Application for Testing Smart Meters

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Abstract—This paper presents our developed application for smart metering, which we are using to test the interoperability of different smart meters, compatibility with transmission technologies, to measure data volumes, test data security, and also ensure data security through the whole life-cycle of smart meters. The paper concludes with future development and planned features of our application, which is already being used for testing smart metering technologies at the Smart Grid Lab at BUT.

Keywords— DLMS, electricity measuring, smart metering, testing application

1. INTRODUCTION

In today's modern age, more and more elements of everyday life are being connected to the Internet and this brings us to terms like IoT (Internet of Things), smart grids and 5G (5th generation networks). This trend has also reached energy measuring technologies and it is being referred to as smart metering. For this purpose there exist multiple protocols and standards, but the most promising one is the standard DLMS (Device Language Message Specification). One of the biggest advantages of using DLMS is the interoperability between smart meters (in short SMs) from different manufacturers. A disadvantage can be in higher data complexity and also larger overhead data.

According to the Czech Republic legislation, we have a new law (act no. 359/2020 Sb. [1]), it comes into force in 2024, and this law requires from electricity distributors to mount SMs to all customers, whose energy consumption is higher than 6 MWh per year. This means more than 1 million new SMs in the Czech Republic. It also specifies a level of security on SMs. The specified security level is high/secure enough by today's standards, but we need to count with longevity (15+ years) of electricity meters to ensure, that they will be capable to secure all the data in the future with higher security requirements.

1.1. State of the Art

Before deploying new SMs into everyday usage, we need to test all of it's functionalities and also compatibility between meters from multiple manufacturers in the controlled environment. First real world deployment will be mostly selective, and that means using transmission technologies like NB-IoT (NarrowBand) [2], LTE Cat. M1 (Long Term Evolution) or GPRS (General Packet Radio Service). With regards to the high amount of SMs that will be deployed and with these transmission technologies, we need to consider a data volume that will be needed for communication to the SMs. Data volume is directly related to the price for data transfer in relation to the data plans from the mobile network operators and also to the setup of the mobile network to manage high amount of SMs connected to one Base Transceiver Stations. We need to test all desired parameters (e.g., reading data volume, latency, data security, interoperability), but there is no complete solution on the market that could satisfy all requirements. At the moment, there exist only a small number of applications capable of DLMS communication, some are proprietary from SM manufacturers and they can't be used with SMs from different manufacturers. Some applications are free and some can cost up to 60,000 €. Example applications are:

- Gurux – GXDLMSDirector [3],
- OpenMUC – jDLMS [4],
- DLMS Conformance Testing Tool [5].

1.2. Contribution

This paper is focused on introduction of our application (for testing DLMS and related protocols) called DATEL (DLMS Application for Testing Energy Labs). Our solution can be used to test all the mentioned requirements and it can also be expanded to fulfill any new needs in smart metering testing in the future. All measured data can be used for further research in machine learning, threat detection, and other related areas. We can also use it to test new transmission technologies (e.g., NB-IoT, LTE Cat. M1).

2. USED LIBRARIES

DATEL uses the programming language Java 11 (specifically JDK-11.0.5). It looks that the application is quite small, but appearances are deceptive. It uses a handful of libraries, namely:

- Gurux DLMS – DLMS library,
- JavaFX (OpenJFX) – graphical interface,
- Jmetro – modern graphic look,
- JAXB – XML framework for saving configurations.

The most important library is the Gurux DLMS framework. Gurux LTD is a Finnish company which primarily deals with the DLMS specification. Their library is available for most common programming languages like Python, C++, C# and Java. Until recently the Java version of the Gurux library was their most updated version and it contained most elements that DLMS standard specifies. That is why this application is written in Java. Today Gurux puts most of its afford into C# (.Net) version of the library, because that is used in their client application called GXDLMSDirector. Gurux provides all their products under dual licensing [6]. One license is paid and the second one is open-source using GNU GPL v2.

For testing purposes we are using other programs and devices. To have full control over communication we are using the packet capturing software Wireshark. Because most SMs use the RS485 port for communication, we need to use converters to be able to communicate with them directly with DATEL. There are some USB converters, but most of the time, we are using Ethernet to RS485 converters.

3. DLMS TESTING APPLICATION – DATEL

We developed our own application to be able to test DLMS meters from multiple manufacturers to satisfy all requirements from electricity distributors and the Czech Republic legislation. The main application window is shown in Figure 1. The left side represents emulated meters, bridges and added meters. Emulated section can be used with our own server application, that can emulate multiple meters with different configurations on a single device. In this case, you are only specifying the IP address and the port, rest will be configured automatically. The bridges section is used to bridge different type of communication. The last meters section represents real meters, which can be used for testing and all parameters need to be configured manually. That means setting up all DLMS parameters (e.g., client and server address, interface, referencing, authentication, passwords, IP address or serial port, etc.).

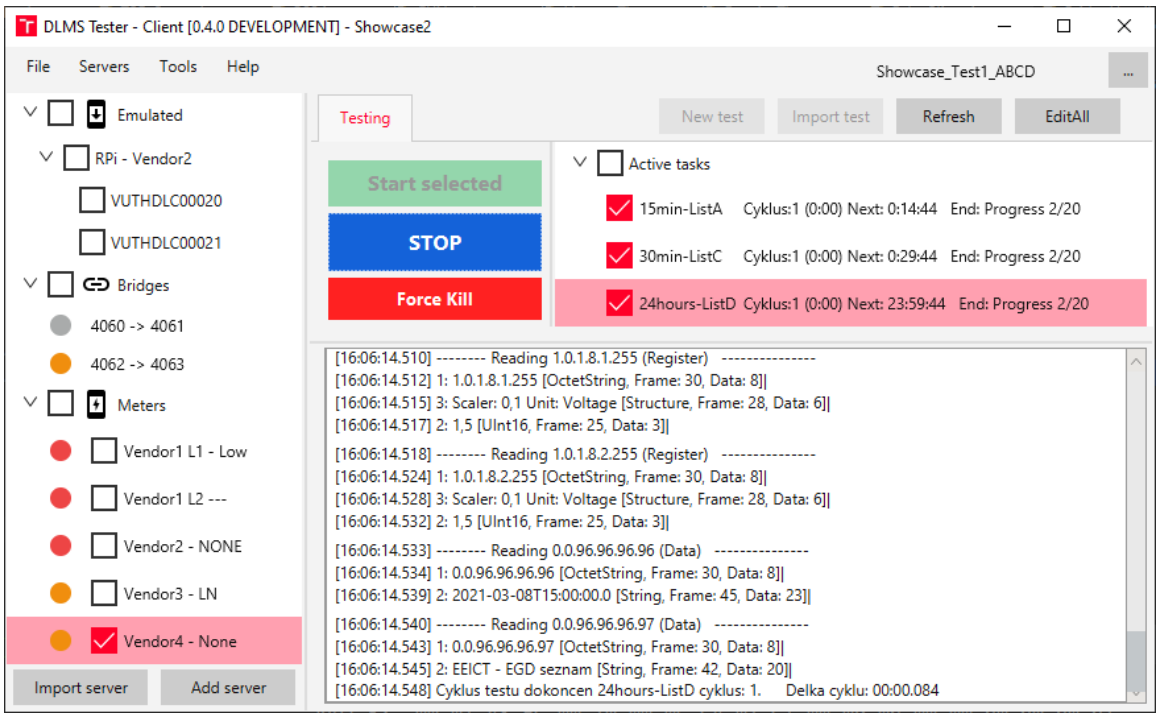

Figure 1: Main application window

The top right part is for testing configuration. The largest portion of this window is filled with the text terminal output. This output contains read values from the test '`24hours-listD`' during testing a meter marked as '`Vendor4 - None`'. All important functionality is described in the next sections.

4. DLMS DATA READING

Manual data reading (DLMS client) enables you to read values directly from the meter. Our manual reading is slightly improved, in comparison to other DLMS applications, in a way, that we can select which attributes we want to read and we can also specify, whether we want to read an object in multiple messages (attribute by attribute) or to read all selected attributes in a list. Another difference is the ability to search in all associated objects. This enables you to find desired objects more easily.

Figure 2 shows the window for manual reading. The object list (1) can be used for selecting objects for reading. All read values are outputted into the console view (4) and to the text fields section (3). This section can be used to write new values to the meter, but it's implementation is very time consuming, because it is necessary to create a new interface for each object type. It can be also used to call object methods (e.g., reconnect on a disconnect control object). Lastly, the top part of this window (2) contains the keep alive function and a stopwatch to keep track on how long the connection to the meter is open.

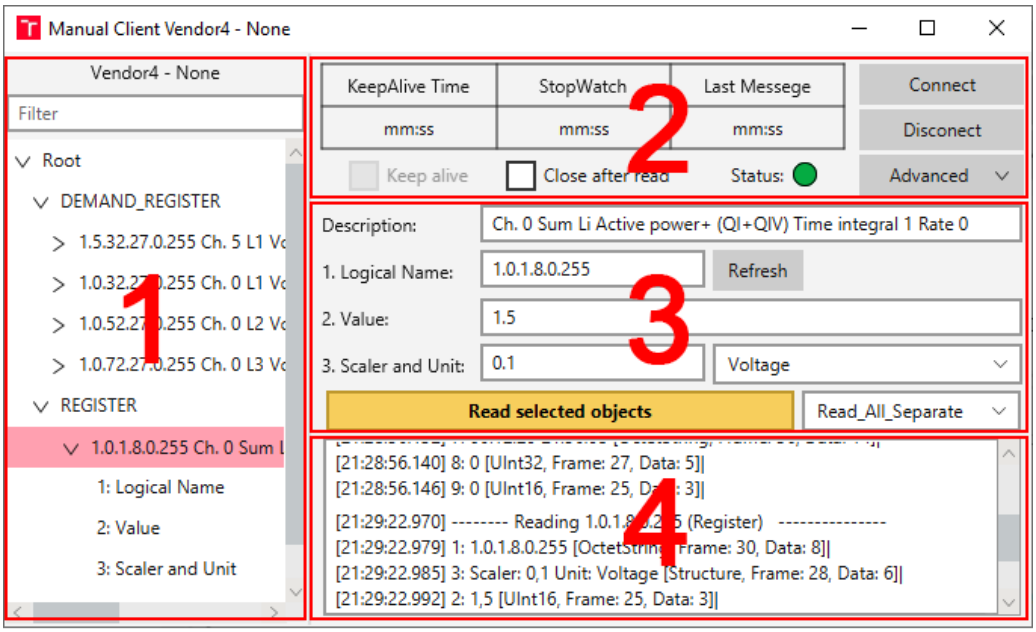

Figure 2: Manual client window

5. SCHEDULED TESTING

The ability to schedule tasks to test meters is the most important part in DATEL. At the moment, we are mostly testing data volumes, that will be needed for remote reading of the meters in real deployment on various transmission technologies, or long-term testing of a technology .

The tester can add multiple tasks and specify all needed parameters like starting time, ending point (specified by time or cycles count), period (time to repeat cycle), wait times, reading type and the most important parameter is selection of all objects, that will be read during one task cycle. Objects can be searched in associated files from a meter or can be written manually into the text input field. After all parameters are filled and confirmed, this new task is added into the main window to the testing list (top right in Figure 1). The tester can change the order and also enable or disable any task. After selecting all desired tasks and meters, the test can be started in the main window by clicking on the '`Start selected`' button. During testing, all specified information is saved into logs. If all running tasks had set ending points, testing will be automatically terminated, otherwise the test needs to be stopped manually.

Test evaluation is the next step after testing. Completed tests logs can be open in our log parser, and this parser will go through all log entries and after that it will print the results (e.g., number of transmitted and received messages, error messages, number of connection losses or it can count transmission delays between transmitted requests and received responses). It can also count the success rate of received

messages. Together with raw data logs we are using software for capturing data packets (e.g. Wireshark) for better error recognition and thorough results. Final results and even raw data can be used for further research e.g. designing wireless technologies specifically designated for smart metering. All captured data and knowledge can be also used for testing new implementations for meter manufacturers or finding deviations in their implementation from the standard.

DATEL is already being used for testing real smart meters in combination with new communication units developed at BUT. In Figure 3 DATEL is reading values from multiple SMs connected to communication units. This setup is used for testing SMs and also for verification of new technologies (e.g. LTE Cat. M1) before deployment to a production environment.

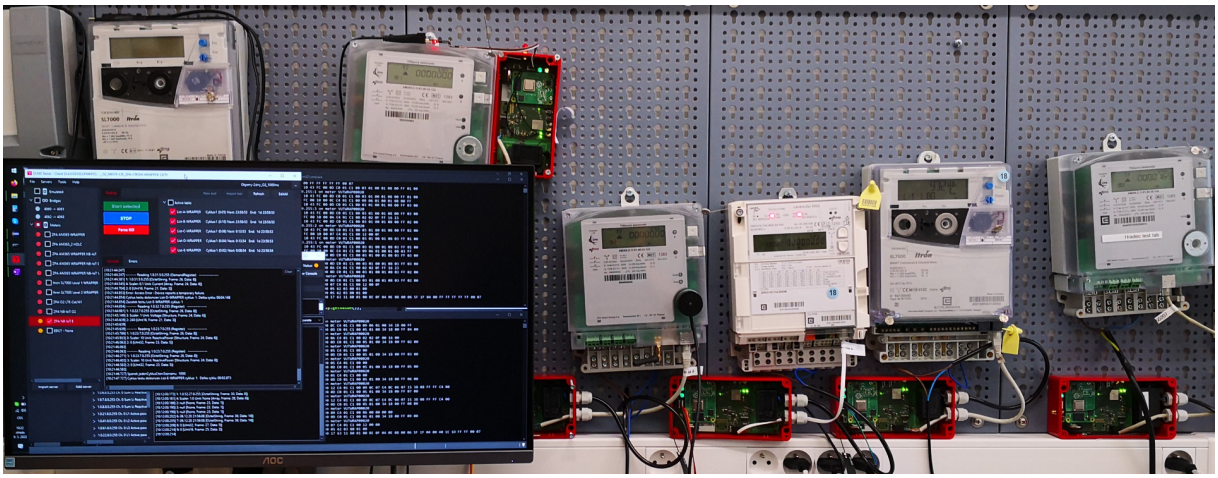

Figure 3: Smart Grid Lab at BUT

6. SECURITY FEATURES

DLMS offers multiple security levels called Security Suites. All suites are using for encryption AES-128 (Advanced Encryption Standard). The Suite 0 uses a pre-shared key and Suites 1 and 2 use key exchange for establishing symmetric keys. Multiple key exchange models (specified in [7]) are supported by the DLMS standard and all are using the ECDH (Eliptic Curve Diffie-Hellman) key exchange algorithm.

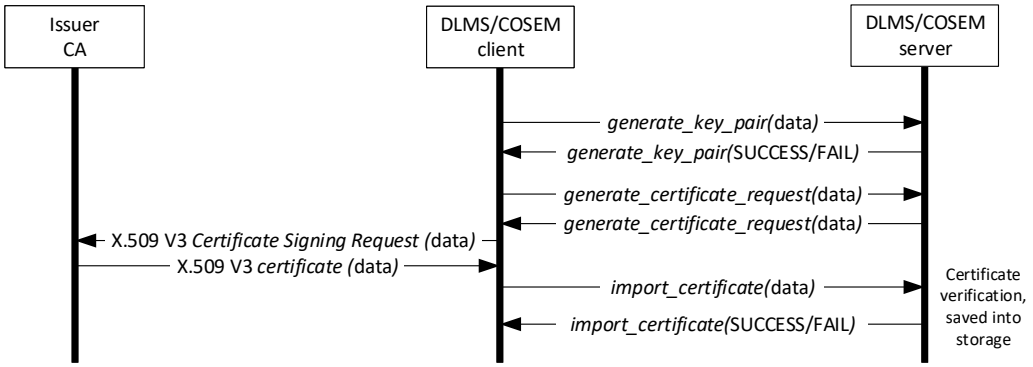

Figure 4: Certificate request and exchange [8]

DLMS Security Suite uses multiple digital certificates for digital signature and key agreement schemes. For this reason, we implemented controls for new certificate generation on client and also on server side. The standardized principle for creating new certificates on the server side is shown in Figure 4. This principle can be controlled in DATEL with only one difference: for testing purposes it is not necessary to have a real CA (Certificate Authority). This part is directly implemented in our application. In fact, our client side also works as a certificate authority and it can be used to sign new certificates. We want to fully implement DLMS Security Suite 1 and 2, because with securing data in this way, there is a possibility to lower overhead data capacity in comparison to tunneling DLMS data in TLS tunnels. Also with working Suite 1 and 2 we can possibly help and test security implementation on new SMs from manufacturers to ensure their solution will work with other SMs and reading centrals in production environment.

7. CONCLUSION

This paper presents the development of our DLMS testing application – DATEL, that can be used to test all required parameters from electricity distributors and also from the Czech Republic legislation. DATEL uses Java 11 and the Gurux DLMS library. Compared to other applications, we can specify custom testing (periodically read values from SM), we can read all attributes separately, etc.

DATEL contains small adjustments in comparison to Gurux's flag software. It is possible to open multiple windows to edit multiple meters at once. This can help with configuration of multiple meters, connecting to the same meter with different access levels, or when you are debugging why this communication media is not working when the same meter was working on different media. DATEL is already being used for testing SMs and other related technologies, and it can help with future development of technologies more suited for energy measurement or for analyzing new smart meters to ensure interoperability.

As a future work, we work on the security side of DLMS with Security Suites and even with tunneling this communication inside other more secure data channels.

8. FUTURE WORK

DATEL already implements some important functionalities, but we can still add new functions. At the moment, the most important future task is the implementation of key exchange mechanisms into the DLMS library. In that way, we can finally have fully working Security Suites with **key exchange** mechanisms. The most difficult part is to have working key exchange inside DLMS messaging. We are currently preparing other alternatives for protecting DLMS data, and the most obvious solution is using tunneling of DLMS communication in more secure and flexible technologies e.g. **TLS tunnels** (Transport Layer Security). There are also some requests from electricity distribution companies to look into TLS tunneling. With this it is possible to setup security more precisely for this use case and also be more flexible than waiting for standardization of a new Security Suite.

Alongside, we are planning to **rework logging** part of the application in a way, that we can use raw logs directly in other programs (mainly table processing) to visualise data more easily in charts and tables. To be able to do that, the main log needs to be formatted in a slightly different way or we can make more logs each containing various important data. Together with new logging, we plan to use **TShark** and be able to launch packet capturing automatically together with testing.

Next planned feature is small modification of scheduling tasks in testing. Now all tasks are executed together at specified times and cycle periods. In some cases we need to execute task B after task A has completed all of its cycles. This can be configured, but it is very difficult as of now. Another small tweak is the ability to add some tasks to only some meters. Last change in testing is the capability of connecting to multiple meters at the same time.

Another planned feature is a **DLMS server**, which can be used directly from DATEL and it can be configured only by cloning data from real meters. This requires some verification process of downloaded data, because every meter usually has some customized part, which does not behave according to the specification or some values are not accessible.

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