Smart and Self-powered Wireless Energy Metering

Davide Brunelli*, Giacomo Paci°, Martino Ruggiero#
** University of Trento, ° University of Bologna, # EPFL*

We present the design of a Wireless Sensor and Metering Network (WSMN) with energy harvesting capability for long lasting monitoring power consumption of AC appliances. Energy harvesting makes the monitoring activity completely energy autonomous and the network can operate unattended eternally. The system consists of a network of measurement devices which is open to connect Smart Grid Management services and Energy Configuration and Optimization Tools in the Cloud. Each node integrates a WISPES W24TH module to provide perpetual analysis of energy measurement.

I.

II. Introduction

Energy saving in residential and commercial buildings is one of the key themes in sustainability strategies for the near future. The building sector is responsible for the 40% of the overall energy consumptions and it is divided in conditioning (heating, cooling and ventilation) and electrical (appliances) consumptions. Despite numerous energy efficiency policies, the electricity consumption continues to grow.

The aim of the project is to build a WSN system for real-time monitoring power consumption of AC appliances in different kind of buildings, so that end-user can understand their power consumption and reduce them. The system provides the following parameters:

- Real-time current evolution;
- RMS current and power consumption values;
- FFT analysis of current samples;

Information on power consumption is collected by sensors in a WSN based on standard IEEE802.15.4. We adopt this standard since is allow ZigBee protocol which defines specific profiles tailored on smart homes [2] and energy metering (i.e. ZigBee “Smart Energy” and ZigBee “Home Automation”).

This system requires an ultra-low power operation because each node uses two batteries, even if it can be also powered with energy harvesting units.

III. System Design

The photo of the sensor node with current sensor is shown in Fig.1. The node is a WISPES W24TH which features an enhanced 32-bit RISC processor, 2.4GHz IEEE802.15.4 compliant transceiver, 128kB ROM, 128kB RAM, and a rich mix of analogue and digital peripherals.

The main electrical specifications of AC current transformer are: maximum current 100A, output type current (33mA at 100A) and number of turns 1500. Thus the AC current transformer produces a small secondary current that is 1500 times smaller than the current in the main wire.

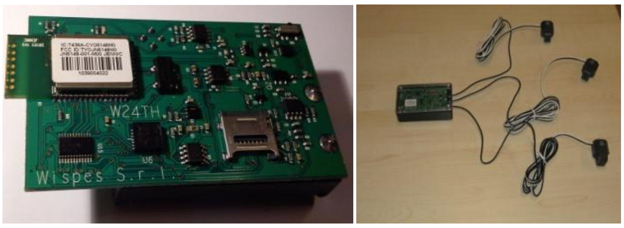

Fig. 1. Sensor node platform and the complete node with 3 current sensors

A Raised Cosine Filter (RCF) reduces the high frequency noise. A RCF is a low-pass filter which is commonly used for pulse shaping in data transmission systems. The frequency response $|H(f)|$ of a perfect raised cosine filter is symmetrical about 0 Hz, and is divided into three parts: it is constant in the pass-band, it sinks in a graceful cosine curve to zero through the transition region and it is zero outside the pass-band. The response of a real filter is an approximation to this behavior. The filter is designed as a Finite Impulse Response filter (FIR) (f=12.5KHz, corner frequency 500Hz, -6dB). We assume a constant RMS voltage in converting current to power. This is acceptable for applications which monitor only Apparent Power. The power measured by the system ranges from 1W (230V*4,3mA) to 1KW (230V*4.3A).

A Fast Fourier Transform (FFT) on the incoming current signal separates the component frequencies, up to the 7^{th} harmonic (7f).

The network consists of several sensor nodes organized with IEEE802.15.4. As shown in the Fig. 3 the network consists of a coordinator that will interface with a service cloud and sensor devices. The coordinator generates a beacon which wake-up end nodes and starts the ADC sampling, processing and data transmission.