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An easily-deployable wireless sensor network for building energy performance assessment

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Abstract

In the process of building performance assessment, it is often necessary to resort to assumptions to fill in missing information. We address the issue of scarcity of information about the building properties by employing new sensing technology. The aim of this paper is to introduce an open-source, modular and low-cost wireless sensor network of building performance assessment, which is independent of an onsite landline internet connection. Due to its modularity, the WSN can be complemented with new sensors without altering the system. We present the design process, the deployment and monitoring results of an easily-deployable wireless sensor network (WSN) for in-situ performance assessment of occupied buildings. A case study of the deployment of the WSN in a single family home in Switzerland is presented. We demonstrate the quick installation of the WSN and live measurements over multiple months. We derive the thermal properties of the envelope (U-values) from the measured data, and compare them to the values used in the code-based assessment of the building.

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Keywords: Building Energy Performance Assessment, Performance Gap, Data-Driven Building Retrofit, Wireless Sensor Network, In-Situ Measurements

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1. Introduction

In Switzerland, the refurbishment of the existing buildings is essential to the achievement of any endeavor to reduce the greenhouse gas emission and/or energy consumption [1].

Sunikka-Blank and Galvin identified a performance gap consisting of prebound effects for existing buildings and rebound effects for newly built and retrofitted buildings in Europe [2]. The results of [2] indicate a difference of 30% on average between actual energy consumption and rated energy consumption in prebound scenarios. Khoury et al. [3] observed similar effects in Switzerland. A study of the Swiss federal office of energy [4] shows, that for specific building types, the median values of the energy consumptions meet the threshold values for the energy consumption stated by the building code. However, the wide distribution of the samples indicate that a large share of the buildings fail to meet required energy demand. Reasons for the gap include inaccurate assumptions, occupant behavior, deviations from the planned design and variations in workmanship.

There is a trend towards more measured data in building science motivated by the observation that standard assumptions differ significantly from the actual value, resulting in inaccurate calculations and simulations [5]. With the rapid development in electronics hardware, measurement equipment has become more widespread. Historically, all measurements were carried out with some sort of data-logger. The data was stored locally during the measurements and subsequently analyzed. These data-loggers have become smaller and battery driven, what made them more usable for in-situ measurements. Data-loggers equipped with a variety of sensors are commercially available. The Open Source Building Science Sensors project develops an Arduino-based open-source data-logger, with the aim to provide a low-cost and flexible data-logging solution for the scientific community [6].

The main disadvantage of using data-loggers is that the logged data is only available after the measurement has taken place, and therefore, inconsistencies can only be discovered once the measurement has ended. Wireless sensor networks (WSN) can alleviate this and other issues associated with data-loggers, e.g., multiple measurements with different sensors, fault detection and data processing (e.g. [7]). We developed a WSN, to address the issue of scarce and inaccurate information about the building's properties and its occupants. The WSN is open-source and modular. It can be extended to new sensors.

The remainder of this paper is structured as follows. In section 2 the development of the WSN is described. In section 3 the results of an in-situ measurement campaign in a Swiss single family house are presented. In section 4 the results and learnings from the sensor network deployment are discussed. Finally, section 5 concludes.

2. Wireless Sensor Network

The fast development in integrated electronics, wireless communication and battery technology made inexpensive remote sensing possible. In addition, the development of an open-source hardware and software community made these electronic devices widely accessible. In this section, we present our design for the wireless sensor network.

2.1. WSN Topology

The sensor network consists of three main components: sensor node (S), router node (R) and gateway (G) (Fig. 1a). The sensor node is battery operated, carries the sensors and sends the measured data to the gateway. Router node can relay data from sensor nodes to the gateway. The gateway receives the data from the sensor nodes and forwards it over the mobile network (GPRS) to a webserver. The radio modules are organized in a mesh network. In case that

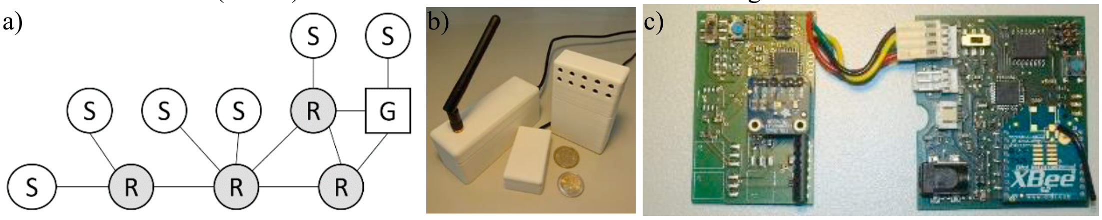

Fig. 1. (a) WSN topology, (b) assembled WSN components: gateway (left), router node (center), sensor node (right), 2 CHF coin and 2 € coin for comparison, (c) sensor board (right) and communication board (right)