Time synchronization in distributed sensor network

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***Abstract*—Time synchronization in a distributed sensor network is a key issue. Data from the sensors are properly synchronized are very good material for further analysis. In the paper a network of medical sensors is presented. It is important to obtain a properly synchronized data from the sensors. This guarantee that the data can be processed to detect correlation between different signals. For the purpose of accurate time synchronization, the simple and efficient algorithm is presented.**

***Index Terms*—time synchronization, Bluetooth, wireless sensor network, MOnOff**

I. Introduction

In distributed sensor networks, time synchronization between sensors is very important [1]. This is especially important when data is collected from the sensors must be processed together. In the case of an attempt to correlate the data synchronized them is very difficult or even impossible. It is therefore important that the data collected from the sensor network can be aligned in time to the selected position.

There are many different techniques for synchronization of the distributed sensors. One of the simplest is the registration of all sensors of one typical event. Then you can harvest data from the sensors identify this event and all the data aligned to that point. This technique, however, requires that the sensors can also register specific event [2], [3].

Another technique for measuring synchronization of the sensor is to synchronize the clocks of sensors. Synchronization is usually performed against a clock master, which is treated as a pattern. This technique is used for example in the NTP service [4].

In this paper we would like to present a simple algorithm for time synchronization in sensor networks. The algorithm allows for adaptive synchronization of sensors with unknown time delay. The presented algorithm was applied in the MOnOff system which has also been described. The technique of time synchronization allows to achieve a relatively high accuracy with very simple mechanisms. This can significantly reduce the resources needed to carry out synchronization.

II. MOnOff System Description

The MOnOff system is a network of wireless sensors used to monitor of patients with the movement and outside the movement disorders. The system is used to monitor the progress of therapy where different drugs and different doses of medication are used. The MOnOff system consists of the four sensors placed on the patient wrists and legs. Each sensor of the MOnOff system collects data from the accelerometer. Additionally sensors on the wrists collect data from the temperature sensor, the skin conductance sensor and the blood pressure sensor.

Data from each sensor are stored on its internal flash memory. After the experiment, data are downloaded to the computer. On the computer all data are processed with use of the neural networks. The processing of the collected data is to search for specific states among them. Therefore, it is important that all the data collected were well synchronized. This makes it possible to find the relationships between the various signals e.g. the specific physical activity and body temperature.

The use of neural networks necessitates the need to synchronize data from various sensors. The accuracy of the synchronization must be sufficiently large to be able to uniquely identify each of the state of health of the patient. In the presented system the data are acquired at the rate of 100 samples per second. Therefore the clock in each sensor must be synchronized with an accuracy of 10 ms.

III. Clock Synchronization Algorithm

The structure of the communication channel between the Host and the Device is presented in Fig. 1. In the MOnOff system the Host is a mobile phone and the Device is a single sensor. A Bluetooth module used in the MOnOff sensor is a BTM-112 manufactured by Rayson Technology.

The UART buad rate between the Device microcontroller and the Bluetooth module is set to 19200 bps. Thus the time required to transfer data from microcontroller to the Bluetooth module can be calculated very accurate. Other transmission parameters are unknown.

The algorithm of the clock synchronization is based on the measurement of the transmission channel delay. The measurement is done in both direction, between the Host and the Device. The Host sends a ping packets to the Device at regular intervals. The Device responds on ping packet and sends it

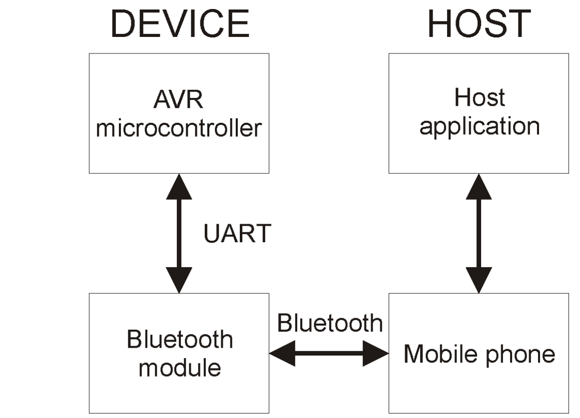

Fig. 1. Structure of the communication channel

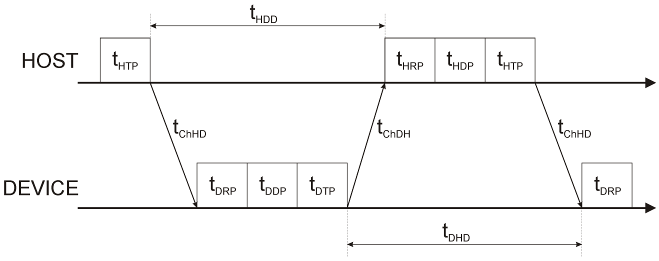

Fig. 2. Time dependence on the Host and the Device

back to the Host, which finally sends the ping packet back to the Device. The Host and the Device measure time between sending and receiving the ping packet. As a result, the Host and the Device have an information about the channel delay, which in fact is different on both sides. Structure of the channel delay measured by the Device and the Host is presented in Fig. 2.

The Host measures the t_{HDD} which is delay from the Host to the Device. The values of the t_{HRP}, t_{HDP} and t_{HTP} can be calculated or measured on the Host application. The t_{HRP} is a duration of the process of receiving, the t_{HDP} is a duration of data processing and t_{HTP} is a duration of the process of transmission. On the Device side the parameters are respectively similar.

The time synchronization is done by sending a special packet from the Host to the Device. The synchronization packet contains several significant information. The main part of the packet is a value of the main clock on the Host. The main clock on the Host is a number of 10 ms periods elapsed from the experiment beginning. The synchronization packet also contains the averaged t_{HDD} value and the averaged processing time value.

The Device after receiving the synchronization packet calculates the correction factor of the received main clock value. The correction factor is calculated with formula

$$t_{CORR} = \frac{t_{DHD} - t_{HP} + t_{HDD} - t_{DP}}{4} \qquad (1)$$

where $t_{HP} = t_{HRP} + t_{HDP} + t_{HTP}$, and t_{DP} is respectively defined for the Device.

The correction factor is added to the main clock value. If the result is quite different than the main clock on the Device, then the synchronization packet is rejected. In this situation the Device reports an error to the Host. If the Host receives error after three consecutive synchronization packets, the sensor is marked as corrupted.

The values of each component of the synchronization packet are calculated several times between sending successive synchronization packets. It reduces the fluctuation of the measured delays. The delays in the Bluetooth network may depends on the signal level, noise on the Bluetooth radio frequency and other factors [5].

The Device in response for the synchronization packet, sends the value of its own main clock and the values of the delays on its own side. The Host calculates the correction factor and checks if the synchronization is accurate.

IV. Conclusion

Presented algorithm allows for time synchronization in the distributed sensor network. The technique described in the article provides easy implementation of the time synchronization. The time synchronization achieved accuracy is sufficient to synchronize data form different sensors for use in the artificial neural network processing. The simplicity of the presented algorithm reduces the resources required for handle the time synchronization.

References

[1] J. Feng, R. Pazzi, and A. Boukerche, "The impact of discrete clock on time synchronization in wireless sensor networks," *...Networks, 2009. LCN 2009. ...*, no. October, pp. 1054–1060, 2009. [Online]. Available: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5355000

[2] E. A. Lee and S. Matic, "Event-Triggered Systems Synchronization*," pp. 56–63, 2007.

[3] N. Wei, Q. Guo, C.-j. Li, R.-x. Liu, and X.-l. Kong, "An Event -Triggered Time Synchronization Scheme for Sensor Networks," *2008 11th IEEE International Conference on Computational Science and Engineering - Workshops*, pp. 3–7, Jul. 2008. [Online]. Available: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4625031

[4] D. L. Mills, "Network Time Protocol (NTP)," p. 14, 1985. [Online]. Available: http://www.ietf.org/rfc/rfc958.txt

[5] R. Casas and H. Gracia, "Synchronization in wireless sensor networks using Bluetooth," *Intelligent Solutions in ...*, pp. 79–88, 2005. [Online]. Available: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1438715