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Virtual DLMS Meter as a Service

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Abstract

For proper management of the increasing energy consumption in today's world; there is a need for the development of smart power systems. Advanced metering infrastructure is an integral component of the smart grid. For the automation of substation level energy analysis, smart meters are necessary which utilize Device Language Message Specification (DLMS)/ Companion Specification for Energy Metering (COSEM) protocols as the base standard for architecture, functionalities and communication. For the proper growth of the smart infrastructure for the power system, the importance of meter data is increasing. In this paper, a virtual meter is developed to mimic the meter and to make the users understand the behaviour of the meter and the DLMS specifications without the necessity of having the meter itself.

Keywords: Advanced Grid Metering Infrastructure, DLMS-COSEM, Power System, Sub-Station Interface Energy Meters

1. Introduction

1.1 General

One of the essential elements of a smart grid is Advanced Grid Metering Infrastructure (AGMI). Availability Based Tariff (ABT) meters, which are installed at the sub-station interface points are used in grid metering to calculate the energy flow. At the interface point, the grid metering module assists in deciphering energy flows coming from the smart meter. Meter data is one of the important data sources that can be used for a variety of grid management tasks, including load forecasting, forecasting renewable energy, managing and preventing outages, online energy accounting and transmission loss calculations, dispatching energy efficiently, settling schedule deviations, and ensuring reliable, dispute-free billing, accounting, and settlement of energy transactions[1,2].

The purpose of the DLMS simulator is to help in preparing the development and testing environment without having a huge number of real meters. Utilities, System integrators, and Head End System (HES) suppliers can analyse the HES/ Meter Data Management Software (MDMS) at the vendor selection or integration stage itself for their AMI projects and identify the problems before initiating the meter deployment, and later compare and contrast various HES/ MDMS systems. All the recorded data from measurement points on the field is managed and stored for the long term by MDMS. Raw data is stored by MDMS before the billing and report process. After the storage, this data is corrected, cleaned and processed. Several smart metering use scenarios may be simulated to help end users make decisions that would be difficult or impossible with the operational meters. HES manages the communication drivers, measurement drivers as well as network getaways. The simulator may be used by HES/MDMS developers for internal validation and performance benchmarking, as well as for showcasing the capabilities and scalability of their HES/MDMS[3-5].

So the deployment of the smart grid requires the use of safe and trustworthy tamper-resistant meter data exchange. Automation of the power system is vital for the dependable and secure functioning of the power system. AGMI, a component of automation, is being used in the power system. Energy meters with smart interfaces, Data Concentrator Units (DCU) for collecting and sending meter data, redundant communication networks for high meter data availability, a central Data Acquisition System (CDCS), and grid management software make up the AGMI[6].

DCU is a communication device, which collects data from sub-station interface energy meters and sends it to the control centre, similarly, it will accept control commands from the control centre and pass those commands to sub-station energy meters. DCU transfers the collected data to the control centre in dual communication modes for high data availability. DCUs are the DLMS-based clients for the

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data aggregation and control of meter parameters. DCU provides data to the control centre after regularly requesting it from the meter. Additionally, it is in charge of delivering the requests from the control centre for any modification of meter characteristics, including changes to the billing cycle, time zone, load profile, etc.

Virtual DLMS meters can also be used for academic, training, research and development purposes in the area of AGMI and AGMI security solutions. It can also be used in the testing of HES and MDMS solutions. These simulators contribute to the development of accurate energy measurement methods, enhanced energy management practices, and informed decision-making, supporting the overall advancement of the energy sector. This environment would also be useful for the testing of DLMS client/server working and protocol level analysis[7,8].

1.2 Motivation of the Present Work

Smart meters have become an integral part of the AGMI system. To make the best use of the metering service, it needs to be made available to the various HES and MDMS systems[9]. To analyze, there is a need for multiple meters which may not be feasible to be present physically. There is a need for an environment where HES and MDMS systems could plan for the training of the meter data and analyze the behaviour of the meters. Virtual energy meter simulators fulfil the need for testing, training, system optimization, data analysis, and cost/resource efficiency in the energy sector. They enable the validation of energy metering systems, provide a platform for training and education, facilitate system optimization and decision-making processes, and offer a cost-effective and environmentally friendly alternative to physical meters in the testing environment.

1.3 Contribution of this work

The paper's contribution proposes developing a meter simulator which is compliant with the DLMS standards. In brief, the major works carried out here may be summarized as:

(i) Development of a meter simulator which would support multiple meters and clients at a time.

(ii) The simulator would be extended to support the logical name both with and without ciphering.

(iii) The simulator will have the provision of communication via Ethernet.

1.4 Paper Orientation

After a brief introduction in this section, Section 2 explains the metering standards, including the authentication mechanisms and security suites, followed by the requirement for a meter simulator in Section 3. Section 4 describes the architecture of DLMS based meter simulator. Finally, the paper is concluded in Section 5.

2. Metering Standard-DLMS DLMS/COSEM

Metering Standard-DLMS DLMS/COSEM is a globally accepted standard for energy metering[3,4]. Companion Specification for Energy Metering (COSEM) specifies meter functionalities in the form of interface classes and methods. DLMS specifies the messages and transportation details of the data. In the DLMS-COSEM Communications Application Association (AA), the establishment is the first phase of communication. After the successful establishment of AA, meter data exchange takes place. Application release is the last phase of the communication which happens after the completion of the meter data exchange. Previous research has been done in this area such as[10-13] which mentioned a client/server model of the DLMS/COSEM architecture with HDLC as the data-link layer and parameter identification of energy meters along with some underlying issues.

2.1 DLMS Authentication Mechanisms

The authentication process occurs during the AA phase. In DLMS there are three types of authentication mechanisms, *i.e.,*

1) No security (Lowest Level Security) authentication
2) Low-Level Security (LLS) authentication (based on the secret key)
3) High-Level Security (HLS) authentication (4 pass – Mutual authentication)

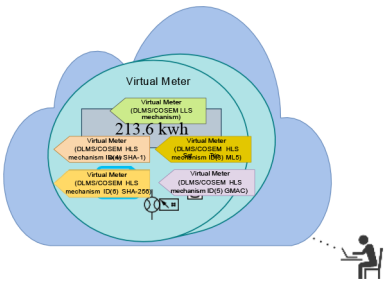

Figure 1. Virtual meters as a service architecture.

In HLS, the following are the major security IDs which have been put under consideration for this work.

1) Mechanism ID(3) – HLS MD5
2) Mechanism ID(4) – HLS SHA-1
3) Mechanism ID(5) – HLS GMAC
4) Mechanism ID(6) – HLS SHA-256

The meter developed could even be provided as a cloud service to the users, who want to experiment or simulate any test cases concerning their requirement in the area of the work as depicted in Figure 1.

3. Requirements of Virtual DLMS Meter

The virtual DLMS meter simulator is primarily needed by the developers and testers to have an environment where they can plan for the training of the meter data and analyze the behaviour of the meters. There are many factors which are associated with the meter simulation; such as encryption, packet level understanding and the change of the meter parameters. The simulator also works on the encryption of the data from the meters and protection of the data from getting attacked. There is a high level of encryption in the client as well as the server side; which is known only to the respective users. Thus, ensuring a high level of security as defined in the previous section.

The DLMS Meter Simulator allows to simulation of DLMS meters and enables the utilities, system integrators and HES manufacturers to run use cases and evaluate various key performance indicators including the data acquisition time, communication failure rate, etc. It can simulate negative and very large/boundary values as well as data gaps in meters to verify HES/MDMS validation functions. Various practical communication issues such as network delays, meter going offline, etc. can be simulated to assess the impact on the overall data acquisition time.

For the applications involving the use of DCUs for establishing transparent communication, which follows the DLMS standard, there is a requirement of having a smart metering infrastructure to test and do the validation. This DLMS meter simulator could be quite useful in these cases.

This simulator enables the developers and testers to overcome the unavailability of real meters during the development and testing phase of any project. This tool allows us to perform DLMS operations that are not possible using real meters such as simulating large/boundary values, negative conditions, timeouts, and different types of security. It would reduce the development time for meters, meter interface cards, data concentrators and HES. The basic methodology behind the meter is depicted in Figure 2.

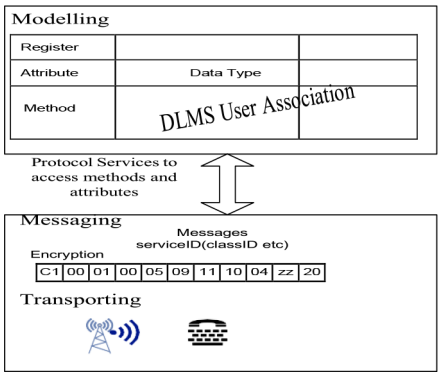

Figure 2. Methodology behind the meter.

4. Virtual DLMS Meter Simulator

Meter Simulator is a software tool used for testing and development purposes in the field of smart metering. DLMS is a standard communication protocol used in the energy sector for exchanging data between utility meters and data concentrators, enabling remote meter reading, control, and management.

The DLMS Virtual Meter Simulator simulates the behaviour of a physical meter equipped with DLMS protocol capabilities in a virtual environment. It allows developers, integrators, and testers to emulate the communication between a meter and a data concentrator or other components of a smart grid system. The DLMS-SIM software toolkit includes a DLMS meter communication protocol simulator and data simulator, which assist in simulating the realistic payload packetization process. It helps the user understand and analyse meter data exchange procedures and security features through the DLMS/COSEM communications.

The data simulator mimics the properties of the meter to generate the data for 35 days. Users can select and configure 5-minute or 15-minute data time blocks as per their requirements. Interactive GUI helps in configuring the meter/server and client, displaying the requests and responses of the clients and servers. DLMS-SIM can be used for testing, demonstration, understanding, and implementation of AGMI communications and solutions. It also helps in preparing a testing environment having multiple meter simulators and client simulators.

DLMS-SIM Server helps to simulate multiple DLMS/COSEM protocol-compliant servers (meters) simultaneously on different port numbers. Each meter simulator supports multiple clients for data communications simultaneously.

DLMS-SIM tool kit consists of both a meter and a client simulator. It helps the user in understanding and analyzing the DLMS Packet. Interactive GUI helps in configuring the meter and client, displaying the requests and responses from the client and server.

DLMS-SIM can be used for testing, demonstration and implementation of AGMI solutions. It helps in preparing a testing environment having multiple meter simulators and client simulators. This simulator can also be used for the study of communication vulnerabilities as it is developed as per the DLMS/COSEM standard and associated security features in the standards.

5. DLMS Meter Architecture

5.1 DLMS-SIM Profiles

DLMS-SIM can provide Instantaneous and Load profiles of data. The values are simulated and provided to the client as per DLMS-COSEM protocol. DLMS-SIM also allows the user to configure the block of data required, *i.e.,* it can simulate and provide the data of load profile for 5-minute periods for a maximum duration of 35 days.

5.2 DLMS-SIM Services

DLMS-SIM supports the GET service of DLMS-COSEM to extract data from the meter/server. The GET services can be invoked by a data extraction request from the client. The GET request can be made in different modes like Normal, List and block transfer. DLMS-SIM supports all the modes of GET service provided by DLMS-COSEM.

5.3 Packet Monitoring and Analysis

The packet monitoring and analysis window contains all request packets from clients, corresponding request responses, detailed descriptions, and their origin details (IP, Port). Communication logs can be downloaded from the packet monitoring window for further detailed offline analysis. The downloaded communication log file is in JSON format. The packet monitoring window for the DLMS SIM tool kit is given in Figure 3.

5.4 Packet Description and Analysis

The packet description and analysis window contains all requests from the client and response packets from the meter simulator. The fields like wrapper, application contest, encryption status, Client system title, association type, initialization request and association status are available in the corresponding request- responses are described in Figure 4. It indicates the meaning of every byte that it represents, which helps the user to understand the protocol.

5.5 Meter Configuration

The major features of the DLMS meter architecture include the capability of simulating multiple meters at a time with each meter supporting multiple clients. The virtual meter supports Logical names with and without ciphering and Supports all association types, *i.e.,* Lowest, LLS, HLS(3(MD5), 4(SHA1), 5(GMAC), 6(SHA256)). It keeps up both the Get request (normal, with-list, block transfer) and Action request. All ciphering modes, *i.e.,* only authentication, only encryption and authenticated encryption, are possible to be executed. The communication is based on Ethernet (IP-based) and this virtual meter can request Object Identification System (OBIS) codes of choice.

DLMS-SIM server simulator helps to simulate multiple meters instances. The virtual meter simulator developed tested for five meters but can be scaled up to 50,000 in one server based on deployment server configuration. Each meter is tested with ten clients but it is scaled up as per the requirements. The simulator was designed not only to cater to the substation level ABT meters but also to DLMS-based household meters. The reference figure can be found in Figure 5. Each meter simulator can be configured with various parameters like Meter listening port number, the System title, LLS password, HLS password, Authentication key, Block cipher key, Load profile – time interval selection (5 mins/15 mins), and Load profile supporting days selection (1 day to 35 days). The features of the DLMS simulator are listed in Figure 6.

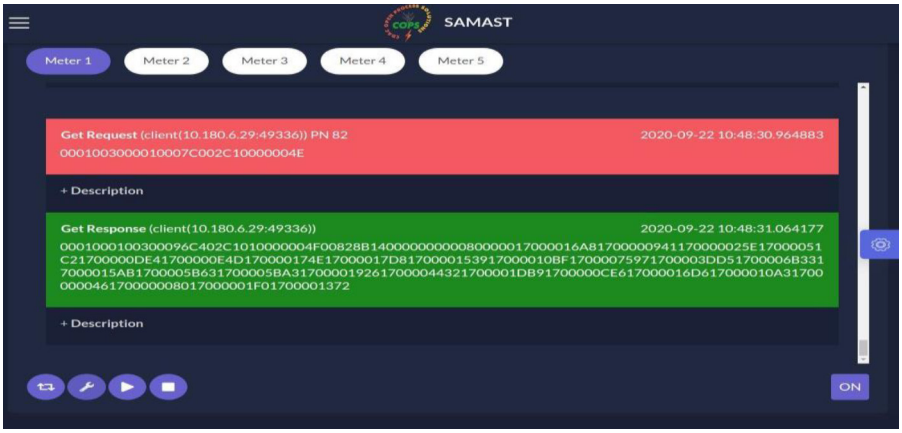

Figure 3. Packet monitoring and analysis.


```
{
"1": {
"client(10.180.6.13:45584)": {
"Time_Req": "2023-12-08 10:12:59.071760",
"Association Request":
"0001002000010038603 6A10906076085740508010 1A60A04084D4D4D0000BC614E8A0207808B07608574050
80201AC0A8008414243443030303 1BE10040E0100000065F1F040060FEDFFFFF",
"Des_Req": {
"wrapper": "0001002000010038",
"Applicaton_Contest": "60857405080101",
"Ini_encryption_status": "False",
"Client_sys_title": "4D4D4D0000BC614E",
"Association_Type": "Low_Level_Security",
"Association_Password": "4142434430303031",
"Initialisation_Request": "01000000065F1F040060FEDFFFFF",
"Association_Status": "Success"
},
"Des_Res": {
"Applicaton_Contest": "A109060760857405080101",
"Applicaton_Result": "A203020100",
"Meter_Title": "A40A04084D4D4D0000BC614E",
"Initialisation_Response": "BE10040E0800065F1F040000501F01F40007",
"wrapper": "0001000100200037"
},
"Time_Res": "2023-12-08 10:12:59.081285",
"Association Response":
"0001000100200037613 5A109060760857405080101A203020100A305A103020100A40A04084D4D4D0000BC
614EBE10040E0800065F1F040000501F01F40007"
}
},
```


Figure 4. **Packet description and analysis.**

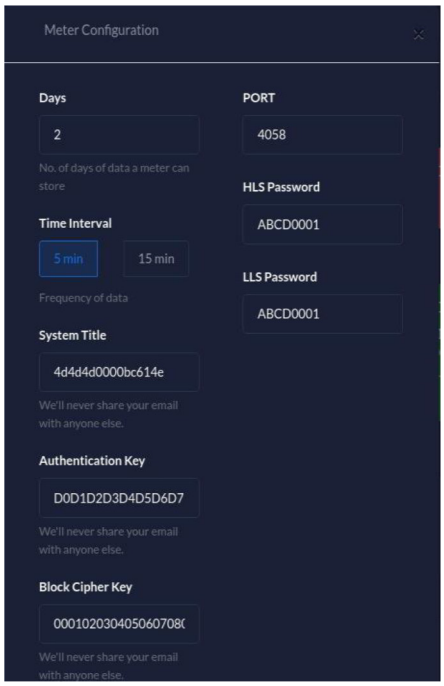

Figure 5. Meter configuration.

Features	COPS DLMS SIM
Communication profile	TCP-IP
Application context	Logical Name without ciphering Logical Name with ciphering
Authentication mechanisms	No Authentication Low Level Authentication High Level Authentication with Mechanism ID – 3,4,5,6
Multiple meter simulation	Presently provided with 10 Meters. An extended version can be provided which supports millions of meters based on requirements
Multiple clients Support	YES - Presently provided with 10 clients. An extended version can be provided which supports millions of meters based on requirements
Profiles	Instantaneous and Load Profiles.
Ciphering	Security Suite - 0 Supports all ciphering modes. -Authentication. -Encryption -Authenticated Encryption.
Configuration	Allows changes in Security keys.
Communication log	Comm. log can be downloaded in JSON file

Figure 6. **Features of DLMS simulator.**

6. DLMS SIM Exchange Mechanism

After successful application association, meter data message exchange takes place. DLMS-SIM supports the following unprotected/protected message data exchange formats as per DLMS/COSEM standard.

(i) Unprotected/Plain text message data exchange
(ii) Protected/cipher text message data exchange
  (a) Authentication only message data exchange
  (b) Encryption only message data exchange
  (c) Authenticated Encryption message data exchange.

6.1 Application

(i) For testing and analyzing the working of DCUs.
(ii) Understanding the meter communication fields.

(iii) Training in the field of AMR.
(iv) Understanding of DLMS-COSEM Protocol.

7. Conclusion

In this paper, the role of importance of DLMS standards for meters is mentioned, followed by the importance of the meter simulator in today's research. The meter simulator discussed in this paper allows a user to connect to the meter virtually, rendering it ease of use. The user-friendly nature of the simulator helps users to readily simulate real instances for carrying out the studies. It allows a researcher to connect to multiple meter instances for carrying out the analysis. The user can also adopt different configurations for different meters at a time, making the simulator adaptable and convenient for various kinds of analyses. This also supports heterogeneity within the same protocol. It helps HES manufacturers to run use cases and evaluate various key performance indicators. It becomes a useful simulator helping meter providers, and more generally all actors, to develop smart equipment. It is an entirely developed platform, to be integrated into the target hardware and can integrate communication modules, objects, classes, and much more. This service is the master key to implementing reliable and cost-efficient smart equipment in a reasonable time. The virtual DLMS simulator can be extended to support the HLS encryption ECDSA in the upcoming versions and also can be extended to support millions of meters on the server.

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