A Perspective on Wireless M-Bus for Smart Electricity Grids

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***Abstract*—The Internet of Things (IoT) enables long-range outdoor networks, such as smart grid and municipal lighting, as well as short-range indoor systems for smart homes, residential security, and energy management. Wireless connectivity and standardized communication protocols become an essential technology baseline for these diverse IoT applications. The focus of this work is wireless connectivity for smart metering systems. One of the recent protocols in this field is Wireless M-BUS, which is being widely utilized for remote metering applications across Europe. Therefore, in this paper, we detail a novel multi-platform framework designed to serve as a data generator for the protocol in question. The developed software allows to construct Wireless M-Bus telegrams with a high level of detail according to the EN 13757-4 specification and then schedule them for periodic transmission. The evaluation of the data generator is done in real scenario by using previously developed prototype equipped with IQRF TR72DA communication module acting as a smart meter with implemented software framework. As a result, the evaluation of communication distance between the developed Wireless M-Bus prototype and commercial gateway was tested in case of indoor scenario at Brno University of Technology, Faculty of Electrical Engineering and Communication.**

***Keywords*—Low power communication; Energy efficient wireless communication; Wireless M-BUS; Data generator; Machine-to-Machine; Smart Grid**

I. Introduction

The term Internet of Things (IoT) has gained enormous notoriety with the explosion of wireless sensor networks and smart devices [1], [2]. This unprecedented growth, continued by home automation scenarios and wearable electronics, is predicted to reach 74.5 billion connected devices by 2025 [3], [4]. Furthermore, by 2024, the overall IoT industry is expected to generate a revenue of 4.3 trillion US dollars across different sectors such as device manufacturing, connectivity, and other value-added services. Recent improvements in affordable sensor and actuation technologies, i.e., embedded devices along with the emergence of novel wireless communication technologies as positive indicators, support the forecasted trends. No doubt, it could be stated that what appeared a decade ago as a science fiction is decisively materializing today, bringing along tens of billions of networked devices with enormous economic impact [5].

Once we reminded the matters in 2006, the Energy Services Directive (ESD) 2006/32/EG was passed by EU [6], which demanded to reduce the energy consumption of its members by about 9% from 1996 to 2015. According to the related energy blueprint, the EU's greenhouse gas emissions are to be reduced by 20% in 2020 compared to 1990 levels. Furthermore, the Energy Efficiency of Buildings Directive requests the energy monitoring, certification and minimum standards on the energy performance of new buildings [7]. The European countries have originated different projects to achieve this goal. Utility companies are among the largest CO_2 emitters making them an important point of leverage to reverse the situation. Smart grids and smart meters play (as predicted in the past) a critical role in helping the utility companies in reducing their carbon emissions, and thus allowing to manage the distribution grids more efficiently.

As a result, less power consumption, fewer emissions, and reduction of the frequency and duration of outages are expected. For example, all new buildings in Germany should be equipped with metering devices that monitor the current energy consumption of consumers (smart meters) starting from 2010. Moreover, 80% of the buildings must be equipped with smart meters by 2020. Significantly, 53 million automatic electric meter readers have been deployed over the past six years only within Europe.

Continuing with the introductory discussion, the IoT spans long-range outdoor communication networks such as the smart grid as well as shorter-range indoor networks that enable the connected home, residential security systems, and energy management in case of a natural disaster. Wireless connectivity and standards-based software protocols, as they stand today, provide the critical enabling technology for the IoT scenarios. The Machine-type Communication (MTC) market is already flooded with energy efficient wireless communication systems known as Low Power Wide Area (LPWA) networks [8]. Technologies like Sigfox, LoRaWAN, Narrowband IoT (NB-IoT) or LTE-M represent a novel communication paradigm, which will complement traditional cellular (Global System for Mobile Communications (GSM), Long-Term Evolution (LTE))

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and short-range wireless technologies (ZigBee, Bluetooth, Z-Wave, legacy Wireless Local Area Networks (WLANs)) in addressing diverse requirements of IoT applications [9], [10].

Nevertheless, the right decision always depends on the specific scenario as the wireless solution is not omnipotent in the IoT landscape. It is necessary to utilize a specific physical channel that can be wired or wireless, with determined band-pass and coverage factors. Wired communication technology allows a total coverage and a bandwidth up to 100 GHz with the use of optical fibers. The drawbacks are indeed the cost and complexity of the installations. Wired communication is going to be replaced by wireless channels wherever service requires a mobile connection or the high infrastructure cost cannot be sustained. As for infrastructure costs, GSM networks require high investments as well, but wide bandwidth [11], total coverage of areas, and mobility are so indispensable that high service costs are allowed. Other services, like remote metering, do not require wide bandwidth, but people are reluctant to bear additional costs to the consumption. Nonetheless, although terminal devices are not mobile, those must be battery powered for specific applications of water and gas monitoring. Since these batteries may not be recharged periodically, they must have a minimum of 5 years of autonomy.

Most of the modern meters designed to read the electricity, water and gas consumption fall into the category described above. More in details, these devices are featured with either a long-range radio-module allowing direct connection at the GSM / GPRS / LTE network or a short-range radio module requiring the network of Machine-Type Communication Gateways (MTCGs) installation. The latter solution has the drawback of requiring additional infrastructure, although not extremely costly. The reason to prefer the use of the latter solution instead of the former ones is the possibility to have the battery life increase due to the lower power consumption of the short-range RF-module. In this scenario, a typical problem is the network coverage offered by the MTCGs in the presence of aleatory obstacles typical of a city environment [12].

Many software tools can simulate the signal propagation potentially assisting the positioning of the MTCG with respect to the meter [13]. Unfortunately, the actual coverage does not overcome the 50 – 60 % of the installed meters in most cases. For this reason, the meter manufacturer is forced to set the maximum transmission power for the RF-module. This choice goes in contradiction with the need to have the maximum battery life in order to avoid frequent replacements [14], [15].

From our previous experiences with an industrial segment, one of the most useful wireless communication protocols for smart metering to emerge in recent years is Wireless M-BUS (WM-BUS) being widely used for metering applications across Western and Central Europe [16]. Phrases and expressions such as smart home, smart factory, metering automation or advanced energy consumption reduction have gained the popularity in recent years and, therefore, have come to the awareness of each of the European inhabitant. The advance-never-stopping industrial procedures have brought the urge to measure and monitor numerous quantities, based on the field of business, to the foreground. With that, advanced metering systems are being more required than ever before.

These infrastructures are designed to communicate with metering devices, for instance, gas, electricity, water or heat meters, at a modifiable scheme. By implementing a system of this manner, the customer generally gains many advantages ranging from low maintenance costs and needs to easy meter readout[1]. It may come as a surprise that these systems have already been developed and in many places, they are soon to be deployed or even already in place. Furthermore, a considerable part of already-in-duty devices uses a Wireless M-BUS communication protocol to communicate with the outer world.

The primary goal of this paper is to present a software tool capable of testing these networks via simulating sensor-like behavior in uni-directional communication with the data collecting servers in a test. This tool would be helpful for public utility companies that could apply it for initial testing of their concepts, designs, and performance evaluation of the designed Wireless M-BUS networks without the need for having any hardware sensors installed.

II. The Role of Wireless M-BUS in Industry 4.0

M-BUS (wired) was developed in the early 1990s and later extended with its wireless form in 2005 when the first draft of the EN 13757-4 was published, approved a year later [17]. That was 5 years before IoT and Industry 4.0 terms started gaining popularity in 2011 and even longer before they came to the mass market attention in 2014 [18]. Despite that, Wireless M-BUS presents a solid competition to protocols and networks tailored just for Industrial Internet of Things (IIoT, which is a specific subset within regular IoT and represents more or less a synonym for Industry 4.0 [19]), such as Sigfox, LoRa(WAN) or NB-IoT. Since it follows very similar goals (sensor-independence, battery-longevity, meter-automation), but holds a few years advantage, it is even better established, settled and stabilized than most of its competitors [20].

For the above-stated reasons, no drop in WM-BUS popularity is expected within the Industry 4.0 era. However, it is still constrained to metering applications. A typical example is a regular electricity meter check performed for a supplying company, which happens regularly in the form of a human employee marching door to door, accessing each household's technical room or utility closet, visually reading the desired value from the dial and noting it down. This procedure is labor-intensive, error-prone, unreliable (nobody home), and finally time-consuming.

With technology such as Wireless M-BUS, these readouts do still require a human worker traveling through the country to visit each client. However, the data is collected wirelessly, directly into the storing device and without the need of reaching for the meter inside the house. More than that, if the

[1]See "Six benefits of Industrie 4.0 for businesses" by Control Engineering, 2017: https://www.controleng.com/single-article/six-benefits-of-industrie-40-for-businesses/5c57cc3925c0ff323553da64108d5c0c

operational range of the meter's transmitter is large enough, the readouts can be performed from a car driving by, for all the customers at the street at once [21].

III. Wireless BUS Data Generator

The key contribution of this paper is represented by the Java application, developed for generating WM-BUS data in the form and structure as demanded by the user. A short user-side explanation follows here.

The evaluation was done using the previously developed hardware platform [22] utilizing the newly developed WM-BUS data generator. Measurements took place at Brno University of Technology, Faculty of Electrical Engineering and Communication, Czech Republic.

A. Graphical user interface

The first window presented to the user upon starting the program in the graphical mode is portrayed in Fig. 1 below. For this reason, it will be referred to as *Layer 1* window.

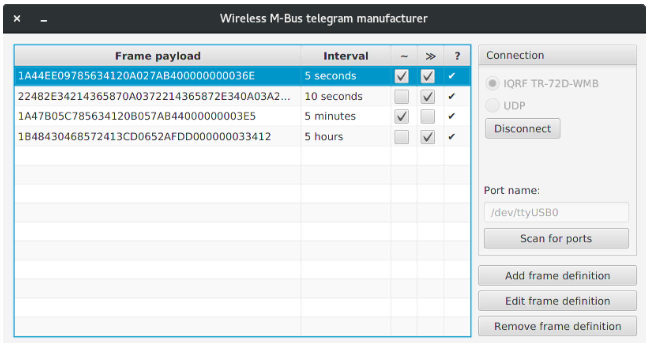

Fig. 1. Generator's GUI: *Layer 1* window, list of defined telegrams.

1) Layer 1 window: This window shows a table of all frames that the user has defined and for each of them the interval that the frame is set to be sent in, a toggle for turning the fluctuation, an on/off switch to control whether the respective frame is scheduled to be periodically sent at the given interval or not, and a status indicator (showing whether the last frame transmission succeeded or failed). These controls are provided on a per-frame basis. For the purpose of this table, frames are presented by their link-layer content only, thus excluding preamble, postamble and any CRC fields between, and all are displayed as hexadecimal.

On the right side, global options, regarding the transmission of all frames, are placed. This is the option to switch between sending through a serial port to a supported hardware WM-BUS transceiver, or through a UDP socket (e.g., for testing). Based on this selection, more controls are presented, either to specify the serial port name or IP and UDP parameters (source and destination IP addresses and ports).

New frame definition can be added, existing one can be edited or removed. If any type of transmission has been chosen and locked, frames in the table can be scheduled for periodic sending.

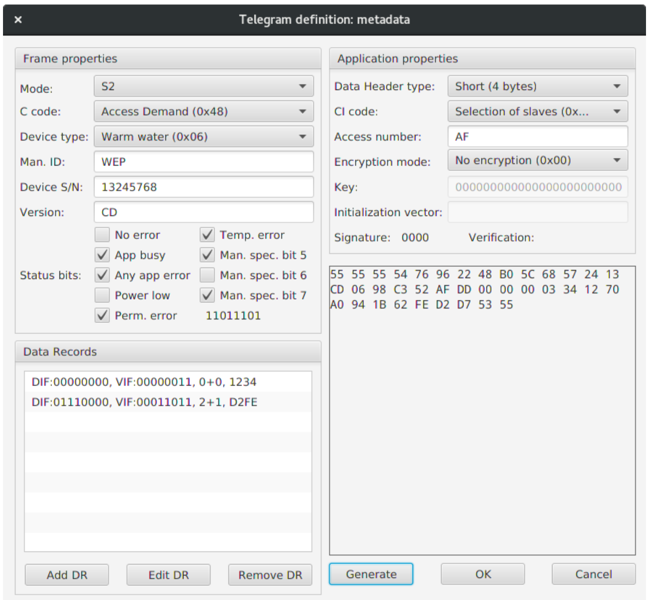

Fig. 2. Generator's GUI: *Layer 2* window, frame details.

2) Layer 2 window: Upon clicking the *Add frame definition* button in *Layer 1* window, a *Layer 2* window is shown, as presented in Fig. 2 below.

The purpose of this window is to allow for the definition of a new frame. All the parameters that are specific to one frame are listed here, including the manufacturer ID, C-field code, CI-field code and others alike. A list of Data Records, defined within this Frame, is presented as well. Similarly to the table in the previous window, Data Records can be added, changed and removed. Before submitting the frame, the user can generate the full byte sequence with no parts omitted, for revision.

3) Layer 3 window: Lastly, when the *Add DR* button in the *Layer 2* window is clicked, a *Layer 3* window is shown. An example of that is shown in Fig. 3. Here, a new Data Record for the frame being specified in the underlying *Layer 2* window can be defined. This includes building a DIF, a VIF, up to ten DIFEs, and VIFEs and the payload.

This structure follows the WM-BUS hierarchy, where one frame holds one or more Data Records and each of the Data Records holds one DIF, one VIF and optionally multiple VIFEs and DIFEs, while the frame itself is the only stand-alone unit. In addition, all the windows behave as modal, which means that before a lower-layer window is closed, the underlying higher-layer window cannot be acted with – for instance, a Frame definition window cannot be closed to proceed to the initial window or have its values modified until its Data Record specification windows are closed.

4) Management dialog: In the case that an IQRF module is attached to the machine and recognized by the application, the option to view a simple management window becomes available. Its appearance is portrayed in Fig. 4. It allows for

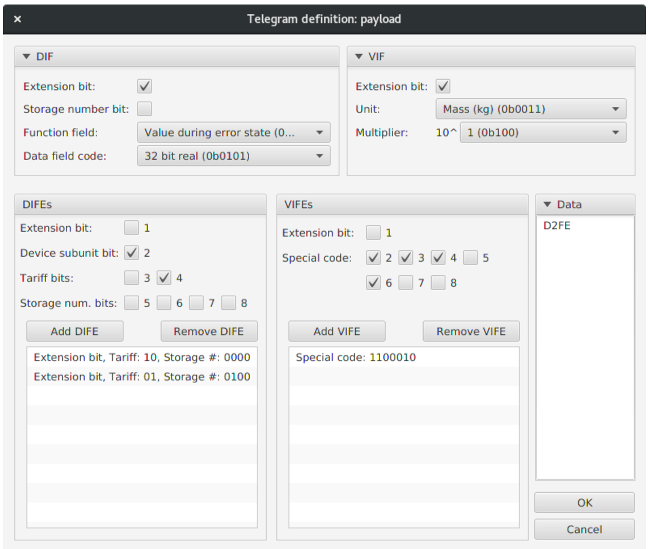

Fig. 3. Generator's GUI: *Layer 3* window, payload details.

basic configuration changes in the hardware: altering the transmission power and synchronicity, restarting the device (which terminates all scheduled periodic operations and closes the connection), and views the reported battery status along with hardware and firmware version numbers.

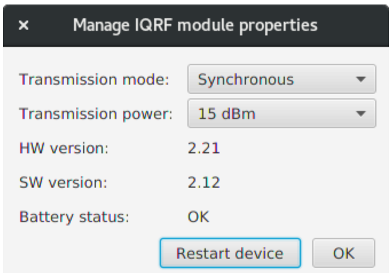

Fig. 4. Generator's GUI: *Management* dialog.

5) Graphical Interface Use-case Illustration: An example of the application's use case is as follows: the user starts the application. *Layer 1* window shows the table without any frames. The user adds a frame, customizes its properties in the *Layer 2* window, adds a Data Record with two DIFEs and two VIFEs and another Data Record without any extensions within the *Layer 3* window, closes the two upper windows and is back to the *Layer 1* window with the frame, which they have just specified, in the table. Connecting to an output channel before sending is necessary. Thus, an IQRF WM-BUS transceiver is attached via USB, the user proceeds through the connection process, and the generator recognizes the hardware. The user now changes the interval to "30 seconds", opts for data fluctuation and ticks the checkbox in the column for enabling it. The frame is sent via a serial port to the transceiver, processed and transmitted via a wireless medium. Status tick now appears at the end of the row signaling successful transmission. From now on, the frame will be sent out to the Wireless M-BUS network every 30 seconds[2], and more frames can be added at any time.

IV. Initial Verification of Communication Capabilities

Within the practical evaluation, we have established an initial test scenario located at Brno University of Technology, Czech Republic. We built the setup with the following components: (i) Wireless M-BUS transmitter, based on wireless module IQRF TR72DA, running our proprietary software acting as a data generator, equipped by the external planar antenna; (ii) Universal WM-BUS mobile device, based on Raspberry Pi 3 with IQRF TR72DA communication module attached and with the external planar antenna equipped in the role of receiving device. The data transmission consists of 15 telegrams which were sent out every 10 seconds. The quality of the radio link is evaluated by the measured Received Signal Strength Indicator (RS SI) as well as by a number of packets lost during the transmission process.

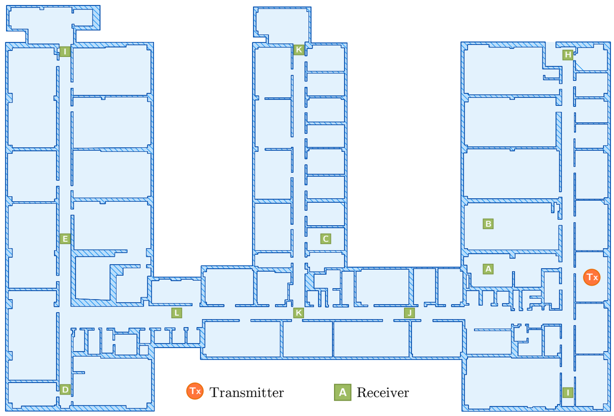

Fig. 5. Wireless M-BUS indoor scenario at Brno University of Technology, Czech Republic.

While performing the initial measurement set, maximal communication distance between the sensor and data aggregation unit was measured in case of indoor scenario. The realized Wireless M-BUS setup for indoor testing is shown in Fig. 5, where all the important points are displayed. The "orange circle" represents the Wireless M-BUS data generator acting as a transmitter. The "green locations" stand for the positions, where we placed the receiver device and tested one-by-one all the critical parameters of the communication link.

The list of possible combinations of configured power levels on both communicating sides as well as the average RSSI levels obtained during measurements are shown in Table I. At each location, all combinations of RF levels were performed. Locations L and J represent stairway, so at this point measurements for both surrounding floors were made

[2]Changing the interval of an enabled frame will cause it to be sent immediately again, then further obey the new interval.

TABLE I. SUMMARY OF CONFIGURED RF POWER LEVELS ON BOTH DEVICES (TRANSMITTER AND RECEIVER) TOGETHER WITH AVERAGE OF MEASURED FIELD STRENGTH (RSSI) FOR ALL MEASURED INDOOR LOCATIONS.

TX [dBm]	RX [dBm]	Location															
		A	B	C	D	E	F	G	H	I	J4	J5	J6	K	L4	L5	L6
-30	-30	-124	-121	N	N	N	N	N	-120	-123	N	N	N	N	N	N	N
	-12	-117	-116	N	N	N	N	N	-116	-118	N	N	N	N	N	N	N
	0	-114	-112	N	N	N	N	N	-117	-115	N	-123	N	N	N	N	N
	12	-105	-119	N	N	N	N	N	-124	-121	N	-119	N	N	N	N	N
-12	-30	-110	-105	N	N	N	N	N	-110	-109	N	-116	N	N	N	N	N
	-12	-103	-108	N	N	N	N	N	-118	-112	N	-110	N	N	N	N	N
	0	-107	-112	N	N	N	N	N	-105	-108	N	-114	N	N	N	N	N
	12	-101	-99	N	N	N	N	N	-109	-104	N	-113	N	N	N	N	N
0	-30	-98	-115	-132	N	N	N	N	-103	-101	N	-110	N	-127	N	N	N
	-12	-93	-96	-127	N	N	N	N	-105	-99	N	-114	N	-124	N	N	N
	0	-95	-95	-121	N	N	N	N	-95	-100	N	-107	N	-121	N	N	N
	12	-96	-88	-118	N	N	N	N	-94	-98	N	-102	N	-116	N	N	N
12	-30	-89	-89	-109	-128	-137	N	N	-97	-93	-124	-98	-122	-115	N	-130	N
	-12	-81	-83	-105	-119	-124	N	N	-99	-95	-117	-99	-124	-118	-128	-112	-127
	0	-79	-87	-99	-108	-121	N	N	-92	-98	-113	-95	-116	-108	-114	-116	-116
	12	-67	-75	-101	-112	-118	N	N	-88	-92	-109	-89	-110	-111	-109	-110	-118

at these locations. Following the results in Table I, even the combination of power levels on transmitter and receiver was set to the lowest profile, the Wireless M-BUS data transmission was still possible to establish with no packet loss.

V. CONCLUSIONS AND OUTLOOK

Industry 4.0 holds the promise of increased flexibility, mass customization, improved quality, and enhanced productivity in manufacturing and thus enables companies to cope with various challenges such as increasingly individualized products, shortened lead time to market, and high product quality. So far, much has been said about wireless communication technologies and their implementation within the Industrial IoT or Industry 4.0 landscape.

In this paper, we conducted our research activities related to remote metering scenarios where the Wireless M-BUS acts as the communication protocol used for MTC data transmissions. Wireless M-BUS was first designed to meet the requirements for the automatic reading of electricity, water and gas meters requiring only a low data rate. However, as we enter the IoT era, network designers realize that many industrial and commercial sensing applications also have low data rate characteristic as well as requirements for long battery life, low-cost, long wireless range, and easy-to-install RF modules.

We provide a description of the targeted Wireless M-BUS protocol, its communication modes, data structure, information fields, and their extensions and options for encrypted communication. A vision of the protocol's deployment and utilization in the years to come is given as well. Section III details the primary goal of this work – Java multi-platform application, which can generate Wireless M-BUS data from both graphical and command-line interfaces. It allows for precise protocol data unit specification and is able to send the message definitions in the form of telegrams to the Wireless M-BUS network using supported hardware transceiver. An internal description of the software part is provided including explanations on crucial classes, functionality, auxiliary elements, and comparison with similar existing software. In Section IV, we reveal our field test with the developed hardware platform utilizing the WM-BUS data generator. The tests were performed at Brno University of Technology, Faculty of Electrical Engineering and Communication. The obtained data indicates that created scenario based on WM-BUS communication protocol can handle the data transmissions for the intended area.

Given the description of the Wireless M-BUS communication protocol, based on performed research, laid the basis for the following parts. The software-hardware combination, created as a ready-to-use generator solution represents a powerful option in the area of testing Wireless M-BUS networks.

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