor networks (BSN), such as sensing accuracy, long life time and network latency, is essential as weak wireless links and node failures reduce the system reliability. The physical dimensions minimize hindrance to the natural movement of the body while still supporting nodes placement [1, 6]. One important problem associated with BSN is the effect of body movement on the wireless connection. For example, the absorption [7] and obstruction [8] of wireless signals through the body, and data collision [9] are common difficulties to be overcome.

In this paper, several experiments were conducted to enhance the network performance by using the wrist movement of runners of the body for transmission of data blocks to minimize data loss and increase the network life time.

2. Measurement Setting

Two wireless accelerometer sensor nodes and a central hub form a star network on the human body (see Fig. 1). The nodes sense body movements, store and send information [8]. In the tests, acceleration samples from the axis parallel to the forearm were recorded every 20ms at both nodes and sent to the Hub on the chest. The tests involved the participation of a human volunteer and were conducted under the project code for responsible conduct of research (Ethics approval ENG/20/13/HREC). This paper follows previous work on dynamically choosing reliable window times for sending data during the movements of limbs while running [9]. To ensure all information is delivered successfully, the data were stored and sent only at these predictable reliable time windows - one in each movement cycle.



Participant details
Sex: male
Age: 26
Height: 1.80 cm
Weight: 70 kg

Fig. 1. The test subject wears two sensors (Nodes 1 and 2) on the wrists and a hub on the chest.

3. Experimental results

Running is a periodic and repeatable action for a number of cycles. Different humans are unlikely to have the same running style and speed, and therefore, they generate different running cycle lengths [10]. Cycle lengths vary for the same runner depending on his/her limb movements. In this experiment, the length of a running cycle was determined from the acceleration samples. Fig. 2 shows the time required to finish ten consecutive wrist cycles for the same test subject. The measured cycle length changes slightly. The average time was 460ms; which means that on average the nodes are required to send 23 acceleration samples from each wrist every cycle (sampled every 20ms). Each acceleration sample is 2-bytes long (excluding the transmission overhead) and requires 13.5mA to transmit over the 2.45GHz frequency channel. The 240mA battery capacity gives a node lifetime of around three hours for continuous transmission. The network life time can be increased significantly by selecting one burst transmission point every cycle while forcing additional sleep time for the radio transmitter to avoid unnecessary transmissions.

Throughout the test, the sensor node data was stored and sent continuously to the Hub. By comparing the stored data at the node and the hub, the link reliability was calculated. The average was 70% so that 30% of the data were lost when the connection fails. Other tests for different body limbs showed higher data losses [9].

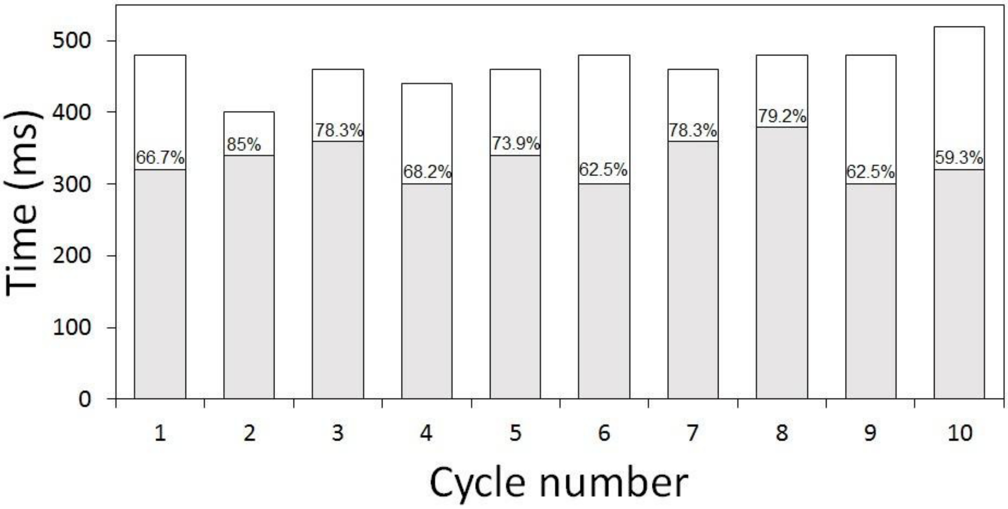


Fig.2. Classical continuous transmission with 50Hz sampling rate, the time of ten consecutive running cycles for a novice runner, and successful information delivery in each cycle (shaded).

To avoid this loss and to avoid data collisions, the gesture transmission method was adopted. Data were stored continuously and only transmitted when a specific acceleration condition is met. This condition defines the beginning and end of a reliable transmission window and their locations within the running cycle. This varies between different runners [10]. The nodes save all samples locally in a block array and start sending these samples one by one at the appropriate time. Link failures will be minor and do not affect the transmission of other samples for the same node (the block array is received with 1 or 2 samples missing). The time required for sending these samples depends on many parameters including, sample size, array size and data rate. In our configuration each sample takes around 5ms to be delivered to the Hub, and a total average of 23 samples array will require a maximum time period of 115ms to transfer. Fig.3 shows a small part of the acceleration data stored at the Hub node.

Both Node1 (right wrist) & Node2 (left wrist) store the data samples in a block arrays and forward all of their information to the Hub at the right time to ensure successful delivery. This is done by setting a minimum acceleration value condition to trigger transmission. The Hub node receives data blocks and stores them in memory. The block numbers help to keep the received data organized and classified with the sender identity (blocks with odd numbers are used by Node 1 and even numbers by Node 2). The black bars identify the locations at which wrist nodes forward their data blocks of acceleration samples. For example at 230ms of the Hub time (Fig.3) the first block of information from Node 1 is received. After the same period of time, the first block from Node2 follows, and so on.

In these measurements, more than a 1000 samples were sent from Node1 and Node2 during running, and only a few samples were lost at the Hub compared to the traditional continuous sending method. In more details; 1000 out of 1007 samples were received by the Hub from Node1, and 1015 out of 1024 samples were received by the Hub from Node2. These lost samples are spread over more than 50 burst transmission for both nodes, and therefore, does not affect the analysis on the total received acceleration values. Overall, the link reliability was 99.30% and 98.92% for the connection between Hub-Node1 and Hub-Node2, respectively.

More sensors can be fitted into the network reliably by carefully considering their transmission burst locations to overcome multiple transmissions at the same time, and by selecting the acceleration sampling rate with respect to the specific runner cycle length. By reducing the data resolution there will be less time required to forward the data blocks, thus allowing more time in each running cycle for the other nodes. In our current example, each node require a 115ms to forward their data blocks to the Hub. If we need to add two more nodes to our network, the total nodes transmission time required will be 460ms which is the same length as our participant running cycle, which make the network crowded. Even if the transmission conditions for these additional nodes were defined so that a burst communication occurs exactly after the triggered nodes communication with the Hub, the assumption that each running cycle is the same length is wrong. Therefore, adding a margin of uncertainty is essential for the network design and conditions setting.

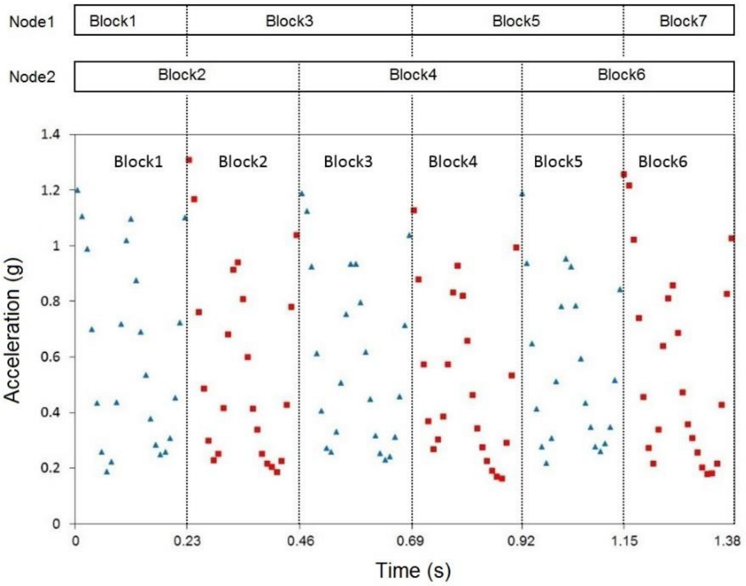


Fig.3. The acceleration data points (Node 1 triangles, Node 2 squares) are transmitted in blocks. The transmission is triggered by the detection of an acceleration maximum value [black bars] in both Node1, and Node2.

4. Conclusions

A monitoring body sensor network that collects acceleration samples from the wrist position and performs gesture analysis on the data during running movements shows significant improvement. The object of our system is to identify high link quality positions to assist the successful delivery of saved data blocks in the distributed nodes around the body to the central node on the chest. This can be achieved by controlling the transmission time in a dynamic and periodic manner. Future work will include the additional of data compression algorithms at the nodes, the design of an application layout for presenting these important details in more organized way.

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