Efficient Data Transfer Mechanism for DLMS/COSEM Enabled Smart Energy Metering Platform

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Abstract

We report our implementation of DLMS/COSEM (Device Language Message Specification/Companion Specification for Energy Metering) enabled advanced smart metering data collection using our in-house developed data-driven multivariate data pruning technique. Aiming at near real-time smart metering data collection, a working model of a smart energy meter with a data pruning subsystem is developed and incorporated with the data pruning and communication module. The implementation of DLMS/COSEM service layer enables standard pull-based data collection from multiple meters that are connected with a commercial head-end system. Our implementation enables to fetch smart meter readings from multiple meters with significantly reduced data footprint. Our empirical results demonstrate that, dynamic data pruning capability reduces the number of samples by nearly 85%. The bandwidth saving increases with the increasing batch size, by accounting for all protocol overheads the end-to-end communication bandwidth saving is up to 85%. The DLMS overhead is negligible for larger batch size.

Keywords: Smart energy meter, DLMS/COSEM, OBIS (Object Identification System), smart data pruning

1 Introduction

Smart meters are aimed at monitoring household/industrial power consumption data collection at remotely located data cloud servers without any human intervention. Besides customer billing, fine granular sampling of power consumption profile and periodic collection of data enables the utility provider to do power grid load monitoring, redistribution, etc. Further, these fine granular data are useful for appliance health monitoring and diagnosis, remote control of user comfort, etc. However, collecting such fine granular data from many millions of meters and communicating to the storage clouds pose significant challenge in terms of stable local access connectivity to a large number of meters, communication bandwidth, storage, and managing the data for data analytics. Therefore, in practice, the smart metering features are far from being utilized to its full potential; they are used merely to collect the monthly billing data [1].

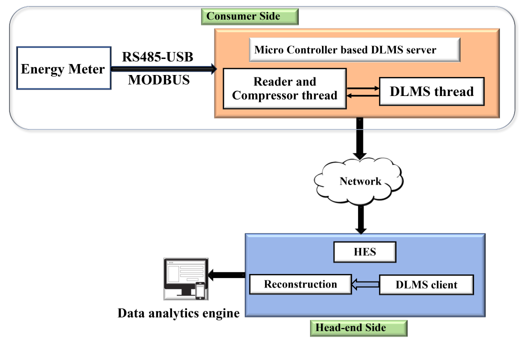


Figure 1. System model of the DLMS/COSEM compliant energy meter with data pruning implementation.

As the study in [1] indicated, efficient means of near real-time data collection is of tremendous interest. In [2], dynamic pruning of smart meter data before its transmission from the end node was proposed and significant resource saving was reported. Subsequently, the work in [3] demonstrated the basic implementation of the smart data pruning and transmission on embedded programming board as well as on specialized microcontroller. However, this basic implementation did not look into the multiaccess challenges. As a result, the implementation in [3] is not practically suitable for commercial metering purpose.

DLMS/COSEM (Device Language Message Specification/ Companion Specification for Energy Metering) is a service layer protocol standardized to enable a smart meter communicate with a commercial head-end system (HES). The three key components which makes DLMS protocol popular are object oriented data modelling, OBIS codes, media specific communication profile. COSEM objects [4] are used in combinations, to model register reading, tariff and billing schemes or load management. OBIS (object identification system) codes are used for identification of meter parameter as well as abstract data. The services provided by DLMS for mapping the data model to protocol data units, transportation of message through a specified communication channel is mentioned in the green book [5]. DLMS/COSEM specifications for a sequence of packet transfers between the meter and HES utilizing the ZigBee communication protocol are reported in [6]. This implementation also enables the

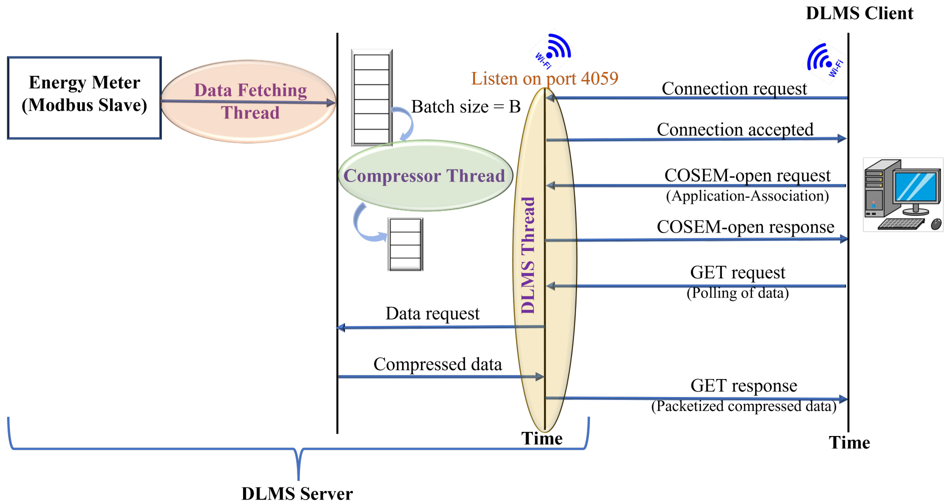


Figure 2. Flow diagram of DLMS based exchange protocol.

HES for catering to more than one smart meters. However, although the DLMS/COSEM protocol has been introduced into the metering system for standardization purposes, none of the studies have implemented the data trimming at the meters for bandwidth saving and decreased complexity of reconstruction at the HES via the DLMS protocol.

To this end, there are two-fold problems that are required to be tackled. (1) Mere incorporation of DLMS service layer and transmission of the meter data continue to pose the challenge of network bandwidth overload, and as a result the advantage of high rate sampling capability of the modern meters are not useful. (2) Integration of DLMS protocol on top of the dynamic data pruning requires a fresh attempt, as the open source DLMS implementation codes need to be customized along with the dynamic data pruning algorithm.

The current work is aimed at filling the gap of integration of commercially available DLMS protocol and incorporation of novel data pruning algorithm, thereby enabling the automated metering features to be fully used without requiring to overload the communication and storage systems. The major effort has been customizing the DLMS implementation in a small memory footprint microcontroller. Subsequently, integration of data pruning and wireless multiaccess connectivity for data collection by the HES are taken up. This short paper delineates how the implementation challenges have been addressed, along with capturing the net end-to-end resource saving benefits through some preliminary results.

2 Implementation of DLMS/COSEM Enabled Smart Energy Meter

2.1 System Model

An overview of the system model is shown in Fig. 1. The system model is divided into two main modules a) server and b) client. The server side consists of a basic energy meter and an external processing node, which collects data from the meter, applies the pruning algorithm and sends the pruned data through DLMS protocol. At the client side, the head end system (HES) receives the compressed data. The HES is programmed with a reconstruction algorithm to reconstruct the actual data from the pruned data.

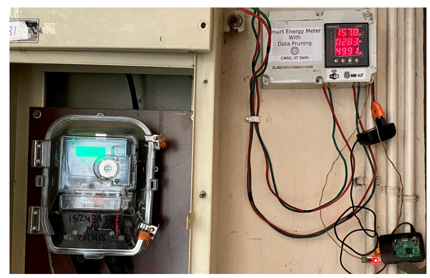


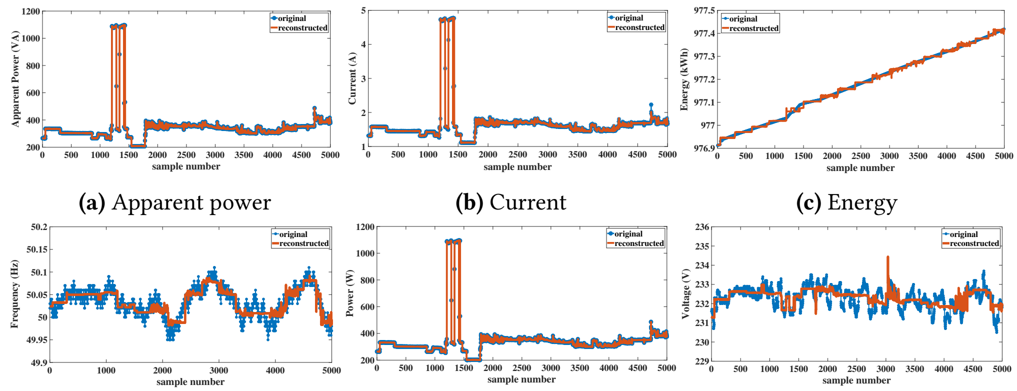
Figure 3. Experimental setup.

A commercially available basic electrical meter Enersol MFR 2810 is used to collect the electrical parameters which is stored in various registers. A Raspberry-Pi3 board is used to fetch the data from the meter over an RS485-to-USB port using modbus protocol. The board is programmed as a DLMS/COSEM server, which is also equipped with pruning algorithm. In response to a pull request from client, the server sends the compressed and packetized data over WiFi.

As shown is Fig. 2, DLMS server listens on port 4059. On initiation of request by client, a connection to the server is established. Subsequently, the client makes an application-association request (COSEM-OPEN) with information about application context name, security mechanism, and details about application protocol data unit (APDU). On receiving acknowledgement from the server, the client can poll the server anytime for data through a COSEM-GET request. On receiving the COSEM-GET request, the server prunes and packetizes the data to send it over the wireless network.

Table 1. Reconstruction error of the parameters

Parameters	Apparent Power	Current	Energy	Frequency	Power	Power factor	Voltage	Average
Normalized root mean square error	0.0621	0.354	0.000717	0.0368	0.0627	0.0656	0.1762	0.1083



(a) Apparent power **(b)** Current **(c)** Energy

(d) Frequency **(e)** Power **(f)** Voltage

Figure 4. The actual and reconstructed samples of the significant parameters.

2.2 Adaptive Multivariate Data Compression

The energy meters collect multiple parameters, such as, voltage, current, energy, power, frequency, etc. at a high sampling rate, e.g, 1 sample/Sec over a batch size of 300 samples for each parameter. Transmitting such a large batch of samples to the HES requires large communication bandwidth and energy. An adaptive multivariate data compression (AMDC) algorithm, presented in [2], is applied to a batch of data to optimize the bandwidth usage. Each column represents a window of samples for a single parameter. The algorithm initially applies Principal Component Analysis (PCA) on this batch of data to reduce the dimensionality of the data through singular value decomposition. The new data matrix contains only the significant features of the original data. In the next step, compressive sensing is applied on each column of the reduced data matrix to further compress the time series of samples. The compressed dataset, with additional information required to reconstruct the original signal, is transmitted to the client as a batch. The AMDC algorithm is programmed on the microcontroller based processing node which is connected to the meter to collect samples and the reconstruction algorithm is executed in the HES.

3 Experimental Results and Conclusion

The data are collected from the meter at 1 sec sampling interval and a batch size of 300 sec, using the experimental setup shown in Fig. 3. Seven electrical parameters, viz. apparent power, current, energy, frequency, power, power factor voltage are collected for a single phase connection. At every 5 min, the DLMS client sends a poll request to the DLMS server. The server compresses the recent batch of data (which is a 300×7 matrix) and transmits over wireless link. The reconstruction error of all the parameters are listed in Table 1. The actual and reconstructed samples are compared in Fig. 4. It has been observed that the volume of data communicated is reduces by 85%. Thus, the memory requirement to store the data in the HES also reduced by 85%. The overall bandwidth saving, achieved by sending the pruned data is 85%.

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