Young Researcher Symposium IEEE Benelux Chapter IAS/PES/PESC,
April 24 – 25, 2014, Ghent, Belgium

WIRELESS SYNCHRONISATION FOR LOW COST WIRELESS SENSOR NETWORKS USING DCF-77

Joannes LAVEYNE*, Greet VAN EETVELDE** and Lieven VANDEVELDE***

* Ghent University, Power-Link, Ostend, Belgium
E-mail: Joannes.Laveyne@UGent.be

** Ghent University, Dept. of Civil Engineering, Centre for Mobility and Spatial Planning, Ghent, Belgium
E-mail: Greet.VanEetvelde@UGent.be

*** Ghent University, Dept. of Electrical Energy, Systems and Automation, Ghent, Belgium
E-mail: Lieven.Vandevelde@UGent.be

Abstract. Wireless Sensor Networks (WSN) consist of multiple end nodes containing sensors and one or more coordinator nodes which poll and command the end nodes. WSN can prove very efficient in wireless distributed energy data acquisition, e.g. for phasor or power measurements. However, these types of measurements require relatively tight synchronisation, which is sometimes difficult to achieve for low-cost WSN. This paper explores the possibility of a low-cost wireless synchronisation system by using the DCF-77 long wave time signal to achieve sub-millisecond synchronisation accuracy. The results are compared with conventional wireless synchronisation. As a trial, the described synchronisation method is implemented in a non-contact electrical phase identifier, which uses synchronised phasor measurements for distinguishing the different phases in an unmarked electrical distribution grid.

Keywords: energy monitoring, phasor measurement, wireless sensor networks, wireless synchronisation

INTRODUCTION

Accurate time synchronisation is extremely important in Wireless Sensor Networks (WSN) [1], not only for setting up efficient communication scheduling between nodes [2] but also for execution of certain tasks such as coordinated movement of synchronised measurements. It is however a challenge to achieve good synchronisation by using low-cost transceiver hardware due to several non-deterministic delays in the firmware or hardware of the transceivers and environmental influences such as radio signal reflections. In Wide Area Measurement Systems (WAMS) the signal offered by Global Positioning System (GPS) satellites is often used [3] as this signal provides both time and position, enabling the receiver to achieve an accurate synchronisation [4]. However, GPS reception in buildings is often limited or not available, and while the cost of GPS receivers has decreased, it is often still not viable to implement one on each node of a low cost WSN. Long wave signals are less prone to reflection by obstacles and their receivers only cost a fraction of their GPS counterparts. They also require less complex host controller hardware and firmware. The DCF-77 time signal is an accurate and publicly available long wave synchronisation signal that can be reliably received throughout Europe.

WIRELESS SYNCHRONISATION

Assuming each node in a WSN has its own timekeeping system, there are two main methods of achieving synchronisation between nodes [5]. The first one is local synchronisation in which the nodes synchronise their local time with the time kept by neighbouring nodes, thereby cancelling out clock drift and offset. The second method is global synchronisation in which a central node broadcasts a synchronisation signal throughout the network, and all nodes synchronise their clock to this signal.

The main challenges in both methods are non-deterministic delays in the firmware of the host controller, the hardware of the wireless transceivers and in the propagation of the wireless signal. According to [5] the total delay can be split up in four components:

- Send time: the time it takes the transmitting host controller to assemble the synchronisation packet and dispatch it to the transceiver radio.
- Access time: the time the transmitting radio requires to transpose the synchronisation packet onto the physical wireless layer.
- Propagation time: the time it takes for the packet to travel from the transmitting radio through the physical medium to the receiving radio.
- Receiving time: the time it takes the receiving radio to transcode the synchronisation packet and dispatch it to the receiving host controller.

All these components include non-deterministic delays which can hamper proper synchronisation. The synchronisation system presented in this paper eliminates or compensates for these non-deterministic delays by abandoning the packetisation of the time signal and focussing on the signal transmitted through the physical medium. It uses a simplified variation on the Reference Broadcast Synchronisation (RBS) method, in which a central node broadcasts a beacon signal containing no actual timing information [6]. Instead, the arrival of the beacon on the receiving radio acts as the synchronisation signal. The presented system relies on implicit timing assumptions between nodes, requiring no additional communication or even avoiding the need for a two-way transceiver. Only relative timing synchronisation is required, eliminating the problem of possible clock drift in the beacon transmitter. When the nodes are in relative proximity to one another, the propagation delays can be assumed to be similar.

EXPERIMENTAL TEST SET-UP

In order to validate the assumptions made in the previous paragraph, several analogue DCF-77 long wave time signal receivers have been arranged in a test set-up, with a known distance between each receiver. Standard UTP wiring with a known cable impedance and length are run between each receiver and one digital oscilloscope, positioned in a central point. When a synchronisation beacon is received on a receiver, a pulse is transmitted through the wiring allowing the oscilloscope to measure the receiving delay between each receiver. Several tests are run wherein the position and environment of one or more receivers is changed, e.g. from an outdoor to indoor environment. This will determine what the effects of the environment are on the synchronisation accuracy. These results are compared to accuracies achievable with GPS based synchronisation [4].

ELECTRICAL PHASE IDENTIFIER

Electrical phase identification is required for common tasks such as balanced connection of single phase loads on a three phase system, single phase energy monitoring or for safety reasons. It is however possible that phase wires are unmarked or share sheathing of the same colour, complicating the identification of the different electrical phases. Devices modulating a high frequency identification signal onto the phase wires are commercially available, but require electrical contact to the wires. Sometimes electrical contact is not possible or safe, e.g. on live wires.

As an implementation of the DCF77 based wireless synchronisation discussed in this paper, a non-contact phase identification system is presented. It employs non-contact current measurements, e.g. through the use of Hall sensors, correlated to the DCF77 based synchronisation system.

CONCLUSIONS

In this paper the feasibility of using DCF-77 long wave time signal receivers to achieve synchronisation in low-cost WSN is explored. The proposed system removes the need for complex host controller hardware and firmware, thereby eliminating a number of non-deterministic delays present in other wireless synchronisation systems. An experimental test-setup is built in order to validate the assumptions, and the results compared to these of conventional wireless synchronisation systems. Finally, a practical implementation of the synchronisation system is presented.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci. Wireless sensor networks: a survey. Computer Networks, Volume 38, Issue 4, 15 March 2002, p. 393–422.

[2] Y.-W. Hong, A. Scaglione. On multiple access for distributed dependent sources: a content-based group testing approach. IEEE Inf. Theory Workshop, San Antonio, TX, 2004

[3] W. Shaobu, G. Wenzhong, W. Jianhui, and L. Jin. Synchronized Sampling Technology-Based Compensation for Network Effects in WAMS Communication. IEEE Transactions on Smart Grid, Volue 3 Issue 2, 2012, p. 837-845

[4] J. Mannermaa, K. Kalliomaki, T. Mansten, and S. Turunen, Timing performance of various GPS receivers. Proc. Joint Meeting Eur. Freq. Time Forum and IEEE Int. Freq. Control Symp., Apr. 1999, pp. 287–290

[5] Sivrikaya, F.; Yener, B. Time synchronization in sensor networks: A Survey, IEEE Network, Volume 18, Issue 4, p. 45 – 50

[6] J. Elson, L. Girod, D. Estrin. Fine-grained network time synchronization using reference broadcasts. Usenix association proceedings of the 5th Symposium on Operation Systems Design and Implementation, Boston, 2002, p. 147-163