Demo: Brzzz – A Simplistic but Highly Useful Secondary Channel for WSNs

Ulf Kulau, Stephan Rottmann and Lars Wolf
Institute of Operating Systems and Computer Networks
TU Braunschweig
[kulau|rottmann|wolf]@ibr.cs.tu-bs.de

Abstract

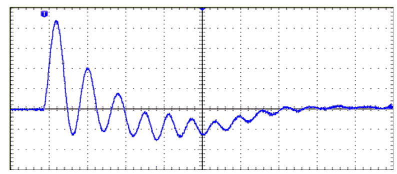
Time synchronization of several nodes is important for many Wireless Sensor Network (WSN) algorithms, components, and application scenarios. Therefore, it would be very beneficial if a low-cost method for such synchronization was available. The same applies to low-power wakeup of nodes. Ideally, a simplistic and almost no-cost channel should be provided that can be utilized to face such challenges like synchronization and wakeup of nodes. In this demo paper we present the idea for such a method and show first results as well as a proof of concept setup. It is based on an electric pulse generated by, e.g., a regular electric fence which can be detected and utilized by usual ultra low-power micro controller units (MCUs) of a sensor node.

1 Introduction

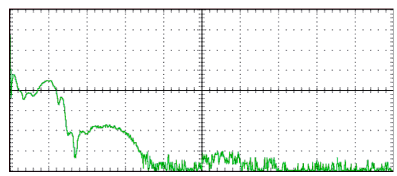
WSNs often need to work autonomously in rough environmental conditions, away from any infrastructure for a prolonged time. Under these conditions, the limited capacities of, e.g., batteries lead to the fact that energy is one of the scarcest resources in WSNs [8, 4]. A common way to allow long life-times is to decrease the duty cycle of nodes. Hence, as the radio transceiver is on the one hand needed to establish a network but on the other hand is one of the most power consuming part of a sensor node, some WSN applications rely on a low-power wake-up receiver to activate a device solely when it is actually needed [7, 3]. But, the additional radio used in these approaches is still not for free and induces an overhead in terms of energy and hardware costs.

2 Basic Idea and Observations

During the deployment of our outdoor WSN-testbed 'PotatoNet' [5, 6] on a trial field of a potato crop research station, we observed that the pulses of a nearby electrical fence coupled into the shielding of the Ethernet connections. As is common in agriculture theses fences are used to protect the crops against boars and other animals. Fortunately, the previous evaluations showed that such pulses do not affect the baseline performance of a WSN [6]. Yet, the question arises whether the pulses could be detected by sensor nodes and used for specific purposes, perhaps also for nodes separated by certain distances. For WSNs in such smart farming applications a broadcast signal that covers the entire network and triggers some operations would be of enormous benefit. This way, nodes can be forced to wake-up. Further, these pulses can be utilized to synchronize the nodes of the network, therefore, addressing the huge problem of clock drift of timers [9] in different nodes.



(a) Pulse in Time Domain.
X-Axis: 50 µs/div, Y-Axis: 20.0 V/div



(b) Pulse in Frequency Domain.
X-Axis: 25.0 kHz/div, Y-Axis: 10.0 dB/div

Figure 1. Pulse of the Electric Fence

3 First Studies

The first objective studies were performed indoors by using a regular electric fence device AKO ND11000[1]. A relatively short fence of about 3 m was connected to the device which periodically outputs a high voltage pulse. At receiver side we placed a digital oscilloscope where a simple wire of 50 cm was used as antenna. The distance between the electric fence and the barely tuned antenna was about 2 m. We measured the time domain as well as the frequency domain of the inducted signal which can bee seen in Figure 1(a) and Figure 1(b), respectively. Awaiting a wide-band signal the actual signal of the electric fence has its center frequency at $f_{brzz} = 25$ kHz and a bandwidth of about 3 kHz.

[1] http://www.ako-agrar.com

International Conference on Embedded Wireless Systems and Networks (EWSN) 2017
20–22 February, Uppsala, Sweden

ISBN: 978-0-9949886-1-4

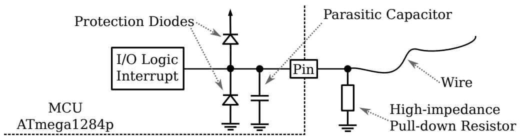


Figure 2. Circuit for Pulse Dectection

In other words, the electric fence spreads out long-wave signals. Considering that a electric fence usually fences a farmland with a perimeter of several hundreds of meters, such fences offer an ideal transmitting antenna for the signal with a wave-length of $\lambda = \frac{c}{f_{brzz}} = 11.96\,\text{km}$. However, for the given scenario and at an impedance of the oscilloscope of $1\,\text{M}\Omega$, the peak voltage in time domain already reaches about 80 V.

4 WSN Experiment

To allow sensor nodes to detect the pulses we equipped INGA nodes [2] with a primitive analog front-end.

4.1 Pulse Detection

Actually a wire and a high-impedance pull-down of $4\,\text{M}\Omega$ are sufficient. The circuit for pulse detection is depicted in Figure 2. The wire is connected to an interrupt pin of the ATmega1284p MCU of INGA. The input pins of this MCU are fused by two diodes per default [1]. Thus, the potentially high voltage that is induced in the wire cannot harm the MCU (cf. Figure 2). A pin-change interrupt is used to trigger the rising and the falling edge of the signal while a timer is fired to measure the period of positive half-waves of the signal. The resulting pattern can be further used to filter the pulses from other interference.

4.2 Real World Evaluation

For a proof-of-concept, we equipped 8 INGA nodes of the PotatoNet testbed with the pulse-detection hard- and software described in the previous section. An electric fence of 200 m length was towed around these nodes while the distance of the nodes to the fence was about 5 m to 20 m. Figure 3 shows the experimental setup. As a result each node reliably receives a bunch ≥ 9 half-waves every 1.33 s and the measured periods validate the 25 kHz signal.

5 Utilization

At current stage we solely evaluate the reliability and characteristics of the pulse detection, indeed, also with regard to changing environmental conditions (e.g. temperatures and rain). However, in assumption that an entire WSN would receive the pulses simultaneously, many applications could utilize these events. As an external interrupt is able to wake-up an MCU even from deep-sleep states, a low-cost and area-wide wake-up is possible. Moreover, it turns out that the amount of detected half-waves gives an indication about the strength of the detected pulses. Within the testbed all nodes receive the same amount of half-waves so that the received signals are strong throughout the presented WSN. Considering several nodes with different distances to the electric fence, the center of a half-wave's period offers an anchor to synchronize the clock. Many time dependent protocols could benefit from such a precise but low-power synchronization as usual RTCs are often insufficient for outdoor applications with harsh environmental conditions and low duty-cycles. In theory it is also possible to establish


Figure 3. Experimental setup for pulse detection using PotatoNet testbed.

a unidirectional broadcast communication by applying an asynchronous protocol (morse code). According to the standard for household and similar electrical appliances and in particular for electric fence energizer, the DIN EN 60335-2-76[2] prescribes a minimum interval of 1 s between pulses of an electric fence. Thus, the achievable baud rate would be fairly low. Nevertheless, for long-term applications such as smart farming this low bandwidth is acceptable to distribute WSN-wide information via such a secondary channel with ultra-low power demand at the nodes. Finally, the detection of external events is not bounded by the existence of an electric fence. The pulse detection can also be applied to other sources, e.g. light switches, but it would need some tuning or amplification.

6 Demonstration

We show the general proof-of-concept by a miniature testbed with a real electric fence and INGA sensor nodes. The nodes detect and analyze the pulses. A central GUI will display relevant parameters such as the amount and period of half-waves. Moreover, the jitter of the pulse detection is evaluated and displayed. Overall, the live demo will verify the feasibility and effectiveness of the presented approach.

7 References

[1] Atmel. Datasheet: ATmega 1284/1284P, Rev. Atmel-8272G-AVR-01/2015, 2015. Retrieved from: `http://www.atmel.com/devices/atmega1284p.aspx`.

[2] F. Büsching et al. Architecture and Evaluation of INGA - An Inexpensive Node for General Applications. In *IEEE Sensors*, Sensors 2012, Taipei, Taiwan, October 2012.

[3] G. U. Gamm et al. Low power wake-up receiver for wireless sensor nodes. In *Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2010 Sixth International Conference on*, pages 121–126. IEEE, 2010.

[4] Holger Karl and Andreas Willig. *Protocols and architectures for wireless sensor networks*. John Wiley & Sons, 2007.

[5] U. Kulau et al. Demo: PotatoNet – Robust Outdoor Testbed for WSNs. In *the 10th ACM MobiCom Workshop on Challenged Networks*, CHANTS 2015, Paris, France, September 2015.

[6] U. Kulau et al. Undervolting in real world wsn applications: A long-term study. In *Distributed Computing in Sensor Systems (DCOSS), 2016 International Conference on*, pages 9–16. IEEE, 2016.

[7] P. Le-Huy et al. Low-power wake-up radio for wireless sensor networks. *Mobile Networks and Applications*, 15(2):226–236, 2010.

[8] F. Schlachter. No Moores Law for batteries. *Proceedings of the National Academy of Sciences*, 110(14):5273–5273, 2013.

[9] T. Schmid et al. Exploiting manufacturing variations for compensating environment-induced clock drift in time synchronization. *ACM SIGMETRICS Performance Evaluation Review*, 36(1):97–108, 2008.

[2] `http://www.din.de/en`