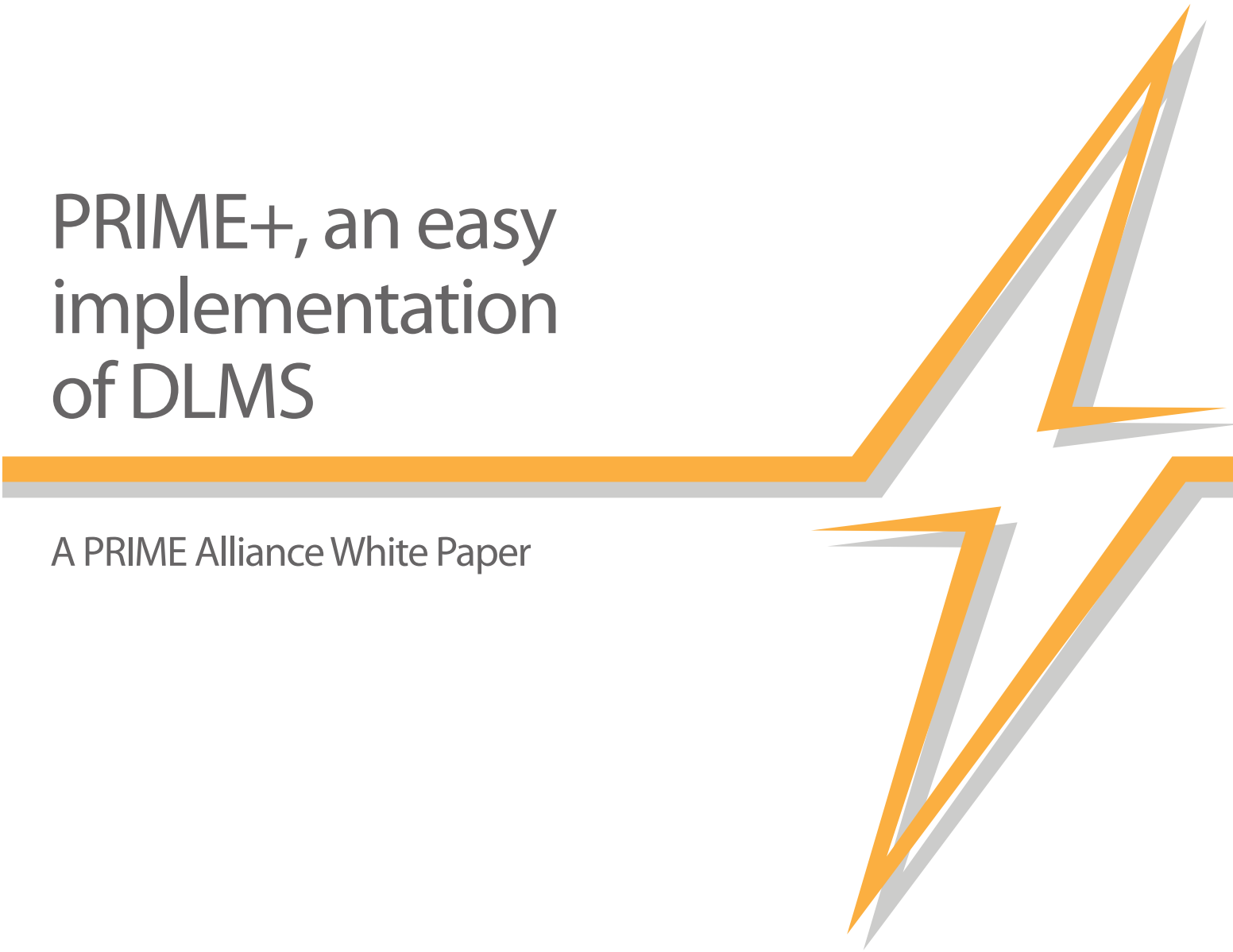
PRIME ALLIANCE®

PRIME+, an easy implementation of DLMS



A PRIME Alliance White Paper

PRIME Alliance AISBL
Avenue Marnix 30, 1000 Brussels (Belgium)
VAT BE 0898.094.492
www.prime-alliance.org

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ABSTRACT

PRIME (PoweRline Intelligent Metering Evolution) is a mature, consolidated, and worldwide Power Line Communications (PLC) standard (ITU-T G.9904) for Advanced Metering, Grid Control and Asset Monitoring applications, promoted by the PRIME Alliance, which meets the objective to establish a set of open international PLC standards.

To date, 32 utilities and associations are using PRIME worldwide. The communication protocol over the electrical cables has been a successful solution for distribution companies due to their capability to control the media and deploy smart grid services in low voltage with limited investments. Compliance with PRIME ensures interoperability among different manufacturers at the communication level in a reliable and efficient way. However, when it comes to smart metering, full interoperability among meters shall be ensured both at communications layers as well as at application layers.

Meters implementing PRIME standard normally use DLMS/COSEM protocol (IEC 62056) at the application layer. The DLMS/COSEM protocol specifications are maintained by the DLMS UA and need to be detailed according to the requirements of each implementation in order to ensure interoperability at the data protocol level; this is, a specific user profile must be defined. This definition of the data protocol profile has traditionally been made by the utilities themselves or by meter manufacturers. However, the definition of the profile implies a deep technical knowledge of the DLMS/COSEM protocol. The absence of this knowledge creates unnecessary risk for companies that want to deploy smart metering systems.

With the objective to simplify these processes for utilities wanting to deploy PRIME for smart metering, the PRIME Alliance has decided to create a generic DLMS profile named PRIME+. As each country or user may have different requirements, functionalities or country-specific regulations, the PRIME+ profile still needs additional definition to adapt it to the requirements of each user. Hence, PRIME Alliance has also developed a questionnaire to collect information allowing to narrow down the generic profile to specific requirements without the need for the user to have knowledge of the DLMS /COSEM protocol. With the help of the questionnaire, users will easily obtain their own User Profile based on PRIME+ Companion Profile, suitable to their requirements, while, at the same time, ensuring the advantages of having a standard solution. With this specific user profile, the applicable tests of the corresponding Test Book, also defined by the PRIME Alliance, can be adjusted and the certification process can be applied.

INTRODUCTION

EVOLUTION OF THE ELECTRICAL NETWORKS

Utilities have traditionally led the evolution of electrical networks, designing and specifying all the equipment that made up these networks. On many occasions, this evolution required particular solutions or adaptations that were shaping the different electrical architectures, topologies and solutions observed today in different countries.

In this evolution, it has always been a principal objective of the electricity companies to standardise solutions and be able to choose between multiple providers while ensuring a high level of quality and reliability.

In the framework of smart grids that began to be designed at the beginning of the 21st century, standardisation has continuously been a crucial objective. In the AMI (Advanced Metering Infrastructure) systems, for instance, this standardisation has meant an evolutionary leap at all levels, having national regulations require the development of functionalities, ensuring quality of service and cybersecurity, and also adapting the product standards to the specifications of each electrical company. In fact, this encourages the product to become more complex while seeking interoperability between manufacturers.

In addition, the standardisation of communications and data protocols are key pieces in this scenario, and the challenges are enormous. In the 1990s, telecommunication companies were confronted with a similar challenge when creating mobile phone networks. The obstacles that had to be overcome to guarantee interoperability between different manufacturers are still remembered today.

In the communication standards of the field of smart grids, both the PRIME Alliance and other alternative associations have developed solutions that safeguard interoperability, and PRIME devices from different manufacturers have demonstrated it through deployments in more than 30 companies around the world.

INTEROPERABILITY AT THE DATA LEVEL

To achieve true end-to-end interoperability beyond the communication layers, data level interoperability must also exist. This means that the different devices in the smart metering architecture have to store the data with the same structure and communicate it in a standardised manner, regardless of the manufacturer. Yet, one additional challenge of electric meters' data is that requirements differ from country to country or company to company. On the one hand, they differentiate because each country's regulator or company establishes different levels of quality, different storage needs, different levels of cybersecurity, etc. On the other hand, the DLMS / COSEM standard itself, the most widespread data protocol for AMI systems, leaves several aspects open to end user specification.

The DLMS/COSEM is part of the solution but not the final solution; it must be complemented by defining all the parameters according to the requirements of each company or country. This is called the definition of a Companion Standard.

The Companion Standard has been defined by the utilities themselves, sometimes creating a country profile in collaboration with all the companies in the respective country. In any case, the created profile must always comply with national regulations and company requirements. On many occasions, the final profile even goes beyond those regulations, with the aim that the meters not yet contemplated in the current regulation are properly prepared for future uses.

In almost all the cases in which the electrical companies have created their profiles, several iterations of the specification have been necessary to reach a coherent profile that ensures interoperability between products.

PRIME Alliance knows the difficulties of a good implementation of the DLMS / COSEM protocol and thus has promoted the PRIME+ Companion Profile, described in this document, usable by all utilities, with the aim of helping utilities to have their own Companion Standard, easily and reliably.

Regulatory Considerations

An AMI system is made up of equipment that performs metrological measurements which requires compliance with national and international legislation. Furthermore, it is composed of telecommunications equipment, whether wired or over the air, which also requires compliance with telecommunications or radio spectrum protection regulations. Also, as electronic equipment, devices shall meet standards regarding electromagnetic compatibility and electrical safety. Finally, it will also be necessary to comply with environmental obligations for all the life cycle of the products, including recycling them after the end of the usage lifespan.

Many of these requirements are impacted by software updates that in this type of equipment are necessary with a certain periodicity. According to the majority of international legislations, a modification of the software implies an alteration of the product and therefore must be analysed under the prism of all the aforementioned regulations.

In conclusion, it is evident that regulations directly impact the definition of the data profile. An example thereof is that some regulations related to metering devices limit the number of times that the firmware of those devices can be updated. These kinds of limitations must be considered in the data profile to ensure that the implementation of the manufacturers is compliant with the regulation.

6 Steps to ensure data interoperability

An AMI system must be defined with an end-to-end vision in order to achieve the envisioned interoperability. Figure 1 shows the six steps recommended to ensure data interoperability.

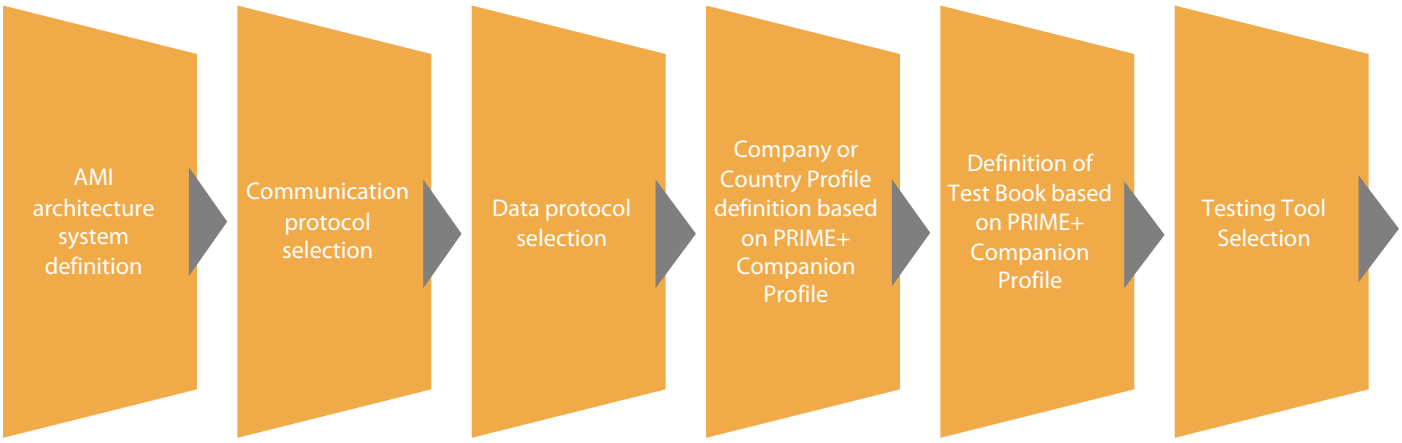

Figure 1. Proposed set of steps to define the AMI system.

- AMI architecture system definition: the architecture shall define all the processes at electrical, communications and data levels. All three levels are dependent on each other; a change in one implies changes in the others.
- Communication protocol selection starts with the media selection: air, electrical cables or other wired technologies. Several options are available in the market for each media, but PRIME offers Power Line Communications using the electrical cable as the most cost-effective solution, while ensuring interoperability and reliability. PRIME certificate ensures the interoperability and reliability at communication level.
- Data protocol selection: the protocol used for metering data needs to be selected in coordination with the communication protocol used and depends on the required functionality. For electric meters, DLMS/COSEM is the international reference; the PRIME alliance offers PRIME+ Companion Profile as a straightforward way to deliver a metering solution based on DLMS/COSEM and PRIME.
- Company or Country profile definition: DLMS/COSEM must be adapted to the requirements of the country or company. PRIME Alliance offers a questionnaire to adapt PRIME+ Companion Profile to the country or company, automating the process to simplify the utility efforts.
- Definition of Test Book based on the Companion Profile to ensure that devices are compliant with this Companion. PRIME offers a Test Book created automatically from the questionnaire to test the Profile implementation.
- Testing Tool selection to verify devices against the Test Book to ensure repeatability of tests, reduction of human errors or speed in the process. The laboratories within the PRIME ecosystem can ensure that devices are compliant with the defined Companion through the adaptation of the existing tools.

PRIME+

The first two steps have been solved by the PRIME Alliance, and now, with PRIME+, the remaining steps are also simplified to utilities, hence ensuring end-to-end interoperability.

PRIME Alliance decided to create a DLMS Profile valid for all the users and countries and which is applicable to all equipment using DLMS/COSEM protocol, trying to simplify utilities' efforts. However, even when the profile includes specific requirements for PRIME meters, it also needs to have enough flexibility to adapt to different user's requirements and regulations of each country. For example, security is one of the areas where utilities need to specify if they want to use authentication, encryption, both, or none.

Beyond the considerations explained above, PRIME+ has also been developed to allow easy adaptation to new technologies and functionalities. For example, PRIME Alliance is working in new technologies, such as a hybrid PLC+RF solution; PRIME+ is conceived to be flexible enough to allow seamless integration of these new technologies.

It is pivotal for metering systems to frequently explore new functionalities and for PRIME+ to be also flexible to include new functionalities without requiring major changes in the overall AMI architecture.

PRIME+ COMPANION OVERVIEW

The fundamental objective of the PRIME + Companion is to reach an open and standardised protocol implementation based on DLMS/COSEM protocol. This section provides a general view of Companion Standard, which focuses on all the communication interfaces for electricity meters for an AMI system. Detailed information can be consulted on the reference document of the Companion.

The main sections in which the Companion is divided in are described in the following sections.

Architecture

The general architecture based on smart meters with different port communications (P0, P1, P2, P3), which implement DLMS/COSEM can be seen in Figure 2.

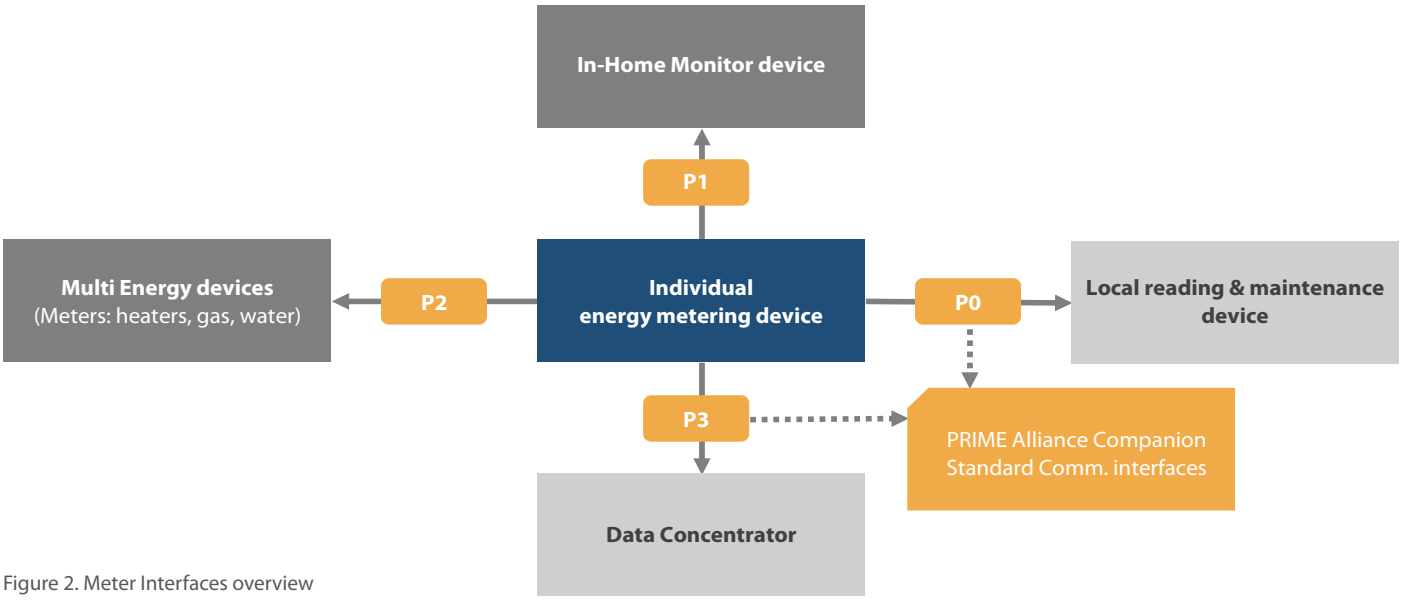

Figure 2. Meter Interfaces overview

Logical devices and associations

In DLMS/COSEM, metering equipment is modelled in physical and logical devices. The device, i.e., the smart meter, is the physical device and this contains multiple logical devices (clients). At least one logical device, the management logical device, must be considered.

Clients and Access Levels

The logical device can have a minimum of 2 up to 6 clients: on one side, some are mandatory: public, reading and management; on the other side, the rest are optional: Firmware, Limited Remote Customized Association and Broadcast Client.

Depending on the client, a given attribute may not be accessible for some services. In addition, the services (get, set or action) are allowed or not.

For all types of clients, the "access rights" of the objects defined inside the Companion must be defined to be managed. This concerns the Get, Set and action services and access rights.

- Public Client: its role is only to support the internal structure of the physical device and must not allow either to read metering data, nor perform any programming.
- Reading Client: used for parameter and energy data reading purposes. It has the access rights to read any attribute, parameter or data register.
- Management client: utilised for parameter reading/writing and energy data management purposes. This client must be able to perform all allowed operations on the devices, including the possibility of firmware update and has the access rights for managing all the necessary object access for a normal operation.
- Firmware client: restricted for firmware update purposes only.
- The Limited Customized client (if implemented): used for remote association and reserved for specific purposes.
- The Broadcast client (if implemented): used for remote association are reserved for specific purposes. Access with LLS or HLS is required and must be able to manage all the objects to firmware update functions.

Communications Profiles

The Companion defines three possible communication profiles to be implemented in the communication interfaces:

- PLC: Communication profile for meters running Power Line Communications (PLC) devices.
- Wireless (2G/3G/4G): TCP-UDP/IP-based protocols.
- HDLC (Optical): Communication profile for meters running High-Level Data Link Control (HDLC) devices.

Local clients have access to the meter through the optical port. The Local clients are: Public, Reading, Management and Firmware. The Remote clients have access to the meter through PLC PRIME or 2G/3G/4G. The Remote clients are: Public, Limited Customized client and Broadcast, as described in the previous section.

Security

Each client has an associated security policy for its securitization and a security context implementation for each one, which can be enabled or disabled. The main aspects related to security are described below:

- Security suite: determines the set of cryptographic algorithms available for the various cryptographic primitives and the key sizes. DLMS/COSEM security suite Ids from 0 to 2 can be implemented. It could be different security implementation for each Suite Id: 0,1,2.
- Security Policy: each security client can have securitisation states according to the Security Suite Id and the Security setup object. In case that any client implementation is not required to be secured, the security policy should remain at 0 in the corresponding security policy object. A secure association can use LLS or HLS AUTHENTICATION and application context LN_CIPHERING (3). HLS authentication requires cryptographic processing of the challenges exchanged by the client and the server.
- Keys: meter must support (at least) the following keys per secure client: Master key (unique for meter), Global unicast encryption key (unique for each secure client), Global authentication key (unique for each secure client), Global broadcast encryption key, Dedicated key. LLS or HLS passwords and/or security keys of the meter cannot be read from any client.
- Invocation Counter: invocation counters must be increased for each protected message. These counters must be reset (to value 0) when the corresponding key is replaced or reset.

Events and Logs

Every event has a unique code to identify the action which it has triggered. They are divided into a total of eight groups of events. Every event is stored in the corresponding event log linked to their group as described below. Some examples of event logs are:

- Fraud Detection Log: contains all events related to the detection of fraud attempts.
- Disconnect Control Log: contains all events related to the Breaker.
- Firmware Event Log: contains all events related to firmware change.
- Power Quality Event Log: contains all events related to voltage variations.
- Others: Standard Event Log, Demand management Logs, Communication Log, Synchronization Events Logs, Finished Quality Event Log, Security Event Log, Failed Security Event Log, M-Bus Event log, Public Lighting Event log, Irms Event log.

Alarm and Error Handling

A selection of events can be created and are treated as alarms (alarm filter). If one of these events occur, the corresponding flag in the alarm register is set. The Companion provides all the possible alarms and their assignment, but it can be programmed to mask out unwanted alarms. Additionally, the alarms can be reset by command.

In addition, a predefined selection of events can set and clear, flags in the “error register” and in the “alarm register”. The error register can be read and displayed at any time to see if there is a malfunction in the device.

Profile Status AMR

In all the Load Profiles included in the Companion, there is an object to include the status code (AMR) linked to the load profile, to give extra information. This status code is used for every entry of the load profile. The AMR status code has a size of 1 byte describing the function for each bit: IV (Data not valid) , CA (clock adjusted), MP (Parameters changed), INT (communication fraud detection), AL (Power down), etc.

Abstract and Electricity Objects

The Companion defines a variety of abstract and electrical objects for their specific use based on the specification of the DLMS UA Blue Book document. COSEM interface classes and their objects can be used for modelling metering use cases general enough to model any application. The objects may have several attributes.

The list of the most significant group objects currently available in the Companion are listed below:

- Association and Security: such us "association LN for Public Association", "Reading Client association" or, "Management association".
- ID's & Control Information: Device ID 1, Device ID 2, etc.
- Time related issues: clock, local time, activity calendar, special days table, tariffication script table.
- Billing Period Reset: data billing period, timestamp of billing period last reset…
- Disconnect, Load Management, Supervision: disconnect control scheduler, disconnect control.
- Errors, Alarms, Events: Alarm Register , alarm filter, Standard Event log…
- FW Upgrade: Image Transfer, Image transfer activation scheduler, active firmware version.
- Public Lighting: Output Relay Control 1, Output Relay Control 2, etc.
- Irms (current RMS): Irms Integration Period, Irms Threshold Value Limit.
- Other abstract object: Global Reset, Former firmware version,
- Electricity Objects: Instantaneous Energy values, Current billing values, Demand Register, Maximum Demand Register.
- Monitoring Profile: Load Profile with Period 1, AMR Profile status, Last Average Voltage.
- Pre-payment Objects: Payment Account, Payment Credit, Payment Charge.
- HAN-IHD Related Objects: USB - port operation mode.
- HAN-ME (M-Bus) Related Objects.
- Local Port Objects: IEC Local port setup IEC, optical Port.
- 2G / 3G / 4G Related Objects: TCP-UDP, IPv4 setup, Push Setup, GPRS Modem Setup.
- PRIME Related Objects: PRIME Physical layer counters, PRIME PLC MAC Setup.

METHODOLOGY

In this section, the methodology implemented by the PRIME Alliance to simplify the way utilities select the specifics of their profile is further described. Some aspects to be considered in the definition are the following:

- Estimated availability of the communications.
- Volume of data to transfer.
- Costs related to the communication assets.

The scheme in Figure 2 shows the flow of the methodology. To adapt PRIME+ to the specific requirements of a user, it is necessary to complete a set of information collected through a questionnaire.

Once the questionnaire is completed, a file collecting the specific information of the user is generated. This file includes all the specifics to be defined on top of PRIME+, ensuring interoperability for that user. This, together with the already existing PRIME+ Companion Profile will generate a document with the complete definition of the user's profile.

Once the profile is completed, the applicable tests of the Test Book defined by the PRIME Alliance are clearly identified and the DLMS/COSEM certification process will be completely defined without additional effort to the utility, assuring compliance with the requirement. This evaluation will be applied with a Testing Tool adapted to the user´s profile and the Test Book.

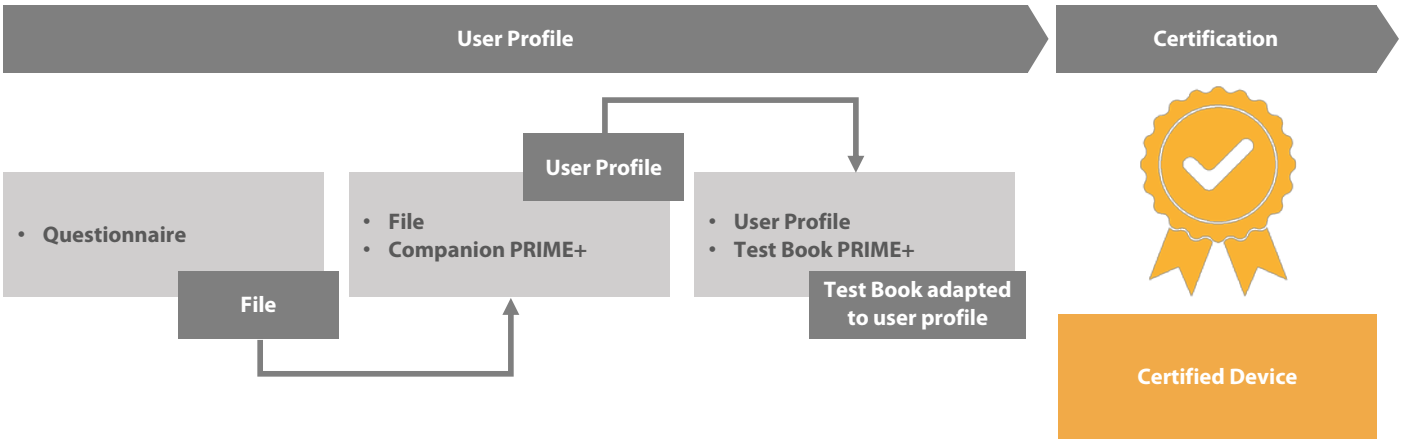

Figure 3. Visual representation for the elaboration of the documentation based on PRIME+ towards the certification.

Step 1: Questionnaire

The first step of the methodology (see Figure 3) is to complete a questionnaire that collects the user's requirements.

The following figures, Figure 4, Figure 5, Figure 6 and Figure 7, show a set of screenshots of the questionnaire to be completed by the users. This questionnaire will generate a File that allows an easy way to define a User Profile without depth knowledge of DLMS/COSEM Protocol.

Information requested falls in the following areas:

- technical electrical information, such as frequency, current and voltage.
- communication protocol information, and more specifically, security policy, access rights and clients.
- functional information such as events, alarms, and metering functionality.

With this questionnaire, both user specific requirements (for example the number of clients, events, etc.) and regulatory requirements (for example, thresholds and limits for power quality or limits on the number of firmware upgrades) are gathered.

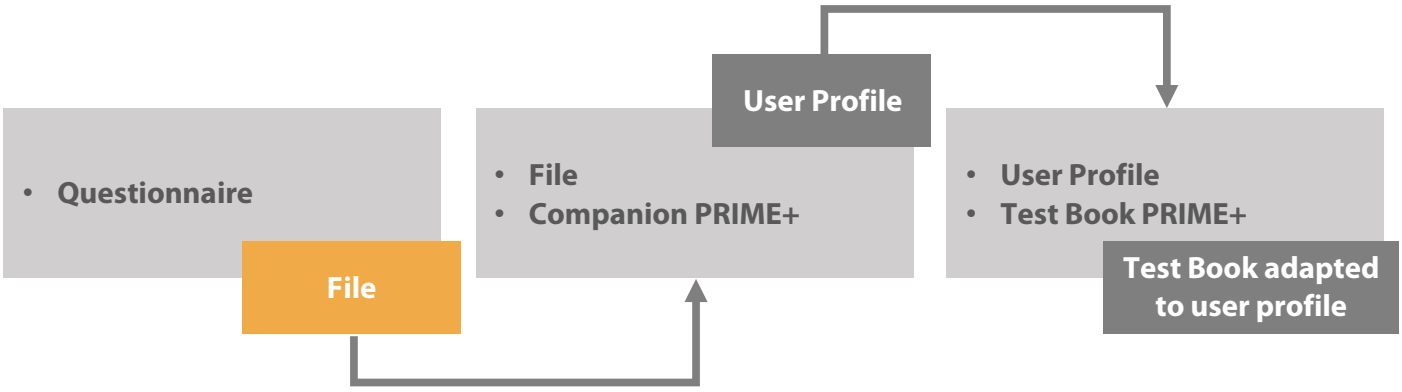

Figure 4. Step 1 highlighted in the methodology.

Figure 5. Screenshot of the questionnaire – Introduction of user information.

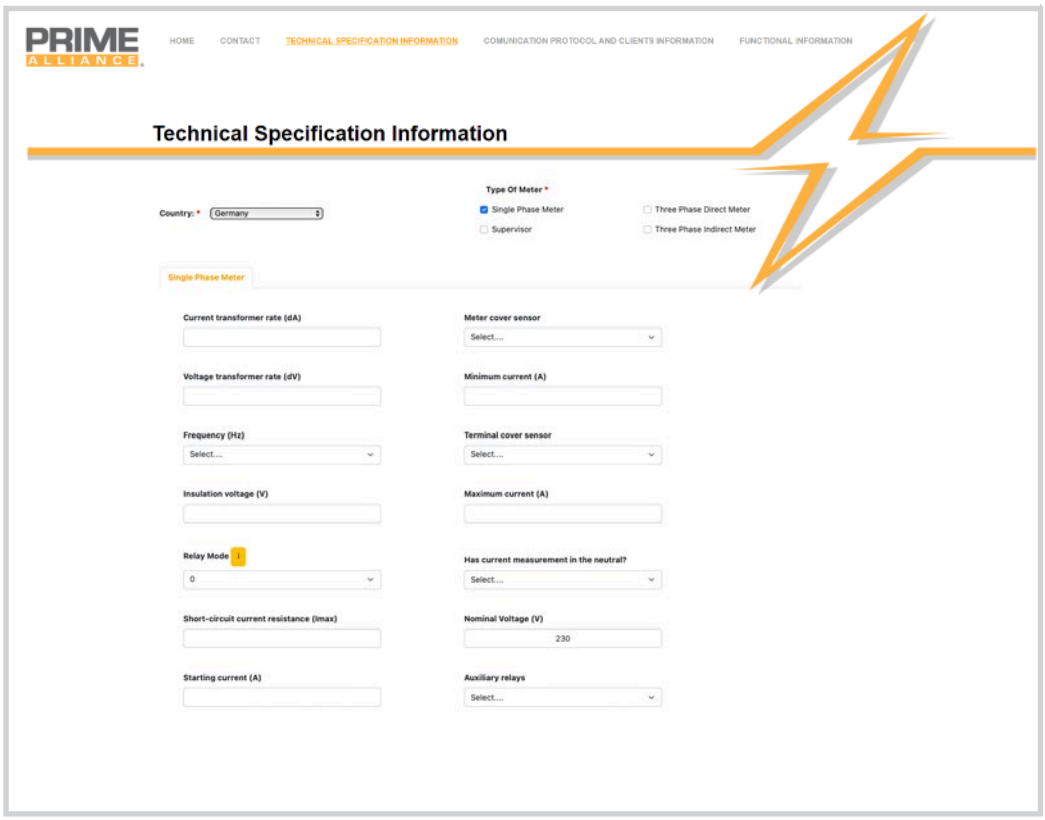

Figure 6. Screenshot of the questionnaire – Introduction of Technical Specification Information.

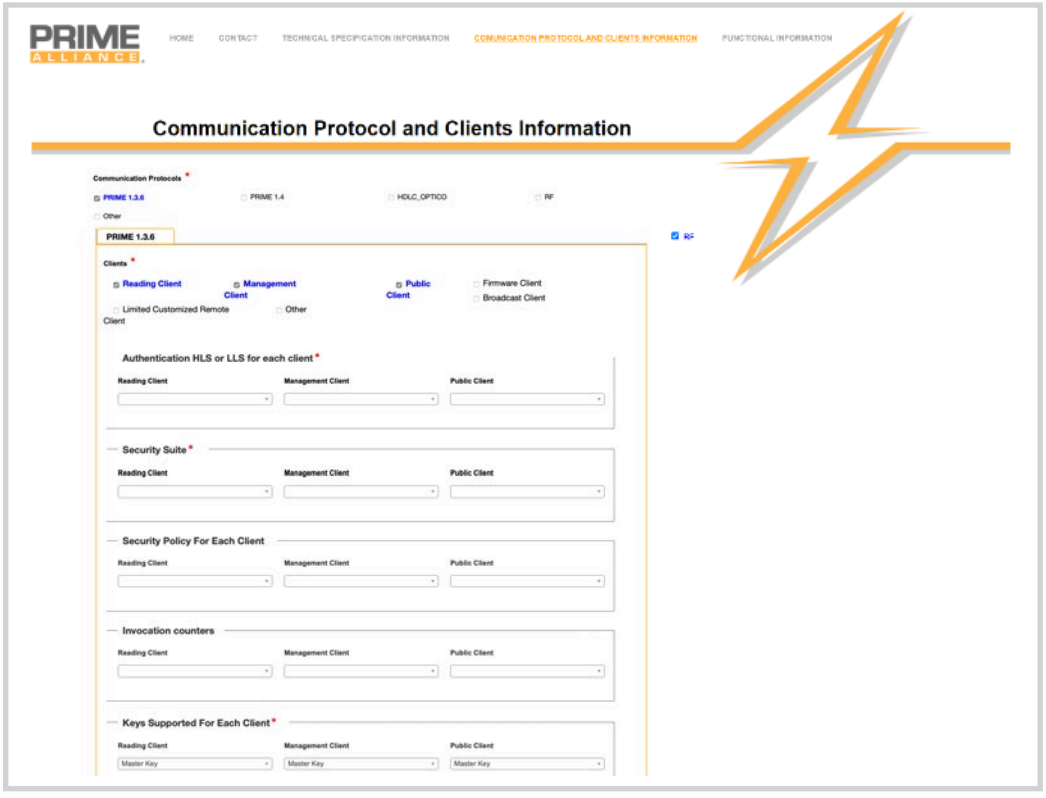

Figure 7. Screenshot of the questionnaire – Introduction of Communication Protocol and Clients Information.

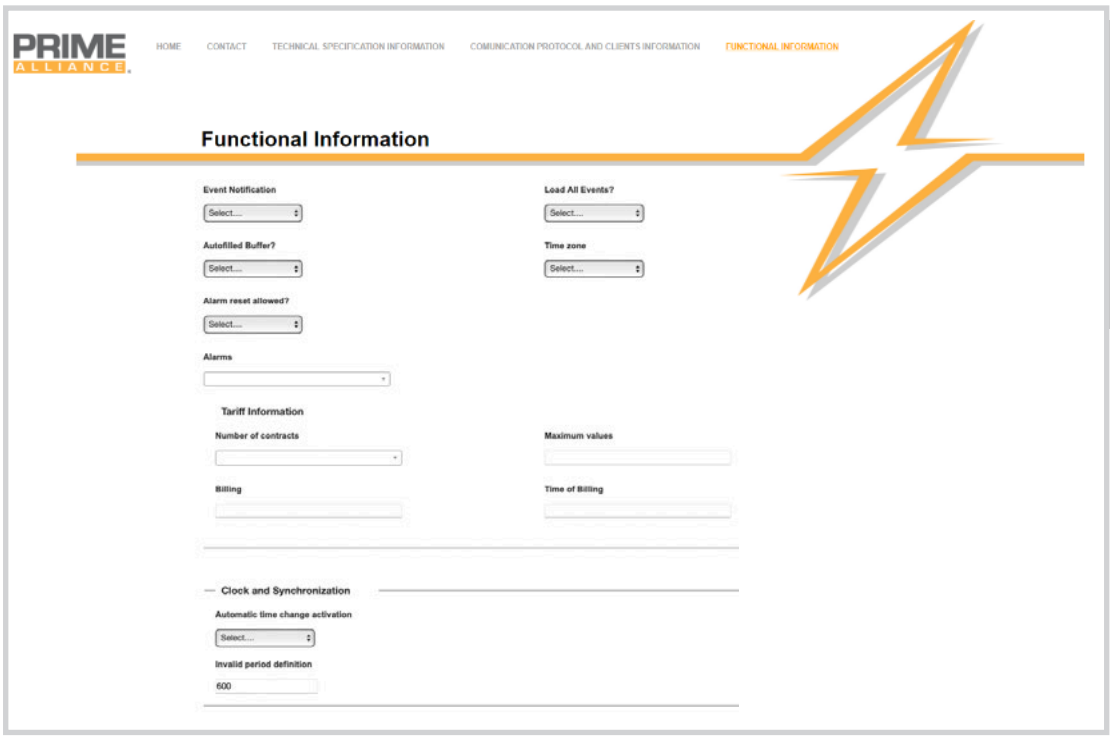

Figure 7. Screenshot of the questionnaire – Introduction of Communication Protocol and Clients Information.

Step 2: User profile

The second step of the methodology (see Figure 8) will elaborate a user profile adapted to the user's requirements, defining those open points that exist in the PRIME+ Companion and limiting them to the user's needs.

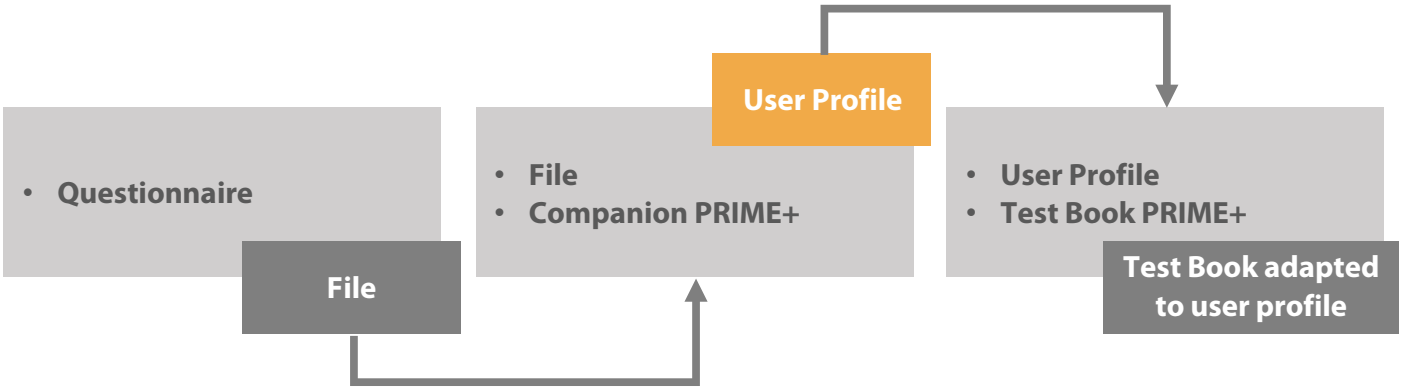

Figure 9. Step 2 highlighted in the methodology.

The user profile is attained by joining the file obtained as a result of the questionnaire and the PRIME+ Companion. This Profile guarantees interoperability among the equipment of different manufacturers and allows the user to have a profile defined according to their needs in a simple manner, without requiring effort or deep knowledge of the technical aspects and DLMS protocol.

Step 3: Testbook Adapted to User Profile

The third step of the methodology will produce a testbook adapted to Companion PRIME+ User Profile (see Figure 9).

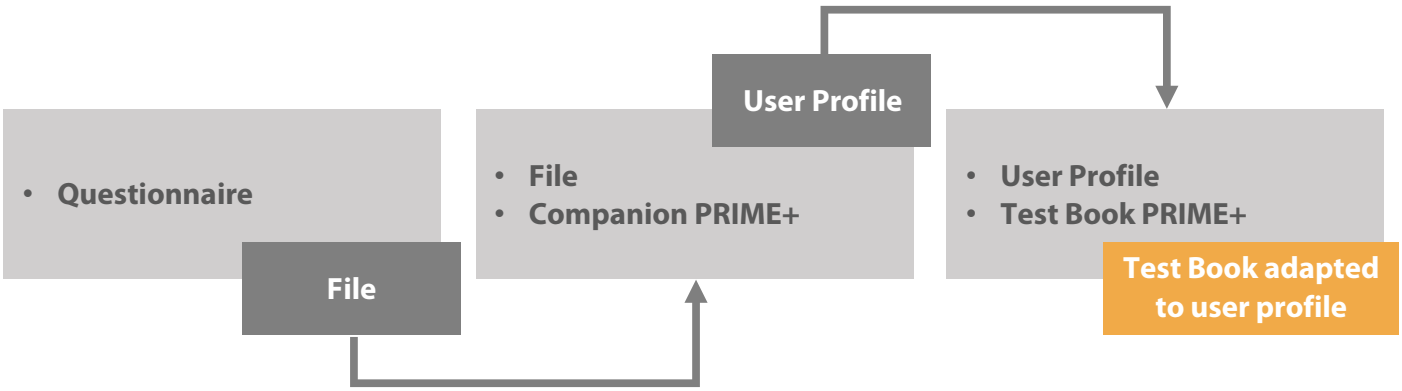

Figure 10. Step 3 highlighted in the methodology.

PRIME Alliance has defined a generic Testbook, including case reports to verify and check all the functionality detailed in PRIME+ Companion. As PRIME+ Companion has open points which need to be further defined and close up on by the user in order to define the User Profile (this by using the questionnaire without additional effort to the utility, assuring the compliance with the requirement), the Testbook document has to be adapted with a consideration of the User profile obtained and the file which resulted from the questionnaire and the PRIME+ Companion. While this process can be done by the users in a simple manner without additional knowledge and effort, Laboratories can easily assist users in the process of further defining high-technical aspects, if required.

A good definition of the Testbook assures that the devices are compliant with all the requirements defined on the User Profile. A testbook adapted to the User Profile is the pillar that guarantees interoperability in field deployments.

CONCLUSIONS

This document presents the PRIME+ initiative, which includes the elaboration of a generic companion profile for electric meters together with an easy methodology to further develop that profile by obtaining a user-specific profile. To that end, the PRIME Alliance has defined an easy-to-follow questionnaire, which collects information from the user and adapts the PRIME+ DLMS/COSEM profile to that user's requirements.

Multiple users from different profiles such as electricity companies, manufacturers and governments can benefit from this methodology and obtain their own User Profile based on the PRIME+ Companion easily. This profile guarantees the suitability of the requirements of the user while assuring the advantages of having a standard solution and interoperability among different manufacturer.

RELATED DOCUMENTS

1. PRIME Standard. "Narrowband Orthogonal Frequency Division Multiplexing Power Line Communication Transceivers for PRIME Networks, Standard ITU-T G.9904."
2. DLMS/COSEM protocol. Device Language Message Specification (DLMS), Companion Specification for Energy Metering (COSEM) - IEC 62056 series of standards.
3. PRIME+ Companion Standard.

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