Wireless Energy Meter

Philip Rings, Lasse Thiem, Thomas Luckenbach

Fraunhofer Institute for Open Communication Systems

FOKUS

10589 Berlin, Germany

[philip.rings, lasse.thiem, thomas.luckenbach]@fokus.fraunhofer.de

Abstract— **This paper describes the ongoing development of an Energy Meter (EM) with an interface to a wireless sensor network based on IEEE 802.15.4 technology.**

I. INTRODUCTION

In the age of ecological awareness, and the conclusion that energy should not be wasted, it is necessary to investigate the places where electrical energy is consumed. The effective energy usage of a device can often be determined by monitoring the according electrical devices over a long space of time. The measuring can easily be done by simple Energy Meters from the local do-it-yourself store. But sometimes the limited functionality of these meters also limits their area of application. If, for example, a refrigerator shall be measured, the power cord may not be easily accessible. And most of the "standard" Wireless Energy Meters show their calculations on a small display directly on the meter. A solution is a Wireless Energy Meter which is able to transmit its measured data wirelessly to a computer. There the data can be interpreted and maybe even compared to data from other wirelessly connected devices.

II. RELATED WORK

In [1] an AC Meter (ACME) development for IP based Wireless AC Energy Monitors is presented. The developed platform consists of four main sections: power supply, signal filtering, Wireless Energy Metering and microcontroller. All embedded Software developments are done with TinyOS. In [2] an electronic system is described to measure the active, apparent and reactive energies delivered to a load of an AC voltage line. The proposed system is directly connected to a PC running visualization software of the power consumption. In [3] a case study of an inexpensive student designed power monitoring instrument for campus submetering is described. This system is build up with an Energy Metering IC connected to a PIC controller. Over a serial interface measured values can be accessed.

III. HARDWARE OVERVIEW

The Wireless Energy Meter (see also Figure 1) consists of two major elements to measure the different kinds of the power consumption. These two elements are the IEEE 802.15.4 [4] ICradio Module 2.4G [5] and the Energy Measurement IC ADE7753 [6] which will be introduced below.

A. IEEE 802.15.4 - ICradio Module 2.4G

The ICradio Module 2.4G is a compact, flexible deployable radio module, which is required for operation in wireless sensor networks (WSN) like in IEEE802.15.4. The 2.4G module consists of an ATMega1281 AVR microcontroller and the AT86RF230 2.4GHz radio chip from Atmel. It is completely compatible with Atmel's free IEEE802.15.4 MAC software.
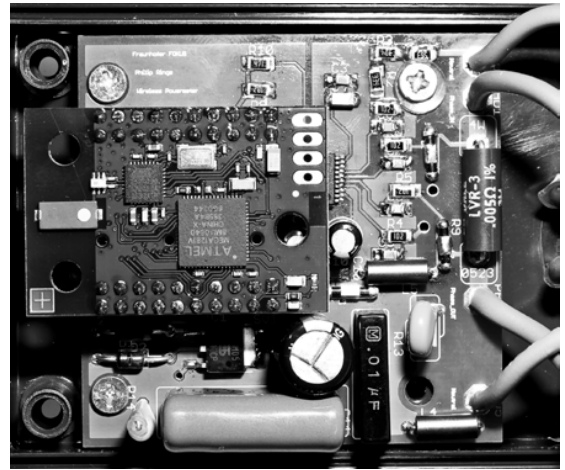

Figure 1.   Wireless Energy Meter (EM)

B. ADE7753

The ADE7753 allows the control and the read out of several energy registers over a serial interface which is compatible to SPI. Through this registers it is possible to read out the accumulated values of active and apparent energy, the rms values of current and voltage and for example get information about the line period. In addition, it is possible to write to the ADE7753 registers to configure for example gains or compensate offsets among all the operations.

C. Wireless Energy Meter Hardware Design

The needed voltages for the two main hardware components, the ADE7753 and the ICradio Module 2.4G, are provided by a power supply which uses direct rectification. For the current sensing a shunt resistor is used, over which a comparatively low voltage drops when a current flows. The voltage sensing is done by a simple voltage divider, which scales the line voltage from 230Vrms to about ±0.5V. Two low-pass-filters at the analog inputs of the ADE7753 prevent

the measured signals from containing aliasing effects which could produce error components during the calculations. The analog-to-digital conversion of the voltage and current metering and afterwards all signal processing for the energy accumulation is done by the ADE7753. This IC is therefore controlled by the microcontroller which also is responsible for controlling the transceiver and keeping contact to the IEEE802.15.4 network. To make the node's hardware scalable, the ICradio Module 2.4G is connected to the invented circuit board via contact plugs. So a firmware update or the connection of additional hardware components can easily be done (see also Fig. 1).
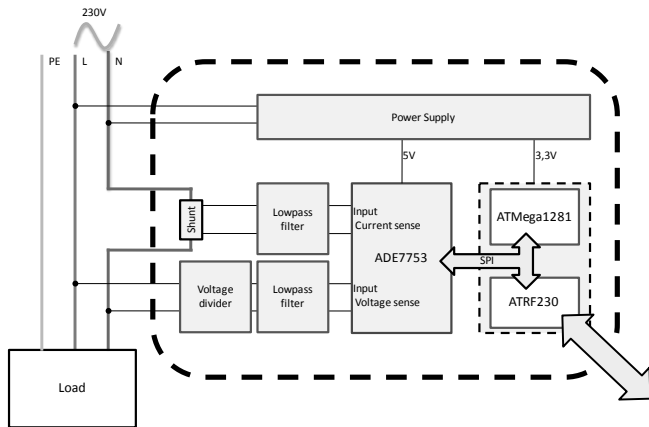
Figure 2.   FOKUS Wireless Energy Meter hardware design

D.   SPI Communication

The entire communication process to the ADE7753 takes exactly 225us (see also Figure 3). During this time frame the transceiver has no SPI connection to the microcontroller because only one device at time can transfer data to the microcontroller via SPI. Thus, the EM node is temporary not part of the wireless network. In multi-hop networks the routing protocol has to take this into account. In this current setup the communication is done by a pull mechanism of the node itself to a sink node in a peer-to-peer star network.

Read operation	t=0,0s	t=33,6us	t=86,7us	t=138,5us	t=190,4us
MOSI	3F 00	02 00 00 00	17 00 00 00	16 00 00 00	27 00 00
MISO	00 02	00 0B 07 5F	00 20 53 46	00 1C 4D 9E	00 22 10
Adress	0x3F	0x02	0x17	0x16	0x27
Name of register	DIEREV	AENERGY	VRMS	IRMS	PERIOD
Size	8 Bit	24 Bit	24 Bit	24 Bit	16 Bit
Content (Hex.)	0x02	0x0B075F	0x205346	0x1C4D9E	0x2210
Content (Dez.)	2	722783	2118470	2118470	8720

Figure 3.   Results of the SPI communication analysis

IV.   VISUALIZATION

The visualization of the measured consumed power of all devices in a home for example allows a real time feedback to the residents of a home.
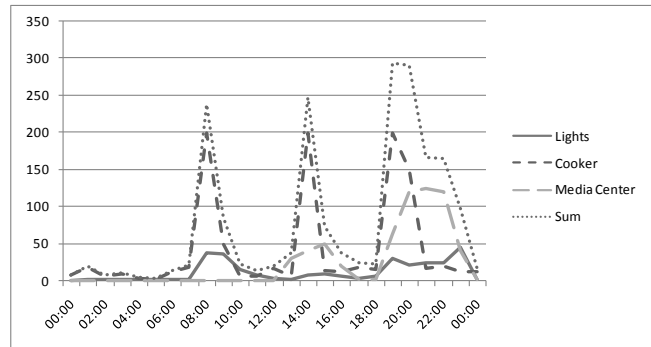
Figure 4.   Typical daily power consumption

V.   MEASUREMENT

For evaluation purposes some measurements with the hardware design were done to prove the system concept. Two of these measurements are described in the following to sections.

a)   Energy

Analyses of the accuracy of the Wireless Energy Meter have shown that the system produces a failure rate of less than 0.1% (see also Figure 5). Several measurements with known parameters of the load have approved the accuracy.

Measurement A	expected [Wh]	determined [Wh]	difference [Wh]	failure (%)
A1	6,27898	6,32245	0,04348	0,00273
A2	6,36768	6,41180	0,04412	0,00281
A3	6,34710	6,39281	0,04571	0,00290
A4	6,34710	6,39646	0,04936	0,00313
A5	6,34710	6,37913	0,03202	0,00203

Measurement B	expected [Wh]	determined [Wh]	difference [Wh]	failure (%)
B1	0,62465	0,62046	0,00419	0,00003
B2	0,62465	0,61807	0,00659	0,00004
B3	0,62465	0,61846	0,00619	0,00004
B4	0,62465	0,62183	0,00282	0,00002
B5	0,62458	0,63625	0,01167	0,00007

Figure 5.   Measurements about the accuracy of the Energ Meter

VI.   CONCLUSION AND FUTURE WORIK

In this paper a wireless energy metering device is described which allows the visualization of power consumption of electrical devices like a TV or washing machine in real time. The current system enables residents to have an immediate overview about the actual and short term history power consumption. Future work will include developments towards automatic and remote control of devices. A further approach could be that once a day accumulated data is sent from the household to the energy provider. This gives the energy provider the opportunity to better calculate the needed

capacities of their power plants. For the customer this offers the possibility to directly get information about better pay scales or to let the provider dynamically change the pay scale.

REFERENCES

[1] X. Jiang, S.Dawson-Haggerty, J. Taneja, P. Dutta and D. Culler, Demo Abstract: Creating Greener Homes with IP-Based Wireless AC Energy Monitors, Proceedings of the 6th ACM conference on Embedded network sensor systems, SENSYS 2008, Pages 355-356

[2] D. R. Muñoz, D. M. Pérez, J. S. Moreno, S. C. Berga, E. C. Montero, Design and experimental verification of a smart sensor to measure the energy and power consumption in a one-phase AC line, Elsevier Journal of the International Measurement Confederation (IMEKO), Measurement 42 (2009) 412–419

[3] P. M. Jansson, J. Tisa, W. Kim, Instrument and Measurement Technology Education—A Case Study: Inexpensive Student-Designed Power Monitoring Instrument for Campus Submetering, IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 56, NO. 5, OCTOBER 2007

[4] [1] IEEE 802.15.4.4 – Homepage, The Institute of Electrical and Electronics Engineers, Inc., February 2007, http://www.ieee802.org/15/pub/TG4.html IEEE 802.15.2 Standard

[5] ICradio Module 2.4G Product Homepage, In-Circuit GmbH, http://www.ic-board.de/product_info.php?info=p4_ICradio-Module-2-4G.html, May 2009

[6] ADE 7753 Product Homepage, Analog Devices, Inc, http://www.analog.com/en/analog-to-digital-converters/energy-measurement/ADE7753/products/product.html, May 2009