Enhancing Electricity Meters with Smart Functionality Using Metering System with Optical Sensors

Mateusz Brzozowski
and Michał Kruszewski

OneMeter Ltd.
ul. Dobrzanskiego 3
20-262 Lublin, Poland
Email: {Mateusz.Brzozowski, Michal.Kruszewski}@onemeter.com

Artur Janicki

Institute of Telecommunications
Warsaw University of Technology
ul. Nowowiejska 15/19
00-665 Warsaw, Poland
OneMeter Ltd., Lublin, Poland
Email: A.Janicki@tele.pw.edu.pl

Abstract—**The article presents on-going work on a system, called OneMeter 2.0, that uses energy-efficient beacons with optical sensors to create an advanced metering infrastructure. The system allows the use of the current, non-smart electricity meters with IEC 65056-21 optical ports to create an intelligent metering system. The core components of the system are described, such as a beacon with an optical sensor, a mobile application, and a data platform. The status of the project is presented, including the number of test installations and initial assessment of the beacon's energy efficiency. Sample visualizations originating from the data analytics platform are shown and explained.**

Keywords–Optical sensor; Beacon; Smart metering; Smart grids; AMI.

I. INTRODUCTION

In times of growing costs for electricity production and increasing problems with air pollution, the need for real-time monitoring of energy consumption is tremendous. Unsurprisingly, the European Commission requires that all member countries equip at least 80% of their electricity customers with intelligent metering systems by 2020 [1]. This is supposed to lead to the creation of smart power grids [2], which would allow for monitoring and managing of country-based and EU-based power consumption.

The process of installing smart meters is very costly and time-consuming, so it is no wonder that the majority of the EU countries, as described in the next section, are not likely to meet the above deadline. Therefore, to improve the process of deployment of smart metering, we propose a system, called OneMeter 2.0, which will use energy-efficient beacons with optical sensors, communicating via the IEC 65056-21 protocol. The system will add intelligent functionality to existing, popular, non-smart, electronic meters, called Automated Meter Reading (AMR) [3], equipped with an optical port – without a need to install smart meters at all.

In this paper, in Section II we will briefly describe the problem of smart metering deployment. Next, in Section III we will present a description of the OneMeter 2.0 system, followed by the current status of the project (Section IV). Finally, we will conclude in Section V with a plan for the future of our work.

This work was supported by the National Centre for Research and Development within the Smart Growth Operational Programme (agreement No. POIR.01.02.00-00-0352/16-00).

Figure 1. OneMeter beacon with optical sensor attached to IEC 62056-21 port of electricity meter.

II. SMART METERING CHALLENGES

A. Smart Metering in Europe

According to the data of the European Commission [4] and European energy regulators [5], so far only three EU members have achieved a full roll-out of smart meters: Italy, Finland, and Sweden. In 2015, in Denmark, Estonia, Malta, Slovenia, and Spain about half of the customers had had smart meters installed in their households, while in the Netherlands it was below 30%. In Austria, Latvia, Poland, and the UK, the household penetration was only about 10% (for Latvia) or below. In the rest of the EU countries, the deployment of smart meters had hardly started.

This means, for example, in Poland, where there are 8 million metering points, only less than 700 thousand are equipped with smart meters. However, a remarkable part of the remaining electricity meters are equipped with optical ports, which are normally used for billing readouts but can be equally used to access the meter readouts using an optical sensor.

B. Existing Solutions

Several solutions exist that aim to acquire energy consumption data from existing electronic, non-smart meters. The Rhino Company offers the so-called RhinoAMI AP device [6], which accesses electronic meters via a DIN bus using a cable

 ISBN: 978-1-61208-691-0

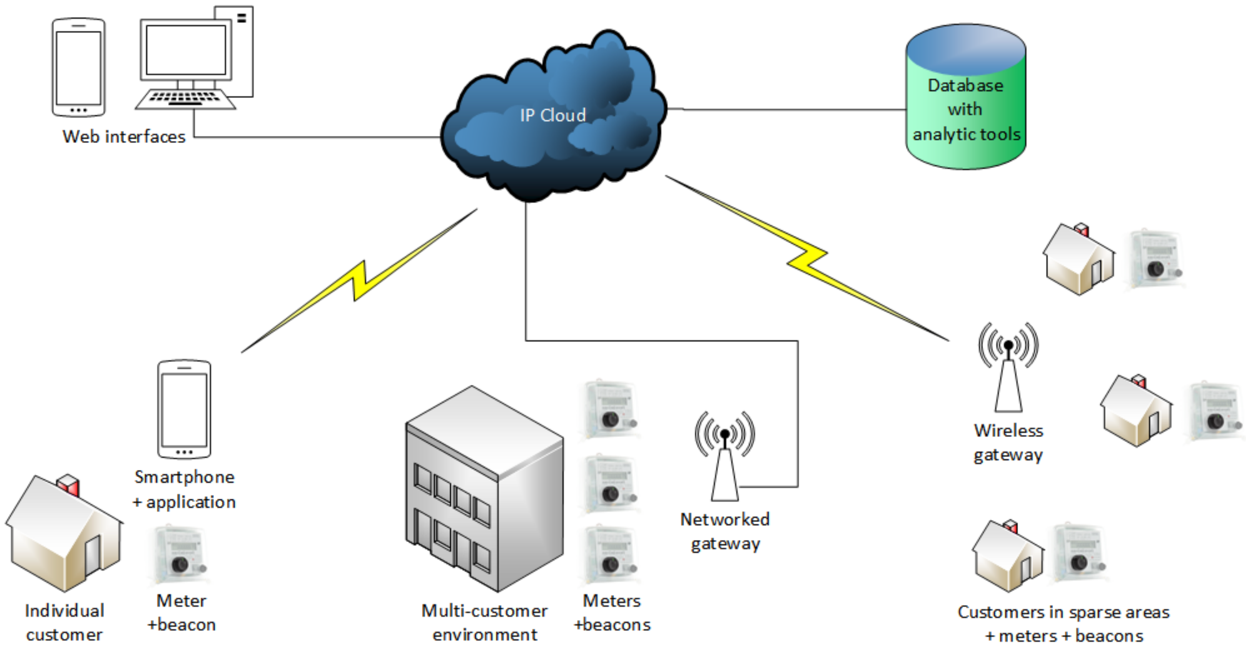

Figure 2. Schematic diagram of proposed OneMeter 2.0 system based on beacons with optical sensors.

connection. Metering data can be then transmitted further, using a GPRS or Ethernet connection. The device requires an external 5-12 V power source.

Smappee [7] is another cable solution, offered currently at 229 EUR, which, in contrast to the previously described system, uses an electromagnetic sensor clipped to the phase cable supplying an electrical installation, e.g., in an apartment or an office. A dedicated application allows the monitoring of the current energy consumption. A proprietary Non-Intrusive Load Monitoring (NILM) algorithm helps to recognize individual electrical appliances. The Smappee metering system is powered by a 100-230 V main supply. It is noteworthy that Smappee, in fact, estimates the consumption instead of reading it from the meter.

A device called mReader®Opto, produced by NUMERON [8], uses an optical sensor to communicate with the meter over the IEC 62056-21 protocol. It requires a USB connection to connect with a smartphone or a computer. It can work on a battery, but only for ca. 2h. The same producer also offers a gateway called smartBOX, which allows a remote transmission of the meter readouts over a network or GPRS.

REDZ Smart Communication Technologies offers another device with an optical sensor: KMK 118 Bluetooth Optical Probe [9]. Its functionality is similar to the previously described device, but here the cable communication is replaced by a wireless one. The device can be battery powered, but the battery life is reported to be only “greater than 24h”. The device is offered at the price of 180 EUR.

C. *OneMeter 2.0 Project*

We are working on a system that utilizes beacons with optical sensors to read data directly from electricity meters. In contrast to other existing solutions, our beacons are energy efficient, allowing them to work on a single battery for over a year. Thanks to a cloud-based data platform and the use of smartphones, our solution enables a fast and cheap deployment of the AMI infrastructure using the existing, non-smart electricity meters.

III. Idea of Proposed Solution

The idea of our solution is based on using a small, energy-efficient wireless beacon with optical sensors attached to an electricity meter (see Figure 1). We propose employing either smartphones or dedicated gateways to transfer measurement data to the cloud, as shown schematically in Figure 2. The details of the proposed solution are described below.

A. *Optical Sensor in Beacon*

A small bottle cap-shaped beacon of 32 mm diameter (compatible with the IEC 62056-21 standard) was designed, equipped with an optical sensor, LED diode, Nordic Semiconductor’s processor nRF51, flash memory, Bluetooth Low Energy (BLE) radio components, and a 3.0V battery (CR2032). The beacon is attached magnetically to an electronic meter equipped with an optical port. The optical sensor is designed with a miniature silicon photodiode of high radiant sensitivity and a low power comparator. The optical sensor, together with the IR LED diode, are able to set up communication with a meter using the IEC 62056-21 (old: IEC 1107) protocol. The amount of measurement data acquired from the meter depends on the meter’s model – some of the meters present only the absolute active energy, while the others allow the readout of more detailed information, such as positive and negative active energy, or reactive energy.

The processor was programmed in such a way that the beacon performs a readout of the meter every 15 min and stores the metering data in the flash memory. The BLE component allows other BLE devices to connect to the beacon to download metering data or to transmit the readout in real time.

 ISBN: 978-1-61208-691-0

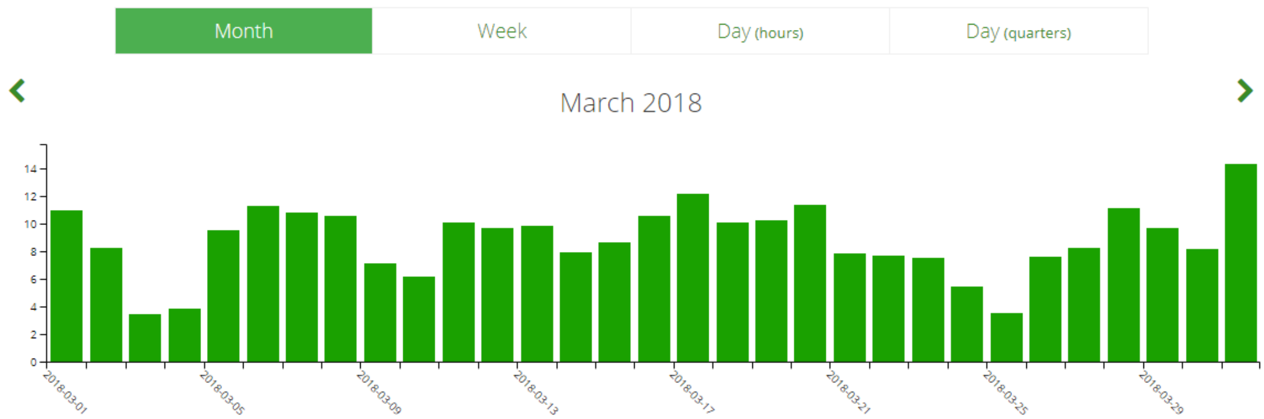

Figure 3. Sample monthly consumption chart for residential consumer. Values shown in [kWh].

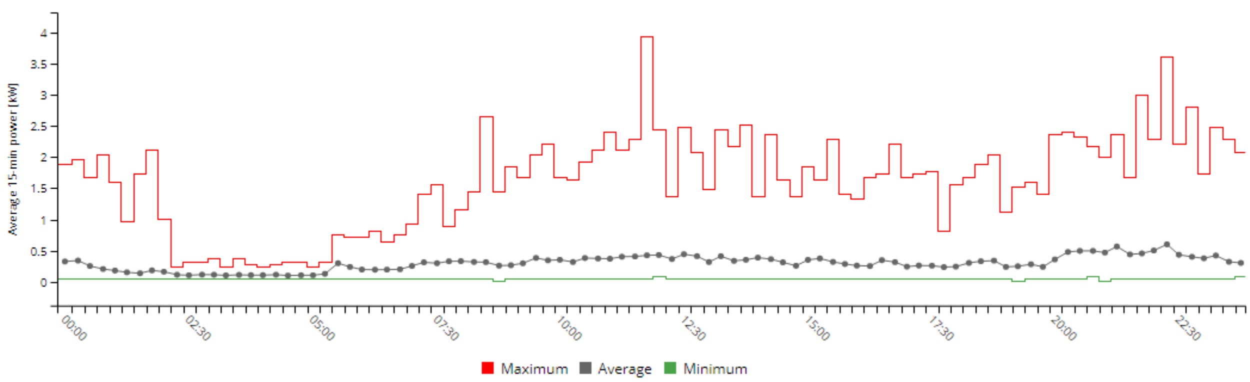

Figure 4. 15-minute daily consumption profile calculated over 2-month period for residential consumer.

B. Smartphone as Gateway

We decided to use smartphones as gateways to transmit measurement data from beacons to the cloud. We designed an Android application, which allows the setting up of data connections between the smartphone and the beacon. The connection is carried out using the BLE protocol version 4.0. When the connection is established, the measurement data, encrypted using the AES protocol, is sent to the data cloud over the smartphone's Internet connection, i.e., via Wi-Fi network or via a data connection from the mobile provider. The synchronization can be triggered by a user in arbitrary moments. The application can also operate in the gateway mode: in this case, the smartphone receives advertising packets and transfers them to the cloud.

Apart from using smartphones, we also plan to deploy dedicated gateways, which would communicate with the cloud using any of the IoT communication protocols, similarly to [10]. This option may be especially needed in rural areas, with less developed infrastructure, as depicted in Figure 2.

C. Data Platform

The data platform provides gathering, analysis, and visualizations of the collected metering data. The initial version of the platform was realized using the MongoDB database with a set of proprietary analytic algorithms.

A web-based user interface allows the visualization of the energy consumption data. The user is able to enter information about their tariff. Thanks to the tariff data imported to the database for various energy re-sellers, the cost estimation of the consumed energy can be calculated. The platform provides tools to generate reports showing consumption profiles for chosen date ranges and information about maximum power demand including, for example, information on the percentage of time a certain power threshold was exceeded.

IV. On-going Research Work

Intensive work on the OneMeter 2.0 system started at the beginning of 2018. The project highlights are presented below.

A. Experimental Installations

To verify experimentally how the solution works in a real environment, we needed to deploy it at the end users' locations. Up to the time of writing this article (October 2018) we have achieved the following approximate metrics:

- 160 business client installations (small and medium entrepreneurships);
- 20 household client installations;
- 40 installations in laboratory conditions;
- 76 meter models verified to work correctly with elaborated beacon;
- 0.8 million valid measurement records gathered in database starting from 1 Jan 2018.

In general, the experience built upon the above-described installations was very positive. Nevertheless, several issues were identified, which were then subject to improvements. One such issue was the problem introduced by Doze and App Standby feature in API level 23 (Android 6.0) – a power saving mechanism, which caused the gateway service installed on a smartphone to stop at random moments. This was solved by implementing the so-called wake lock feature, which prevents moving the gateway application into sleep mode by the smartphone's operating system.

B. Energy Effectiveness of Beacon

We performed several measurements to estimate the potential lifetime of the beacon with a single CR2032 battery. We took the following presumptions:

- 160 mAh of effective CR2032 battery capacity;
- 96 meter readouts per day (i.e., every 15 min);
- 650 B of data returned by the meter at 9600 baud rate;
- data collected by the gateway in real-time;
- 4 s BLE advertising interval.

Detailed information about the current demand and consequent battery usage by various beacon activities is shown in Table I.

TABLE I. BEACON ACTIVITIES WITHIN 15 MIN. WORK CYCLE.

Beacon activity	Current [µA]	Duration [s]	Time share [%]	Energy usage [µAh]	Energy share [%]
Meter readouts	978.04	3.46	0.38	0.94	21.95
BLE comm.	6038.71	1.24	0.14	2.08	48.78
Flash operations	3150.03	0.24	0.03	0.21	4.88
Idle	4.18	895.06	99.45	1.04	24.39

Energy consumption of ca. 4.27 µAh per 15 min. means that the daily beacon's energy consumption is on the level of 0.41 mAh. This implies that the beacon is now able to work without a battery replacement for about one year.

Based on [11] we estimated the foreseen energy consumption after adding support for a LPWAN network. For instance, assuming a LoRa with the lowest bitrate (250 b/s) the device would need a battery with at least 500 mAh capacity to send the daily single OBIS code data once per day. This requires replacing the CR2032 battery with AAA batteries to maintain at least one year of the beacon's uninterrupted operation.

C. Initial Data Analysis and Visualization

So far the data analytic platform allows users to access the following information:

- Monthly, weekly, daily, and 15-min. daily metrics of energy consumption (see Figure 3 for an example).
- 15-min daily consumption profile over an arbitrary period of time, showing average, minimum, and maximum consumption for every quarter (see Figure 4 for an example of a profile for a residential consumer calculated over two months).
- Information on the amount of the energy consumed during peak hours, off-peak hours, and during weekends.
- Cost of the consumed energy over the selected period for the selected tariff, showing the cost of electricity and distribution.
- Load duration curve, showing, e.g., the percentage of time when the power limit is exceeded.
- Comparison of hourly consumption profiles.

The initial feedback from the users, gathered using questionnaires, revealed that the clients were in general satisfied with the information available in the platform and the way it was visualized. However, the need for additional features (e.g., alerts) was reported and will be addressed soon in the project.

V. CONCLUSION AND FUTURE WORK

In this paper, we showed the on-going work on the OneMeter 2.0 system, which, thanks to the beacons with optical sensors, would be able to enhance the existing AMR electricity meters with smart functionality. Contrary to the solutions offered by the competitors, the described system is both wireless and energy-efficient. What is more, the cost of a single beacon is not likely to exceed several EUR, which is significantly lower than that for similar products available on the market.

The proposed system can be highly useful to end users, re-sellers, and distribution system operators (DSOs). Last but not least, the system may provide valuable information to prosumers, which would be able to monitor in real-time how much energy they both consume and produce.

The future work will involve intensive work on developing stand-alone gateways, including the ones using IoT communication protocols. Further work on increasing the beacon's energy efficiency is also foreseen.

REFERENCES

[1] European Union, "Directive 2012/27/EU of the European Parliament and of the COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC," Official Journal of the European Union, Nov. 2012.

[2] R. Morello, C. D. Capua, G. Fulco, and S. C. Mukhopadhyay, "A Smart Power Meter to Monitor Energy Flow in Smart Grids: The Role of Advanced Sensing and IoT in the Electric Grid of the Future," IEEE Sensors Journal, vol. 17, no. 23, Dec 2017, pp. 7828–7837.

[3] F. D. Garcia, F. P. Marafao, W. A. de Souza, and L. C. P. da Silva, "Power Metering: History and Future Trends," in 9th IEEE Green Technologies Conference (GreenTech 2017), March 2017, pp. 26–33.

[4] European Commission, "Second Report on the State of the Energy Union. Monitoring progress towards the Energy Union objectives – key indicators," Feb 2017.

[5] Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER), "ACER/CEER Annual Report on the Results of Monitoring the Internal Electricity and Gas Markets in 2015 – Key Insights and Recommendations," Nov 2016.

[6] "Rhino Energy - Solution - Hardware," https://rhino.energy/hardware/, 2018, accessed 08 Jan 2019.

[7] "Smappee Energy," https://www.smappee.com/be_en/energy-monitor, 2018, accessed 08 Jan 2019.

[8] NUMERON, "Dokumentacja NUMERON, mReader®4," https://docs.numeron.pl/mreader4/, 2018, accessed 08 Jan 2019.

[9] REDZ Smart Communication Technologies Ltd., "KMK 119 – Bluetooth optical probe - Smart wireless auto protocols detection probe," http://probeformeters.com/brochure/REDZ_KMK119_Detailed_Datasheet.pdf, 2018, accessed 08 Jan 2019.

[10] M. Carratú, M. Ferro, A. Pietrosanto, and V. Paciello, "Smart Power Meter for the IoT," in IEEE 16th International Conference on Industrial Informatics (INDIN 2018), July 2018, pp. 514–519.

[11] E. Morin, M. Maman, R. Guizzetti, and A. Duda, "Comparison of the Device Lifetime in Wireless Networks for the Internet of Things," IEEE Access, vol. 5, 2017, pp. 7097–7114.