

Onesait Metering for EDP

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Abstract— Although OUM is a multi-protocol system, the integration of the system with the STG-DC specification in its version 3.4 has not been carried out to date in Minsait's tool. For the EDP requirements fulfillment, it is essential to develop all the necessary modules and communication links to integrate the application and provide MDC and MDM solutions in the EDP infrastructure and for future projects that need to integrate this technology.

Keywords—Data Concentrator, STG, Smart meter, Request, Protocol.

I. INTRODUCTION

The fight against climate change is one of the most important challenges that humanity must face, and the commitment to a decarbonised economy based on renewable energies in a new energy mix is a task for all of us. This is how the Spanish National Integrated Energy and Climate Plan (PNIEC) was born in Spain, which has the minimum objective of reaching 32% renewable energy by 2030. This objective is achievable in a scenario of high decarbonisation and electrification of the economy, using decarbonised fuels in those niches that are difficult to electrify [1]. The challenge of extending these networks to millions of endpoints, potentially geographically dispersed over large service areas, is inherent to the Smart Grid [1].

Faced with this new paradigm, utilities companies are facing a series of digital transformation challenges marked by the migration of the energy supply chain to a new distributed model. Within smart grid development, Smart Metering is one of the fundamental pillars, driven by sustainability and user satisfaction. Minsait has developed Onesait Utilities Metering technology, a smart metering solution designed for utilities that enables a competitive advantage in an energy market affected by global trends, allowing the Utility to collect, certify and export information data from different information sources [15]. EDP (Energías de Portugal), one of the largest electricity groups in Europe, has requested Minsait's services to integrate the OUM solution in its utilities in Spain. Three institutions will be integrated under a single manager (EDP-Spain, Viesgo and Begasa). This project will focus on the analysis and functional development of OUM integration under PRIME's STG-DC specification in EDP.

When integrating different institutions into the EDP Spain infrastructure, a problem arises for the company when it comes to exploiting the information in an agile, simple and transversal way with the aim of offering the new services introduced in the electricity distribution sector. This problem consists of the interoperability and centralisation of the different equipment that makes up the system. In other words, each of the companies that have been integrated into the EDP portfolio used different technologies, different communication protocols, different types of devices and different remote management solutions.

The acquired part of E-Networks has approximately 700,000 Prime counters that communicate with the 1.3.6 protocol. It also has 7,000 Prime 1.3.6 concentrators that communicate with the AMI using the STG-DC standard in its 3.4 version. In addition, the system includes various types of advanced monitoring equipment (using the STG-DC standard) as well as equipment such as routers and fibre optic interfaces.

On the Begasa + Viesgo side there are 700,000 meters that use Telegestore as a communication protocol with the concentrators and 12,000 concentrators that currently communicate with the AMM via a private standard owned by Endesa.

The aim of this project is to collaborate in the integration of these systems in the Minsait OUM multiprotocol tool, with the aim of centralising all communications to enable a single remote management of the entire fleet of equipment so that the user is able to monitor, improve and automate all communications processes that occur with each of the measuring devices that make up the network.

II. STATE OF ART

The electricity metering equipment used worldwide is the well-known electricity meter, which consists of three main elements, namely the metering system, the memory element and the information device. In this sense, the electricity meter performs the function of the network interface with the user, it is the front-end of the network.

This metering equipment can be classified according to its technological characteristics (whether electromechanical or electronic), by its single-phase or three-phase functionality, energy, and operational characteristics as a programmable recorder type device that allows remote management. These meters have evolved significantly in the electricity market as new technologies have been developed.

These devices are based on AMI (Advanced Metering Infrastructure) technology, these devices allow the reading of accumulated energy or instantaneous power, they allow demand records or programming of load intervals previously defined with each user. The Smart Meter concept was born from these new incipient technologies. These devices provide information and control of the quality and programming parameters of the service via the management centre, together with telematic updating of the metering software. Based on these reasons and those described above, the interest in the deployment and implementation of this technology is justified, as well as the importance of all the studies that encompass this world and among which this project is included.

A. AMI Communications Architecture

The acronym AMI, as mentioned above, stands for Advanced Metering Infrastructure and represents the heart and soul of this technology. To begin to describe this standard architecture for advanced metering-based communications systems, it is necessary to discern at a high level what are the main elements that comprise it [17]:

- **Smart Meter:** This is an electronic smart meter capable of recording electricity consumption at configurable time intervals and communicating the information from this recording to the control unit. It is therefore an instrument that fulfils the function of a sensor and an interaction point simultaneously, i.e. a smart node.
- **Data Concentrator (DCU):** It is the backbone of the Advanced Metering Infrastructure (AMI) that supports data acquisition, transfer of energy data to the central database and automated reading of electronic energy meters. DCUs are mainly used in low-voltage electric power systems.
- **Information systems:** These information systems act as a link between data acquisition and further processing. They are designed as databases (both relational and non-relational) and have remote management capabilities. These information systems are characterised by having a complete view of the infrastructure.

These systems are usually heterogeneous communication infrastructures, involving different technologies depending on the specific requirements of each network segment. In Spain, communication between meters and data concentrators is based on narrowband PLC technologies.

Power Line Communications (PLC) is a telecommunications technology that relies on the use of the electrical power distribution infrastructure (typically LV or MV) for high-speed transmission of signals and data. It provides broadband data communications over conductors that are already in use for the transmission of electrical power using a modular signal. This PLC technology is seen as a reliable communication medium for applications such as the Internet of Things (IoT) and Smart Grids [3].

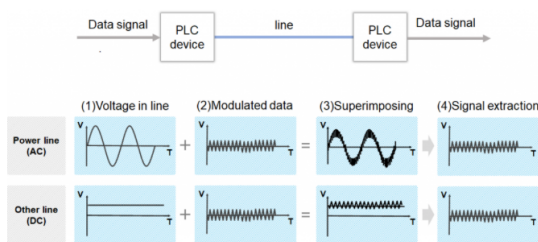


Figure 1: Basic PLC working principle [3].

B. PRIME for AMI Application

PRIME (Powerline Intelligent Metering Evolution) is an open, free, non-proprietary standard for a globally established OFDM PLC technology for advanced metering, network control and asset monitoring applications, and has fulfilled the goal of establishing a set of open PLC standards on an international basis. There are more than 20 million PRIME meters installed in more than 15 countries around the world [5]. Since the beginning of electricity deregulation and market-based pricing around the world, utilities have been looking for a means to match consumption with generation. Traditional electricity and gas meters only measure total consumption and therefore do not provide information on when energy has been consumed at each site. PRIME AMI offers a way to measure this site-specific information, allowing different prices to be set for consumption based on time of day and season [5]. One of the advantages of implementing the PRIME protocol is that it ensures interoperability between different equipment and systems, is not subject to any intellectual property, and is designed to achieve a low implementation cost and high performance, thus accelerating the entry of new operators.

The physical layer, MAC layer and convergence layer of version 1.3.6 of the specification have been considered standard by ITU-T since 2012. Version 1.4 extends the frequency spectrum to allow operation in the North American and Asian markets and includes some enhancements aimed at improving robustness at the physical and MAC level [7, 8]. At the MAC level, a sub-network has a tree-like structure, where two main types of nodes can be distinguished:

- **Base Node (BN):** The base node is the master node that manages a PRIME subnetwork. There is only one BN per subnetwork, and it is responsible for managing resources and connections, it acts as the master node and is at the root of the tree structure, it is the most important element. In AMI terminology, the base node is the data concentrator [7, 14].
- **Service Node (SN):** Service nodes are the core element of the subnetwork. They can be seen as leaves or branches in the tree structure and are initially in a disconnected state, their functions being to maintain connectivity to the subnetwork for the different application layers and to switch information from other nodes. Smart meters must register in the sub-network to become service nodes that depend on their corresponding BN. In AMI terminology, service nodes are smart meters. [7, 14].

Initially the sub-network is composed only by the base node and the rest of the nodes that want to be part of it have to perform a registration procedure.

- **Disconnected:** This is the initial state of any service node before it registers into the PRIME subnetwork. While in this state, the smart meter cannot communicate its own data or switch data from other SNs and its only goal is to search for a subnetwork that it can reach and register on it.

- **Terminal:** This state allows the SN to establish new connections and transmit data, but not to switch data from other SNs.
- **Switch:** This state is the most complex one and allows the SN to establish new connections, transmit its own data and switch data from other SNs.

Finally, a process of registration and deregistration is carried out.

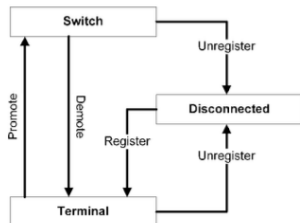


Figure 2: Functional states of a Service Node [11]

C. Onesait Utilities Metering Technology

OUM (Onesait Utilities Metering) is the metering product for utilities developed by Minsait (energy, water and gas) that enables the capture, storage, exploitation and export of metering data in the field of Smart Grids. This software system allows the company a bidirectional interaction with field metering devices, both meters and concentrators, through any WAN communications network.

One of the differentiating features of OUM is that it is a multi-manufacturer system, i.e. the system allows bidirectional communication with any type of measuring device, regardless of the manufacturer and protocol required. One of the bases of the OUM solution is the automation of processes, once the system has been configured it is able to operate in an automated way depending on what is set by the user of the system. All tasks performed by OUM can be executed manually or automatically in order to reduce user intervention.

On the other hand, OUM also has the capability to act as an inventory master of the measuring equipment deployed in the field. Additionally, the system enables the synchronisation of inventories with third-party systems. Therefore, within the Smart Metering application map of any energy business, OUM can be considered as the master of metering data, as it centralises the reception and processing of all the metering data of the business it represents. This system has been developed for use by any type of utility that requires centralised and efficient management and processing of metering data [14].

Onesait Utilities Metering MDC is responsible for managing the data capture process, through a single communication channel with the metering equipment, managing and monitoring these communications. The MDC enables the configuration and management of communications with local and remote equipment as well as field devices. The Figure shows the MDC functionalities described above.

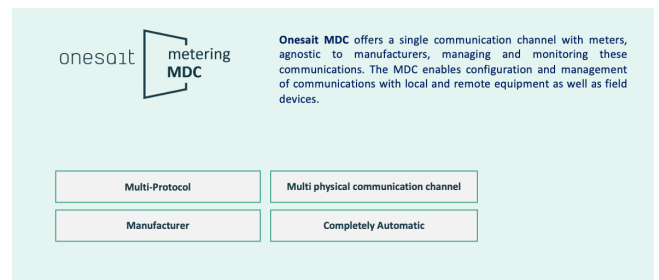


Figure 3: MDC description [14].

Onesait Utilities Metering MDM has been conceived to manage and process the data collected by the system to centralise the processing, storage, completeness, and certification of measurements, as well as the use of other data of interest to Utilities.

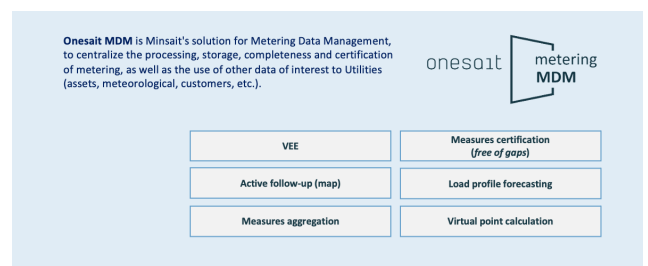


Figure 4: MDM description [14].

The measurement management module represents the most representative part of what is considered an MDM module or functionality, which includes VEE (Validation, Editing and Estimation). This functionality includes the configuration of the measurement cycle of each measurement point or group of points.

III. DEVELOPMENT

This chapter defines the different requests to the equipment that will be registered in the system, both for remote metering and remote management. The communication flow diagrams that make up the main objective of the project will also be presented.

As mentioned above, each of these requests will have the objective of requesting or sending information to the corresponding meter(s). Each request will have a set of parameters that must be entered through a manual execution or a scheduler. First of all, in a first subsection, a mapping of the cross requests with the STG-DC protocol will be provided, which serves as a list of all these requests that will be defined immediately afterwards.

Table 2 represents the mapping of the orders to be integrated in the tool with the corresponding reference given in the STG-DC protocol.

Order	Request STG-DC	Order	Request STG-DC	Order	Request STG-DC
Get Date Time	S06	Get Meter Events From Last	S09	Get Current Billing Values	S27
Get Daylight Saving Time Dates	S06	Get Instantaneous Values	S01	Get Concentrator Events	S17
Get Equipment Parameters	S06	Get Instantaneous Values Between Dates	S01	Get Concentrator Events Between Dates	S17
Get Load Profile	S02	Get Instantaneous Values From Last	S01	Get Cocentrator Events From Last	S17
Get Load Profile Between Dates	S02	Get Advanced Instantaneous Values	S21	Get Firmware Update	S19
Get Load Profile From Last	S02	Get Advanced Instantaneous Values Between Dates	S21	Connect	B03
Get Load Profile Gaps	S02	Get Advanced Instantaneous Values From Last	S21	Disconnect	B03
Get Load Profile Gaps Between Dates	S02	Get Billing Profile	S04/S05/S5B	Set Equipment Parameter	B09/B9b/ B07
Get Absolute Load Profile	S03	Get Billing Profile Between Dates	S04/S05/S5B	Set Daylight Saving Time Dates	B09/B9b/ B07
Get Absolute Load Profile Between Dates	S03	Get Billing Profile From Last	S04/S05/S5B	Synchronization	B09
Get Absolute Load Profile From Last	S03	Get Billing Profile Gaps	S04/S05/S5B	Firmware Update	B05 /B08
Get Absolute Load Profile Gaps	S03	Get Billing Profile Gaps Between Dates	S04/S05/S5B	Set Tariff Structure	B04
Get Absolute Load Profile Gaps Between Dates	S03	Get Traffic Structure	S23	Set Contracted Power	B04/B02
Get Meter Events	S09	Get Contracted Power	S23	Spontaneous Events	S13/S15
Get Meter Events Between Dates	S09	Get Connection Status	S18		

Table 1: Orders Mapping

Definition of orders can be found in the long document.

Once the orders to be integrated in the system for the EDP project have been presented and described, the next step is to break down the communications process that takes place between the different equipment and systems involved. To represent this process and the interactions between the different existing entities, flow diagrams will be used in order to describe the whole process in a very visual way that will make it easier for the reader to understand and follow the communications process correctly.

In order to achieve the objective of representing all orders appearing in the mapping of Table 2, it is necessary to group the orders appearing in the column "Request STG-DC" according to their characteristics of their communications process:

First of all, it is necessary to distinguish between "Pull" and "Push" tasks.

- **Pull:** Pull tasks are tasks that originate from a specific request from the GTS and are usually manual executions requested by the user.
- **Push:** Push tasks are tasks or actions that are performed at the initiative of the DC, or by tasks that have been programmed in the device.

The structural difference between these two typologies is simple. If the task is a Pull task, the corresponding flowchart is read as a whole, but if the task is a Push task, the flowchart would be the same, skipping the first level. This first level consists of the first communication between the STG and the DC and consists of the creation of the record

"Telemetry_user_request". Logically, if the task is a push task, and therefore there is no request from the STG, this record does not exist and it goes directly to the phase where the relevant Job intervenes and updates the records.

Five different groups can be distinguished, which will be used to group the flowcharts. Table 3 shows these groups and assigns a reference to each one, which is the one we will use in the following subsections.

Model	Synchronous	FTP/WS	WS server & name
Model 1	Async	FTP	STG-UpdateRequestStatus
Model 2	Async	FTP	STG-Report
Model 3	Async	WS	STG-Report
Model 4	Async	WS	DC-Order
Model 5	Sync	WS	DC-Request/STG-Report

Table 2: Requests Clasification

As an example, in this document Model 1 and Model 4 will be described to detail. However, the description of the 5 models represented in Table 2 can be found in the long document.

A. Model 1

Model 1 is the set of Asynchronous tasks, which use the FTP protocol for sending and receiving information and use Update Request Status as communication WS.

Table 4 contains a list of the reports that have been constructed pertaining to this model:

Model 1			
Report	Content	Report	Content
S02/S2B	Load Profile /Daily	S09	Meter Events
	Incremental		
S03	Daily Absolute	S17	Concentrator Events
S04	Monthly Billing	S22	Concentrator
	Profile		Firmware Update
S05/S5B	Daily Billing Values	S23	Confirmation
	Profile		Contract Definition
S06	Meter Parameters	S26	Instant Data Values on Demand

Table 3: Model 1 Reports

This model uses in its communication protocol the WS STG-UpdateRequestStatus. This WebService is designed to inform the STG about the status of a request.

It has to be called by the DC after an asynchronous request from the STG has finished at the DC, to inform the STG why the request has finished (normal completion, timeout...) if the information has not yet been passed to the STG (e.g. if the report was sent using Report WS). In the case of periodic reports (scheduled tasks) delivered by the DC you must use this web service to notify the report upload and set IdPet to 0.

In this type of requests, parallel to the URS, the WS UpdateMeterStatus intervenes.

This Webservice is designed to inform the GTS about the status of a request.

It has to be called by the DC after an asynchronous request from the STG has finished at the DC, to inform the STG why the request has finished (normal completion, timeout...) if the information has not yet been passed to the STG (e.g. if the report was sent using Report WS). In the case of periodic reports (scheduled tasks) delivered by the DC you must use this web service to notify the report upload and set IdPet to 0.

In the following, it has been decided to use an example from the list above in order to describe the communication process of this model. The selected example is the reports S09 and S17, Meter and Concentrator Events as it also has the particularity of containing another WS "STG-Report Query".

It should be noted that the rest of the reports listed in Table 4 are represented in their corresponding flow charts in Annex IV. When this task is started, it collects the information from the counters if S09 or from the DCs if S17 and sends it to the STG.

The execution of this task can include as attributes the Groups and event codes to be delivered. The default deadline is given by the periodicity of the task. These requests are in charge of executing the "Get xxx Events" type orders of the OUM tool. The description of the flowchart of these orders will be done in two sections:

1. Execution of the request and receipt of the FTP.

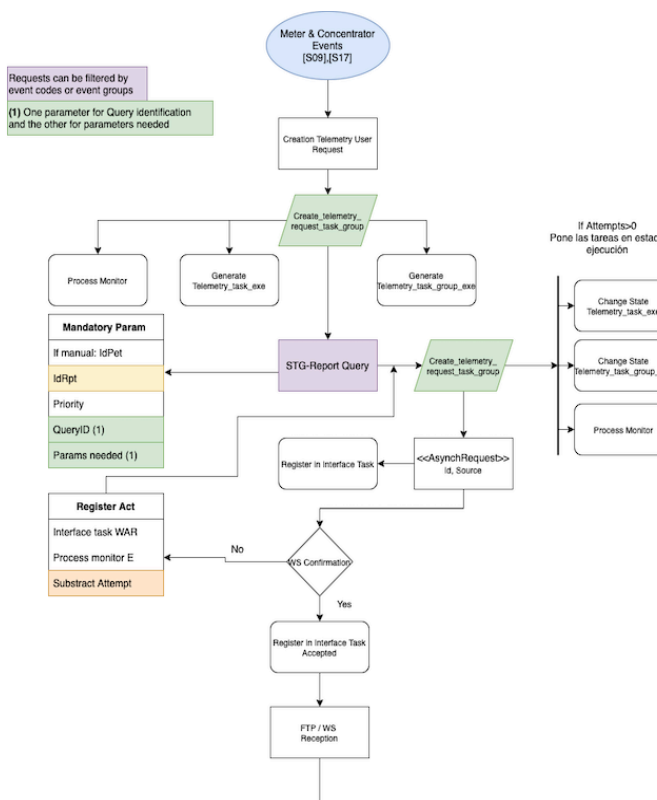


Figure 5: Meter and DC Events FlowChart Part 1

When the user executes the request, the first thing that is created is the record "Create_Telemetry_User_Request", the Job "Create_telemetry_request_task" intervenes and the following records are generated in READY status.

- Process Monitor
- Telemetry_Task_execute
- Telemetry_Task_Group_Execute

Once these registers have been generated, the WS STG-ReportQuery intervenes. This asynchronous WS is used to retrieve events in counters (S09) and concentrators (S17). Requests can be filtered by codes or groups of events. For this purpose, this WS includes different parameters than the previous one: one parameter for the identification of the query and another one for the necessary parameters.

Then, once OUM has the capacity to process the order, the next JOB enters, which is in charge of confirming the WS with the concentrator and aims to put the three indicated registers in the EXECUTION status. If the confirmation of the WS has not arrived, a retry will be subtracted in the registers, the status of the Process Monitor will change to Error and the status of the Interface Task will change to Warning until the confirmation arrives.

Once this WS is confirmed, the system waits and the concentrator sends the FTP file to the OUM system. This system is stored in a record of the tool and contains a reference to its request so that when it is going to be processed, it is known to which process the generation of the file belongs.

The next step will be the processing of the file and the interaction of the system with the WS URS and UMS.

2. File processing and communication resolution

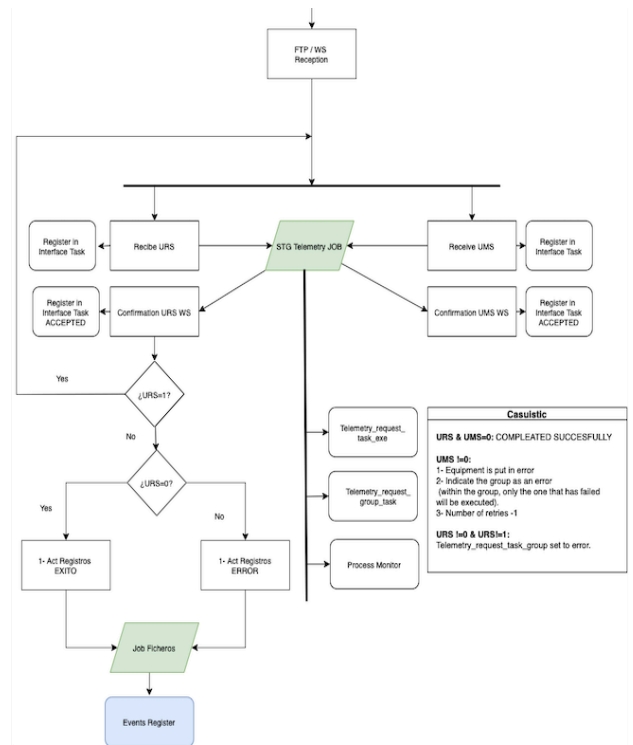


Figure 6: Meter and DC Events FlowChart Part 2

Once the FTP file is received, the *STG-Telemetry JOB comes into play*. This job looks for pending PRIME protocol tasks, groups them, creates the corresponding telemetry_requests and interacts with the AsyncRequest to process the message.

In this particular case, this job will be in charge of interpreting and responding to incoming records by means of WS (URS and UMS) as shown in the flowchart depicted in Figure 29. As can be seen, each time the concentrator notifies it with a URS and its request reference, or with a UMS and its request reference, the *STG-Telemetry JOB* intervenes, which gives rise to the *STG-ServiceJob*. This job, according to the arrival of WS received (URS, UMS) updates the status of the requests in the tables, and processes the files with the name specified in each UMS of the process sent by the concentrator.

From here, the content of the URS is interpreted, which is the Webservice that governs the system and indicates when the communication is finished. When URS=1 it means that the communication is still in progress, while when URS=0 it means that the communication has ended successfully, the rest of possible values indicate error or warning messages that are specified in Annex II. These values are crossed with the values returned by the UMS and the casuistry follows the process indicated in the flowchart table in Figure 30.

Casuistic
<p>URS & UMS=0: COMPLETED SUCCESSFULLY</p> <p>UMS !=0: 1- Equipment is put in error 2- Indicate the group as an error (within the group, only the one that has failed will be executed). 3- Number of retries -1</p> <p>URS !=0 & URS!=1: Telemetry_request_task_group set to error.</p>

Figure 7: URS and UMS Casuistic

Finally, the registers are updated with the corresponding status, and the JOB Ficheros stores the information in the appropriate register.

B. Model 4

Model 4 is the set of Asynchronous tasks, which use WS for sending and receiving information and which use the DC-Order as communication WS.

Table 4 contains a list of the infoms that have been constructed pertaining to this model:

Model 4			
Report	Content	Report	Content
B02	Power Modification	B07	Modification of the Concentrator Configuration
B03	Cut-Off / Reconnection	B09	Meter Parameters Modification
B04	Contract Modification	B9B	Meter Event Handling Modification
B05 B08	Meter Firmware Update		

Table 4: Model 4 Reports

This model is in charge of managing the direct action orders from the STG to the concentrator, i.e. the orders marked with Bxx. Like the report requests, these orders use messages in XML format sent through a WS in the form of a payload.

This model uses the DC-Order type as confirmation WS. It is a protocol in which an action is prepared in a specific measuring equipment, the necessary information is extracted by means of report requests, and finally the action is executed.

Once the DC-Order has been successfully executed, the concentrator must explicitly verify the requested order to each counter by means of a request from the STG.

The sending of an Order Request from the GTS to a counter may result in the execution of different phases or steps (download file update, pre-reporting, execution phase, post-reporting, etc.). These phases shall be executed sequentially in the CC, so that a phase cannot be started until the previous one is completed.

In case of failure in the execution of a phase, the execution sequence shall be stopped and the status of the order shall be reported to the GTS via UMS and URS with the appropriate category and error code.

To describe Model 4, we will use the flowchart corresponding to the *Firmware Update* command, contained in requests B05 and B08.

It is important to note that during the execution of this command, the system prompts the GTS to generate reports S19 or S22 (depending on whether the firmware upgrade is being performed on a counter or on the concentrator). The process of collecting and executing these reports is performed according to Model 3.

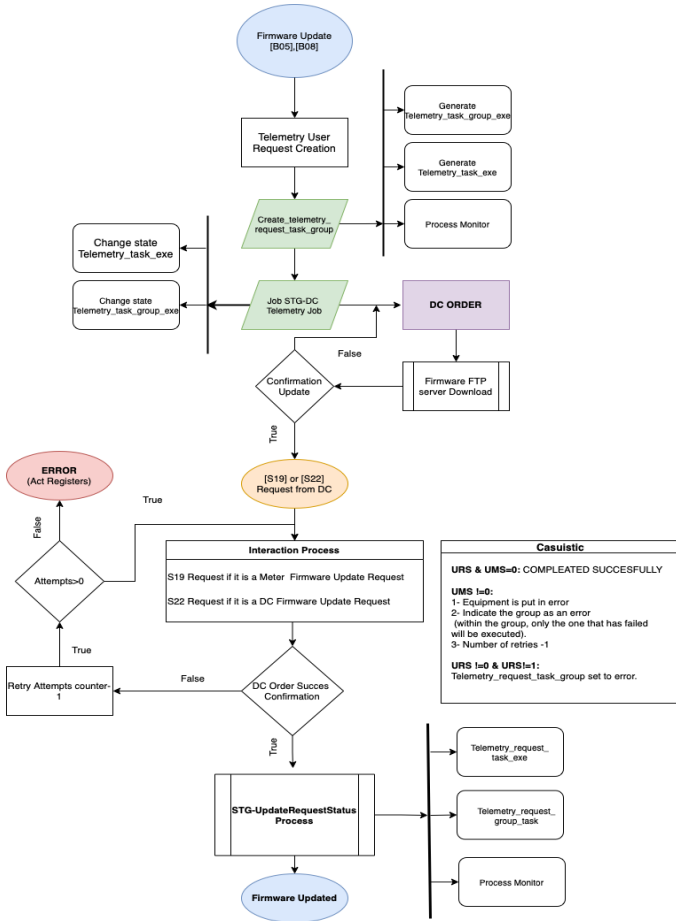


Figure 8: Firmware Update FlowChart

As in all previous cases, the first step in executing the command is to generate the three main OUM system registers through the *Telemetry User Request* script. The *STG-DC Telemetry Job* is executed in exactly the same way as in the case of Model 2 and 3 only this time it precedes a WS of type *DC-Order*. This WS, once it is correctly confirmed, requests an S19 or S22 report to save a previous record (a backup) in case something goes wrong in the process of executing the job.

Once the process of generating the above reports is finished, the system must confirm the WS. To do so, it has a limited number of retries and takes the system to error status in case they are completed.

Finally, the *STG-Service Job* intervenes and by processing URS and UMS following exactly the same process described in Model 1, the states of the registers are updated and the communication is finalised by carrying out the update action in the requested equipment.

IV. CASE STUDY

When drawing the flowcharts necessary to characterise the OUM integration with the STG-DC specification, a pattern is generated when executing the commands. This pattern consists of a series of database records that allow the

traceability of the message in order to correctly communicate the head-end system with the MDM. They contain the necessary information to identify the request, the destination, and the format of the request for its correct processing and to allow the user to monitor and act accordingly.

It can be seen in the diagrams shown in Annex X how three registers appear in the first level and how they are updated in the following levels. These three registers are:

- *Process Monitor*
- *Telemetry_Request_Task_Execution_Group*
- *Telemetry_Request_Task_Execution*

However, although it does not appear directly, intrinsically before generating these three main records, when the MDM executes a manual or scheduled task, it generates another record:

- *Telemetry_User_Request*: This register is in charge of creating the requests in the database. These requests are created in "Prepared" status so that the corresponding Job can later update the records by changing their status for each stage and case that the communication protocol presents.

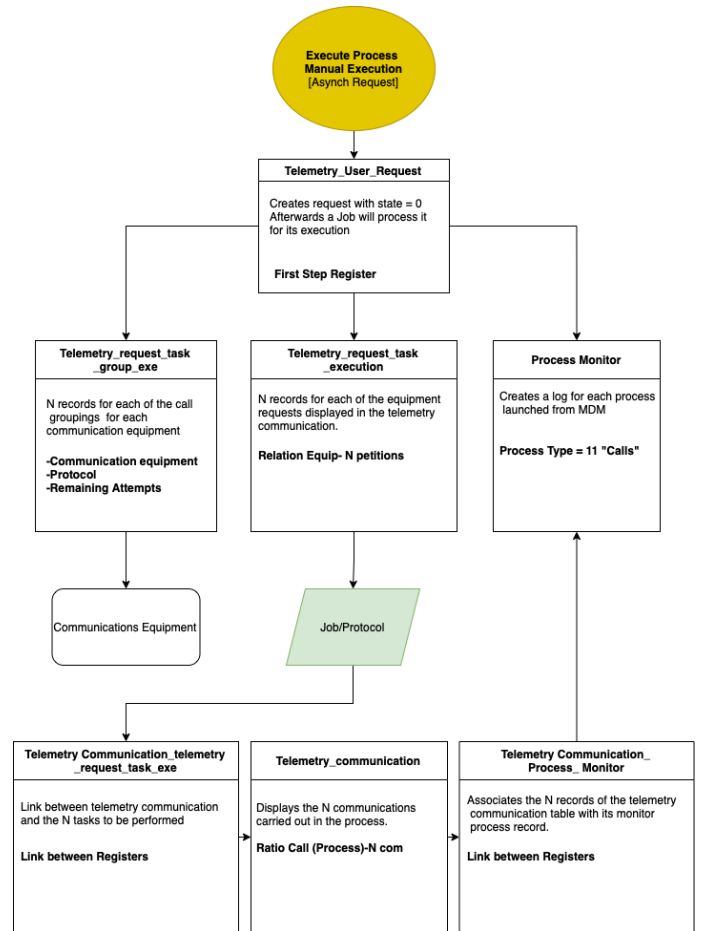


Figure 9: Registers Interactions FlowChart

Knowing these processes at the database level is fundamental to understand the programming logic and the creation of the flowcharts proposed in the project. The generic interaction

scheme that these registers follow is as represented in Figure 9.

This Case Study is presented in the long document corresponding to this project.

V. CONCLUSIONES

In this master's thesis, a functional analysis of the integration of PRIME's STG-DC protocol with Minsait's Onesait Utilities Metering technology has been developed. This functional analysis is featured by its technical component that describes in detail the structure of the communication processes and the main interactions between metering equipment in order to carry out an efficient and organised low-level programming of the different OUM modules.

This project has been approached and developed from an academic perspective within a work environment, so that the practical manual developed in it can be used for the training of professionals within the business environment. To synthesise this vision, it has been decided to schematise the communication flows in flowcharts that allow the reader to follow step by step the communication interactions in a visual and orderly manner.

Therefore, it can be concluded that all the project objectives listed in chapter 1 have been covered, from the study of the STG-DC specification and the Onesait tool to the development of these diagrams.

Additionally, a case study of the execution of a "Manual Request" has been developed to provide the reader with greater visibility of both the user experience and the communication interactions between the different entities involved in the communication process.

Under my point of view, as we move forward, the processing of massive data is becoming more and more important, and the electricity sector is no stranger to this. For this reason, integrating tools such as Onesait Utilities Metering plays an important role due to the value they add to the business. OUM acquires measurements from multiple sources and protocols, incorporates them into a unified repository and processes them, increasing energy efficiency, reducing operating costs and the risk of fraud, and locates anomalous behaviour in the network, reducing the risk of outages.

Finally, the next step to take as Future Works would be to put this manual into practice and start programming requests in OUM under the STG-DC protocol. It is proposed to carry out a modular work in which the scripts of each request can be used to programme the adjoining requests in the same way as has been done with the flowcharts, making a coherent classification.

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