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► **To cite this version:**

Jad Nassar, Benoit Durillon, Nicolas Gouvy, Vincent Lefevre, Flovic Gosselin, et al.. Un démonstrateur WSN pour les Smart Grids. CoRes 2023 - 8èmes Rencontres Francophones sur la Conception de protocoles, l'évaluation de performances et l'expérimentation de Réseaux de communication, May 2023, Cargese, France. hal-04092157

**HAL Id: hal-04092157**

**<https://hal.science/hal-04092157v1>**

Submitted on 9 May 2023

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# Un démonstrateur WSN pour les Smart Grids

Jad Nassar<sup>1</sup> et Benoit Durillon<sup>1</sup> et Nicolas Gouvy<sup>2</sup> et Farah Abdel Khalek<sup>3</sup> et Vincent Lefevre<sup>1</sup> et Flovic Gosselin<sup>2</sup>

<sup>1</sup>Junia, Lille, France. prénom.nom@junia.com

<sup>2</sup>FGES, Université Catholique de Lille, Lille, France. prénom.nom@univ-catholille.fr

<sup>3</sup>Université Savoie Mont Blanc, Annecy, France. prénom.nom@univ-smb.fr

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L'intégration croissante de sources d'énergie renouvelable (e.g. panneaux photovoltaïques, éoliennes) et l'automatisation ont transformé les réseaux électriques traditionnels en Smart Grids. Cette évolution vers un réseau électrique plus intelligent nécessite de pouvoir transmettre en temps réel un maximum de données sur l'usage du réseau. Un réseau de capteurs sans fil (WSN) disséminés à travers le réseau électrique est une solution prometteuse vu les coûts réduits et la facilité du déploiement de tels réseaux. Cependant, surveiller l'ensemble du réseau avec des dispositifs contraints en mémoire et énergie est un défi à considérer. Dans cet article, nous présentons un démonstrateur WSN pour les Smart Grids dans le cadre du projet européen Ebalance-plus. Il consiste en des nœuds de capteur Raspberry Pi et Zolertia Re-Mote qui seront déployés dans les bâtiments de l'Université catholique et Junia à Lille. Ainsi, il fournira un démonstrateur WSN dans un environnement Smart Grid à échelle réelle.

**Mots-clés :** Smart Grid, réseau de capteurs sans fils, Contiki OS, Zolertia RE-Mote, Raspberry Pi, MQTT

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## 1 Introduction

The traditional power grid is being transformed into a smarter one with the integration of renewable energy resources and two-way communication between the utility and customers. Due to its capabilities in sensing, computing and communicating autonomously, A Wireless Sensor Network (WSN) distributed across the grid, on the different measuring and control points, is a potent and plausible solution [RBJD17]. However, sensor nodes in WSN have limitations in terms of power and are highly constrained due to continuous radio transmission. To meet the Quality of Service (QoS) requirements of Smart Grid applications, a WSN must consider these challenges, including the intermittency of renewable energy resources and placement difficulties in high voltage levels.

The EU-funded H2020 project Ebalance-plus<sup>†</sup> aims to increase the use of flexibility and resilience of energy networks, by means of an energy balancing platform, which will integrate smart production, storage and consumption technologies. It has 15 European partners from 10 countries. As part of this project, a wired/wireless sensor demonstrator is being developed in the Lille demo site (université catholique de Lille and Junia). It consists of 120 Raspberry Pi and Zolertia sensor nodes distributed all over the buildings of the University. The aim of this demonstrator is to collect different sensor values from the photo-voltaic cells, electric vehicles, electric meters, hot water tanks, etc. in order to control and pilot the energy production/consumption on campus, and thus to enable the flexibility promised by the Ebalance-plus project. More precisely, two network architectures are implemented : the first one having a wired connection between the different measuring points and the sensors, based on Raspberry Pi version 3 (RPI) modules. The second one relies on low power wireless personal area (6LoWPAN) networks with Zolertia Re-Mote sensors. The collected data are sent over both networks via a MQTT broker/client communication and are stored in a database for a future use. *It is important to mention that the wired network is used to control, monitor and reprogram the wireless sensor network (e.g., detect transmission loss, provide a benchmark for wireless routing measurements, etc.).*

We note that this is an ongoing work and that the physical installation of the sensors in the building is in

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<sup>†</sup>. <https://www.ebalanceplus.eu>

process. This paper aims to present the architecture of our sensor network and to provide a case scenario of its usage in a Smart Grid environment.

The remainder of this paper is organized as follows. Section 2 presents a summary of the previous work on WSN demonstrators. Section 3.1 and 3.2 introduce the hardware and software tools used for the design and deployment of the demonstrator’s WSN. Section 4 illustrates an example of usage of the WSN in a Smart Grid environment. Finally, section 5 concludes the paper.

## 2 Related work

The heterogeneity of IoT applications leads to a large diversity of WSN testbeds, supporting different topologies and network layer protocol options. Many wireless sensor network testbeds are available to the community today. In [ABF<sup>+</sup>15], the authors present FIT IoT-LAB, an open testbed that consists of 2728 motes located in 6 different sites across France, offering an accurate open access and open source multi-user scientific tool. It provides repeatable mobility via electric toy trains, multi-site experiments and energy consumption measurement. In [HKWW06], TWIST supports experiments with diverse node platforms, active power supply and creation of hierarchical and flat sensor networks control of the nodes. In [NGAH13], SmartSantander offers advanced hardware, scale, functionalities proposed to the user, mobility via public buses Multi-site and real-life experiments. In [ACPG07] and [SZC<sup>+</sup>19], other WSN testbeds were developed. However, all of these demonstrators generally operate in controlled environments and are not mainly adapted for Smart Grids.

## 3 Global Architecture

Our demonstrator aims to provide a WSN testbed in a real SG environment [KNL<sup>+</sup>20]. Collected data are provided by (Photovoltaic) PV cells, hot water tanks, electrical equipment, etc. The communication is ensured via 120 sensor nodes deployed all over the buildings of the university. In the following subsections, we will briefly describe the network’s hardware and software architectures.

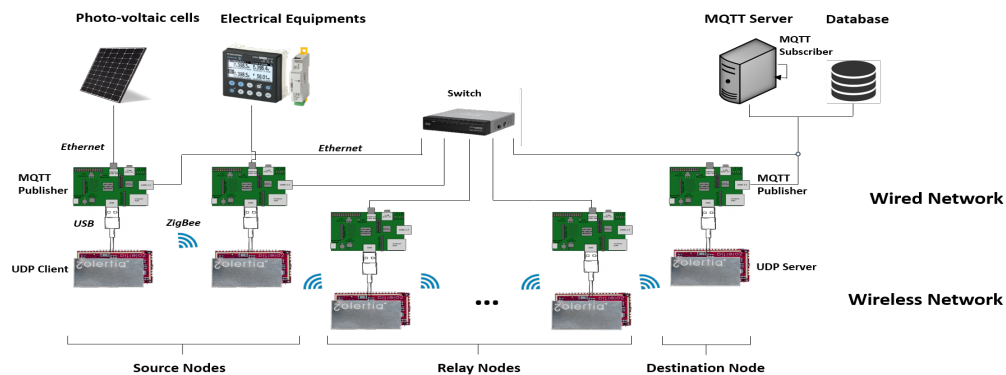


FIGURE 1 – Sensor network architecture

### 3.1 Hardware Architecture

The testbed consists of RPI-Zolertia sensor nodes, communicating over two types of networks (wired and wireless). In figure 1, the global architecture of our testbed and both wired and wireless networks are presented. The wired network serves as a controller to reprogram the wireless nodes, collect data from the different electrical equipment and store it in the database on the server. In a detailed view, a sensor node in our architecture consists of a RPI-Zolertia couple. It is a master-slave type of relation, where RPIs control and manage the wireless network, while Zolertia devices assume the role of processing and routing the received information from the different energy sources.

The wireless network is composed of three types of nodes : (1) *source*, (2) *relay* and (3) *destination nodes*.

*Source nodes* are responsible of reading data from the RPIs (which in turn collects information from the equipment), processing and transmitting it to a one hop relay node. *Relay nodes* receive the data from the *source nodes* and then take care of path computing, processing, and communicating to *destination nodes* across the wireless network. Finally, *destination nodes* process the received data packets to execute specific tasks (i.e., storing them in the database via the RPI).

### 3.2 Software Architecture

As already mentioned, our sensor node consists of a RPI-Zolertia couple. Firstly, RPI nodes are programmed using Python language. They serve first of all to reprogram/reflash the Zolertia nodes. Moreover, they communicate with the PV cells and the electrical equipment using the Modbus TCP/IP Protocol [S<sup>+</sup>99]. The RPI node will choose the data type that it needs to get from the electrical equipment in order to transmit it afterwards to the Zolertia node. Next, and after the data collection from the electric equipment on the RPI level, these data are transmitted to the Zolertia nodes via a serial communication. These nodes are programmed to receive and transmit data in radio signals, taking into account their limited energy resources. Contiki [DGV04], a largely used operating system for memory-constrained devices, is implemented on these sensor nodes, thus enabling the connection to IPv4/IPv6. For that, devices are configured to meet the aforementioned standards and to reach every node in the network. This is done by implementing a 6LoWPAN network. This protocol delegates all the capabilities of IPv6 on a constrained device. On the application layer, and in order to distribute the collected data efficiently, Message Queue telemetry transport (MQTT), a lightweight publish and subscribe protocol, is implemented on both the Zolertia and RPI nodes. A local broker running on the server side is responsible for handling the publishing and subscribing events. On the other side, each sensor node (wired and wireless) publishes the captured values in distinct topics. Data is then handled and inserted in the database by the subscriber.

## 4 WSN usage : providing flexibility in a Smart Grid environment

Using the WSN, the main outcome is to be able to use the flexibility of each equipment and coordinate it at the level of each building, but also at campus scale. Locally, flexibility potential and control possibilities are evaluated in our demonstrator, as several equipment are able to participate and shift their consumption over a day, but are spread across the campus. In addition, to efficiently manage the production/consumption ratio, we have the possibility to monitor and control inverters of the local PV system and the battery. Over the campus, the equipment that can provide flexibility for the management of energy and their respective power are presented in Table 1.

Equipment	Total	Flexibility Gain (Total)
<b>Boilers</b>	13	23.5kW
<b>Air Handling Units</b>	9	75kW
<b>Battery</b>	1	250kWh (-80kW / +40kW)
<b>PV System</b>	1	185kW <sub>p</sub> (peak)

TABLE 1 – Flexibility gain by equipment

The boilers and the AHU act as consumption equipment, the battery acts as an energy buffer (storage/supply) and the PV systems as production units. We should note the fact that all equipment do not always consume at the same time and at their nominal power, the total estimated flexible power will be thus reduced. This figure should be used with caution, as it is highly dependent on time (time of the day, of the week or of the year) and represents only a potential of flexibility. Estimating the real outcome of flexibility is a research field on its own and will be investigated in the future.

The use of a WSN with sensors deployed in the buildings and on the different equipment will help enabling this flexibility by sending control messages, orders, etc. all over the network. This will unlock a certain amount of power that is then available to be shifted at optimized time slot during a period of time.

This flexibility may or may not be used to reach a variety of objectives : reducing the bill, reducing the environmental impact, or increasing the self-consumption ratio.

It is therefore crucial to evaluate it (cost and benefit) in the light of the objective of the entity implementing it, without leaving aside all the consequences of this new system (on user comfort, price and environmental impact, where applicable). The next step of this experimentation is thus to evaluate those aspect for the local demonstrator.

## 5 Conclusion and future work

In this paper, we presented a SG WSN testbed that is being developed as part of the EBalance-plus project. It is made up of 120 RPI-Zolertia sensor nodes that will be deployed at the Catholic University and Junia buildings in Lille to monitor and control energy production and consumption via WSN. The WSN is still under deployment and will be publicly accessible once complete. We presented as well a case scenario of usage of this testbed in order to enable and test flexibility on the electric grid. In the future, we will study the carbon footprint of the hardware, software and protocols used in order to quantify and evaluate the benefit gained for using a WSN for controlling the Smart Grid.

## Acknowledgments

This work was funded by the H2020 European project EBalance-plus.

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