Energy@home Technical Specification

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Notice

Version: 2.1

Scope

Scope of this document is the specification of the Home Area Network (HAN) architecture, the set of devices and application-layer messages that supports Energy@home use cases [R1]. This document is based upon [R8] and it extends ZigBee specifications by defining new ZigBee devices and clusters, leveraging on both the functionalities of ZigBee-based application specification (profiles [R2] - [R5] and CENELEC interworking specifications ([R6] - [R7]). As consequence, clusters taken from both ZigBee Home Automation and ZigBee Smart Energy profile have been adopted by the Energy@home Association and all the new extensions have been designed to be potentially mapped as an extension of existing standard Public profile. On 2013, the ZigBee Alliance agreed to include those extensions into the ZigBee Home Automation profile 1.2 standard ([R11]). This Energy@home document extends the ZigBee Home automation Profile 1.2 standard by introducing new cluster proposals (Overload management, Storage Unit and Renewable Energy Production clusters) and more detailed information related to the Smart Info functionalities and CEMS algorithms.

Foreword

Energy@home is a no-profit association that aims to develop & promote technologies and services for energy efficiency in the home, for the benefit of the environment, based upon device to device communication. Its goal is to promote the development and widespread of products and services based on the collaboration of the appliances within the household and their integration with the Smart Grid.

The Association was founded on July 2012 by Telecom Italia, Electrolux, Enel Distribuzione, and Indesit Company and it is open to new members. At the time of writing the Association counts 26 members from different industries: the electrical system industry (Enel, Edison, and ABB), household appliances manufacturers (Electrolux, Indesit Company, Whirlpool, and Eurotherm), telecommunications (Telecom Italia, Deutsche Telekom, and Vodafone), ICT companies (Reply, and Altran), micro-electronics vendors (Freescale, Renesas, and ST Microelectronics), assurance companies (Europ Assistance, and Assurant Solutions), home automation manufacturers (Gewiss) as well as research institutes (Istituto Superiore Mario Boella), small/medium-sized companies (URMET, Fly-By, MAC, Gemino, and Reloc) and startup (Apio, Lyt Inc).

The Energy@home Association aims to use the new information technologies and electronic equipment's to transform the home environment in an eco-system of devices that communicate with each other's: the electric meter, household appliances, electrical system, and the network of broadband telecommunications, small renewable power plant and energy storage. Communication allows these devices to be integrated in a smart way, increasing energy efficiency, reliability and security of the domestic energy system, and giving consumers more information and power of choice.
The activities of the Association are organized into working groups and, in addition to the definition of architectures and technical specifications, include the analysis of the use cases and the impact on the regulatory environment, experimenting with pilot projects and the dissemination of the specifications.
Energy@home is an acknowledged contributor to the ZigBee Home Automation 1.2 standard that integrates devices, functionalities and use cases of Energy@home.

Acknowledgements

This document is the result of the activities inside the E@h Standardization Working Group. On behalf of the Energy@home Association, we would like to extend our thanks to all internal and external member who participated in the development of this document. Without the broad support from all of them this work would not have been possible.

Founding Members

Ordinary Members

Aggregate Members

Related Documents

[R1] *"Energy@home Use Cases",* Energy@home Association, Rev. 2.0, May 2014
[R2] *"ZigBee Cluster Library Specification"*, ZigBee Application Framework Working Group, ZigBee document number 075123, October 19, 2007.
[R3] *"ZigBee Home Automation Public Application Profile-Version 1.2*", ZigBee Standards Organization, ZigBee document number 05-3520-29, June 6 2013
[R4] *"The ZigBee Specification",* ZigBee Technical Steering Committee (TSC), ZigBee document number 05-3474-20.
[R5] *"ZigBee Smart Energy Profile Specification"*, ZigBee Standards Organization, ZigBee document number 075356r14, May 29, 2008.
[R6] *"Household appliances interworking - Part 1: Functional specification"*, BSI British Standards, document BS EN 50523-1:2009, July 2009.
[R7] *"Household appliances interworking - Part 2: Data structures",* BSI British Standards, document BS EN 50523-2:2009, July 2009.
[R8] *"Use Cases: Smart Appliances Requirements and Data Structures**",*** Indesit Company S.p.A., Rev. 1.0, March 22, 2010 (available on request).
[R9] *"Energy@home, ZigBee and EN50523",* Indesit Company, Telecom Italia, Rev. 1.0, March 22, 2010 (available on request).
[R10] *"ZigBee Smart Energy Profile specification",* ZigBee Standards Organization, ZigBee document number 075356r15, December 1, 2008.
[R11] *"ZigBee Home Automation Public Application Profile-Version 1.1",* ZigBee Alliance, March 2010, ZigBee document number 075367r03
[R12] "*Smart Grid Coordination Group – Sustainable Processes*", CEN-CENELEC-ETSI, public available at http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/xpert_group1_sustainable_processes.pdf
[R13] "*QPSOL: Quantum Particle Swarm Optimization with Levy's Flight*", E. Grasso, C. Borean, Telecom Italia, ICCGI 2014 (The Ninth International Multi-Conference on Computing in the Global Information Technology), www.thinkmind.org/download.php?articleid=iccgi_2014_1_30_10119

Change history

The following table shows the change history for this specification.

Revision	Description
2.0	Original version (public)
2.1	Introduced two new sections related to the Retrieve Load Profile Data and Overload Management scenarios.

Table 1 – Document revision change history.

Information in this document is preliminary and subject to change, however anyone is encouraged to review and provide comments at the following e-mail addresses:

comments@energy-home.it

Energy@home reserves the right to publish future versions of these specifications without any prior notice.

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1 Introduction

Following the European roadmap for the implementation of the Smart Grid[1], where concepts like flexible demand and generation are taken into account, one of the cornerstone requirement for the support of an efficient integration of renewable energy sources into the energy system is the flexibility that a customer could offer to the Smart Grid actors through a so called "Smart Grid Connection Point", that represents the physical and logical interface from the customer to the grid.
The generic architecture that describes the functions involved in the interactions between the Customer and the Grid actors is reported in Figure 1 (page 45 of [R12]).

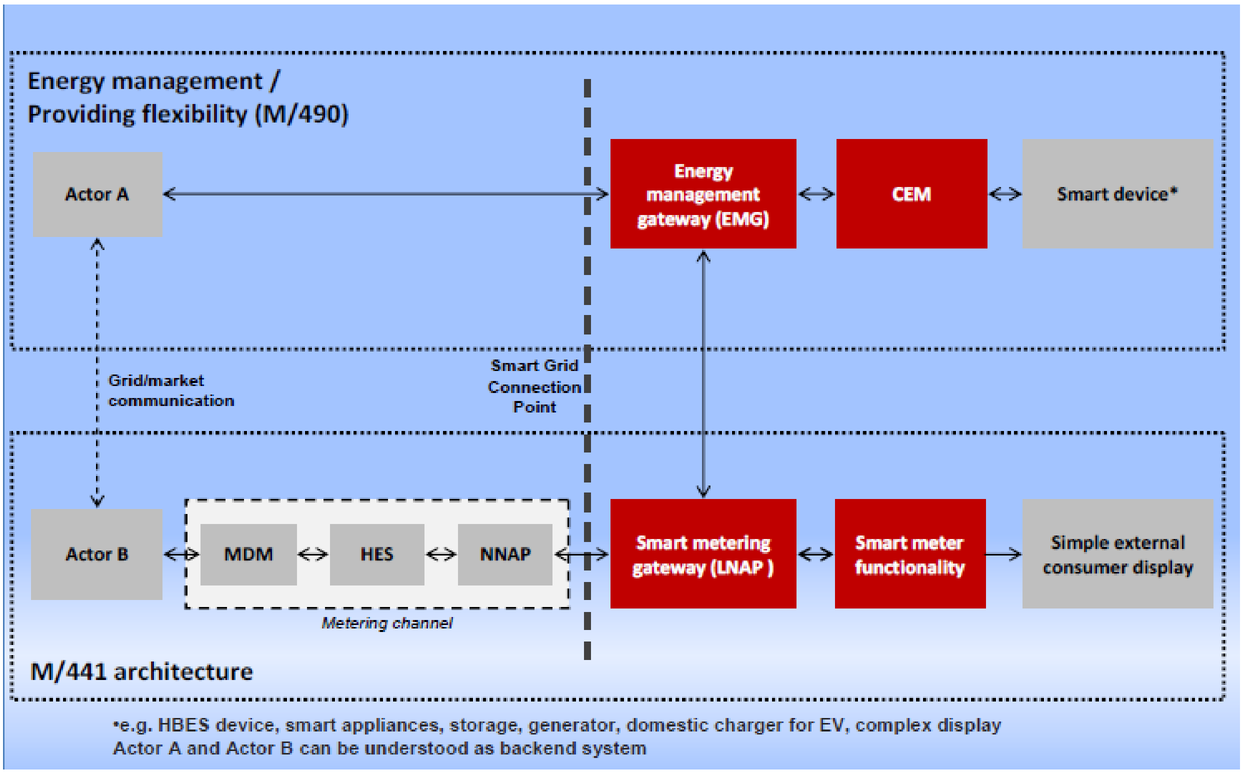


Figure 1: Flexibility functional architecture (Source ETSI-CEN-CENELEC, Smart Grid Coordination Group)

The functional components represented in this figure could be implemented/aggregated in different systems and devices. In this document it will be shown how this generic functional architecture can be mapped in the Energy@home architecture. The Association adopted the system architecture shown in Figure 2, providing to the customers new value added services ranging from simple energy consumption awareness, up to a fully integrated energy management system. The architecture is expected to increase in scope as a result of the on-going collaboration activities and interests of the Energy@home members.

In a Home Domain (later shown in Figure 22), that includes both the HAN (Home Area Network) and the HN (Home Network)[2], all the actors (home devices, CEMS, Smart Info and Customer

[1] Developed by the "Smart Grid Coordination Group" as requested by the European Commission, mandate M/490. Reference: http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/xpert_group1_sustainable_processes.pdf

[2] As reported in the glossary section, the HAN and the HN indicate a residential local area network usually characterized by respectively low and high throughput. HAN is often referred also as PAN (Personal Area Network), while the HN can be wireless (e.g. Wi-Fi) or wired (e.g. Ethernet).

Interfaces) can cooperate through communication mechanism. The aim of Energy@home is to identify and describe the requirements of indoor and outdoor platforms.

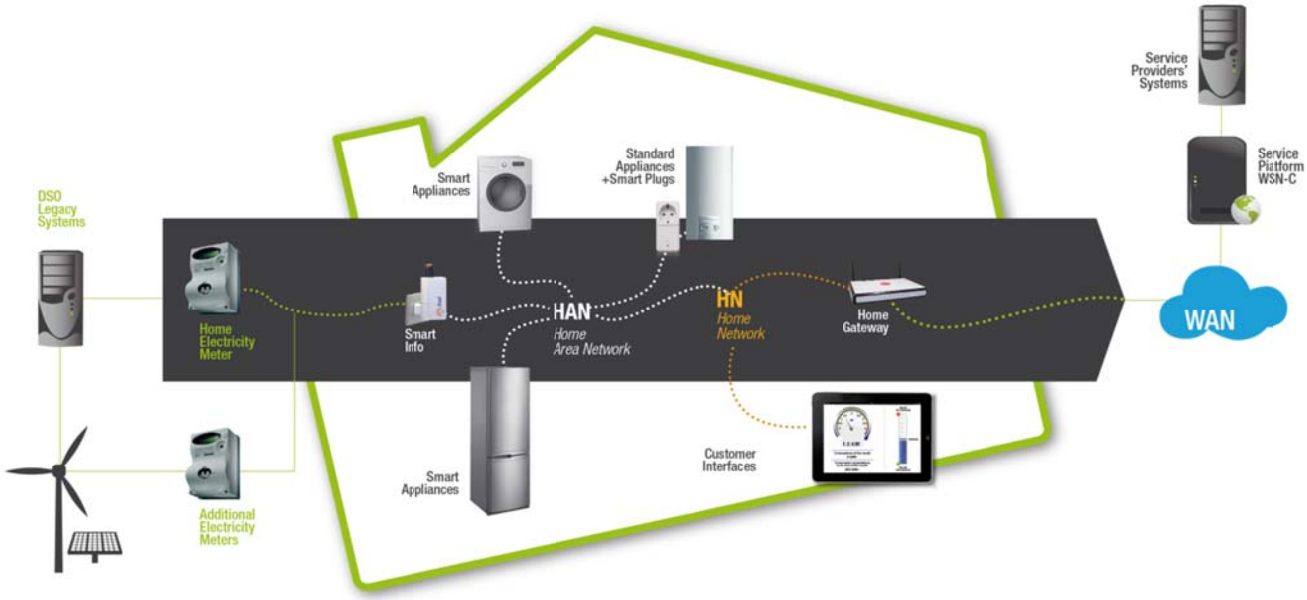


Figure 2: Energy@home architecture

Devices in the HAN communicate with each other via the wireless protocol ZigBee Home Automation version 1.2 developed in collaboration between the ZigBee Alliance and Energy@home and officially ratified in July 2013. These international specifications define all levels of communication including the syntax and semantics of application messages exchanged between the user devices. This ensures full interoperability between systems and devices from multiple vendors.

The HAN will interface with the DSO meter using a smart metering gateway (Smart Info) that provides measurement data recorded by the electronic meter communicating with it via the DSO (Enel Distribuzione) power-line protocol. On the other side, this device is part of the Home Area Network and it communicates using the ZigBee protocol: it can be configured to send push data received from the all the DSO meters and can be queried in polling to acquire on-demand data.

The HAN devices are divided into "legacy devices" and " smart devices”. The first are traditional devices that do not implement any communication skills and can only be controlled through a Smart Plug. In Energy@home have been defined all the messages needed to configure these smart plugs, to receive energy data and instantaneous power, and where the load permits, to control the switch on/off remotely. Smart devices are connected devices for which the messages are defined to identify the type of load (e.g., type of appliance, supplier name, firmware version, etc.) as well as to monitor and control the start and the status of operation, to communicate information to diagnose problems as well as the transmission of statistical information and the tunnelling of manufacturer proprietary information of the appliance. Every electrical load of a smart device can be planned through a scheduling algorithm that uses the data structure defined in Power Profile.
The Power Profile is a vector which represents the energy needs of a device, in the case of a washing machine each element of the vector represents a phase of the washing. Each element is a schedulable phase not interruptible described by 4 fields: the maximum power required, the estimated time required, the expected energy consumed and, finally, the maximum delay allowed

scheduling the phase. The CEMS collects the Power Profile of all devices connected and performs a scheduling algorithm to calculate the delay of each stage for each device; this permits to optimizes the total demand in terms of maximum power and hourly cost of energy that, of course, is always subject to any restriction set by the client (such as the time of termination of a wash) and to the availability of energy from power plants and storage systems in the home.

The main actors in the Home Domain are the following ones:

- **Smart Appliances:** an evolution of the actual and standard white goods; see hereunder some of their possible new functionalities:
    - Display to the customer information on their energy consumptions (e.g. used energy, instant power, etc.)
    - Dispatch in the HAN information on their energy consumptions
    - Autonomously adapt their behaviour according to information on energy consumptions coming from the house. (e.g. reduce their load when global house consumptions goes beyond a threshold)
    - Cooperatively operate with other entities in order to optimize the energy usage through load shifting and load shedding

    In any case, the load control operations either performed autonomously or under an external supervision, shall be performed under the complete control of the appliance, which assures the correct execution of its working procedure and its results and performances. For example, a smart washing machine, when requested to modify its consumption behaviour, shall assure the result of the washing cycle.

- **Smart plugs** (able to provide remote metering and to be remotely controlled) could be somehow included in the Smart Appliances category although they can provide no direct control over the effect of remote control activities. In particular, Smart Appliances will not be controlled by Smart Plugs
- **Customer Interfaces:** see hereunder some of their possible functionalities:
    - Display information on energy usage like instant power, historical data, contractual information and similar, from the whole house (coming from the Smart Info) and from every single smart appliance. The level of details and graphical layout of their user interface is freely defined by every device
    - Transmit control message to Smart Appliances to request a modification of their behaviour
    - Configure Smart Appliances to modify their power consumption profile (e.g. a personal computer used to configure a thermostat to activate the controlled load only in certain time slots)

  The Customer Interface, from this perspective, is connected in the HN/HAN; it is foreseen the possibility to have Customer Interfaces accessing the house from the WAN through a specific interface, but the definition of this interface is out of the scope of the Energy@home project as previously stated.
  Typical Customer Interfaces are personal computers, Smart Phones, PDAs, ad hoc displays, entertainment systems, in-house monitor and similar. The software application, which implements the user interface, could be local in the device or remotely hosted in another device (e.g. the Home Gateway) and accessed through web-services.
- **Customer Energy Manager System (CEMS)** The CEMS is CEM integrated with communication functionalities, it is the gateway between the HAN, the HN and the WAN (e.g. internet). The CEM is a logical function optimizing energy consumption and or production

based on signals received from the grid, consumer's settings and contracts, and devices minimum performance standards. The Customer Energy Manager collects messages sent to and received from connected devices; especially the in-home/building sector has to be mentioned. It can handle general or dedicated load and generation management commands and then forwards these to the connected devices. It provides vice versa information towards the "grid / market". Note that multiple loads/generation resources can be combined in the CEM to be mutually controlled.

- **Smart Info:** it is the element, provided by the DSO, which dispatches energy related information into the HAN. Published data are a sub-set of those already available inside the Home Electricity Meter, hence the Smart Info acts like a proxy of the meter. Additional data could be possibly generated by the Smart Info itself. Noticeably, near real-time instant power (sampled at of about 1 Hertz frequency or higher) should be acquired by another metering device, likely embedded inside the Smart Info. Additional elements (SI') can also be provided by third parties and used to dispatch data generated by other meters into the HAN.

Outstanding components outside the Home Domain are:

- **WSN-C:** Wireless Sensor Network Center: it manages, together with the Home Gateway, the HAN devices and provides service oriented interfaces for the development of third-party applications.
- **Electricity Meter:** An electric meter, able to measure and record usage data in time differentiated registers, and capable of transmitting such data to central utilities system. Moreover, the meter should provide bi-direction communication to allow remote management of the meter.
- **Aggregator:** mediator between consumers and AD buyers, collects requests and signals from the AD buyers, pools flexibilities of consumers to build Active Demand services and makes offers to the markets.

Please note that the proposed classification is mainly intended to identify the main categories of devices in the Home Domain, without any limitation to the possibility for a device to implement functionalities from more than a category. As an example, an advanced Smart Appliance, provided with a rich user interface, could also implement functionalities typical of a Customer Interface. In the same way, while typical smart appliances are smart white goods, also a personal computer, able to perform such operations, should be considered an appliance from this perspective.

2 Sequence diagrams

This section reports a set of sequence diagrams that show the possible interaction between E@h devices. For a full and detailed description of the use cases please refer to [R1].

2.1 Control modes

The interactions between the Energy@home devices can be operated in two different control modes, depending on how each device is willing to participate to the overall system control operation:

- **E@h control disabled:** In this operating mode there is no E@h control. The awareness scenario is covered, but the devices in the E@h network shall not be scheduled and controlled by the Home Gateway or energy Management System;
- **E@h control enabled:** In this case the operating mode is with E@h control, where a full set of Energy@home features are used, e.g. the appliances can be automatically scheduled according to the needs of the user or the pre-emptive and reactive control on the devices is allowed.

Selection of the control mode has to be harmonized by the functional controller (e.g. the Home Gateway or Energy Management System), and how that is done and how it is selected by the user is implementation specific and is outside the scope of these specifications: for instance, a special button on the appliance might be used or, alternatively, a special function on the Central User Interface may be adopted, depending on the implementation.

2.2 Startup and discovery

The device association and discovery procedures are dependent on the underlying protocol used (see for example chapter 4 for the mapping of Energy@home procedures into ZigBee protocol). However, the general startup procedure shall follow the steps listed below, still depending on the operating mode:

1. Case of a Home Gateway NOT present:

Since the Home Gateway is not available, the admission procedure should be managed by another device of the network, responsible for the authorization and authentication of the new HAN devices willing to join, which shall provide user with a user-friendly interface; alternatively, if no user interface would be supported by this device, a pairing mechanism with the other HAN devices shall be enabled (such as button pressed or other peering techniques).

2. Case of a Home Gateway present:

- The Home Gateway opens the network (i.e. enable other device joining the HAN) through an interaction from the user;
- The Home Gateway manages the authorization and authentication of the new HAN devices willing to join the E@h network;
- The services offered by the HAN devices shall be automatically discovered using the underlying protocol service discovery procedure: the E@h devices shall then detect the addresses of the devices they are required to communicate to;
- An auxiliary mechanism for enabling the configuration of the HAN by using an interface exposed by the Home gateway could be supported as well;

An example of sequence diagram for Smart Appliance and Smart Info joining a Home Gateway is reported in Figure 3.

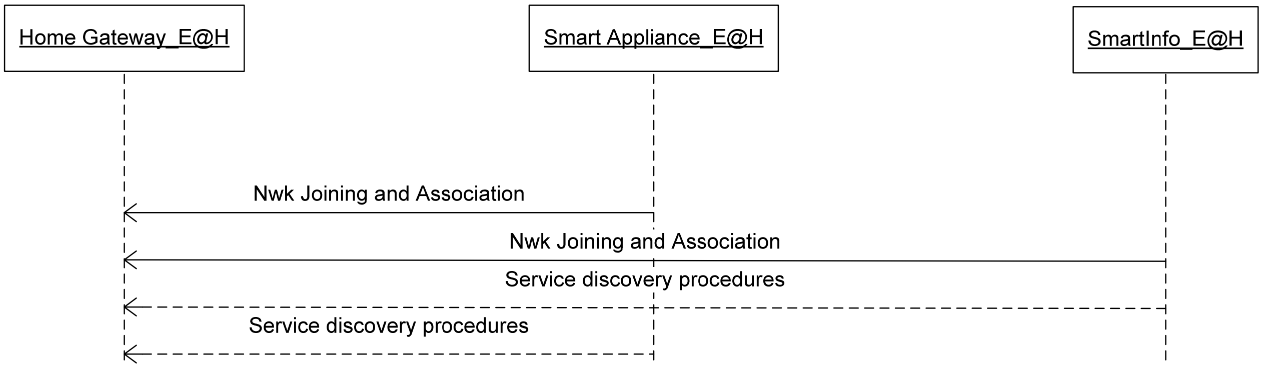


Figure 3 – Startup and discovery procedure.

The service discovery procedure shall leverage on the procedures defined by the communication protocol.

2.3 Customer Awareness

One of the simplest and basic scenario reported in [R1]is the visualization of current energy, power and price data the sequences of messages representing a possible implementation of those scenarios are depicted in Figure 5 and Figure 6. The energy, power and cost information should be distributed on the E@h network using those procedures.

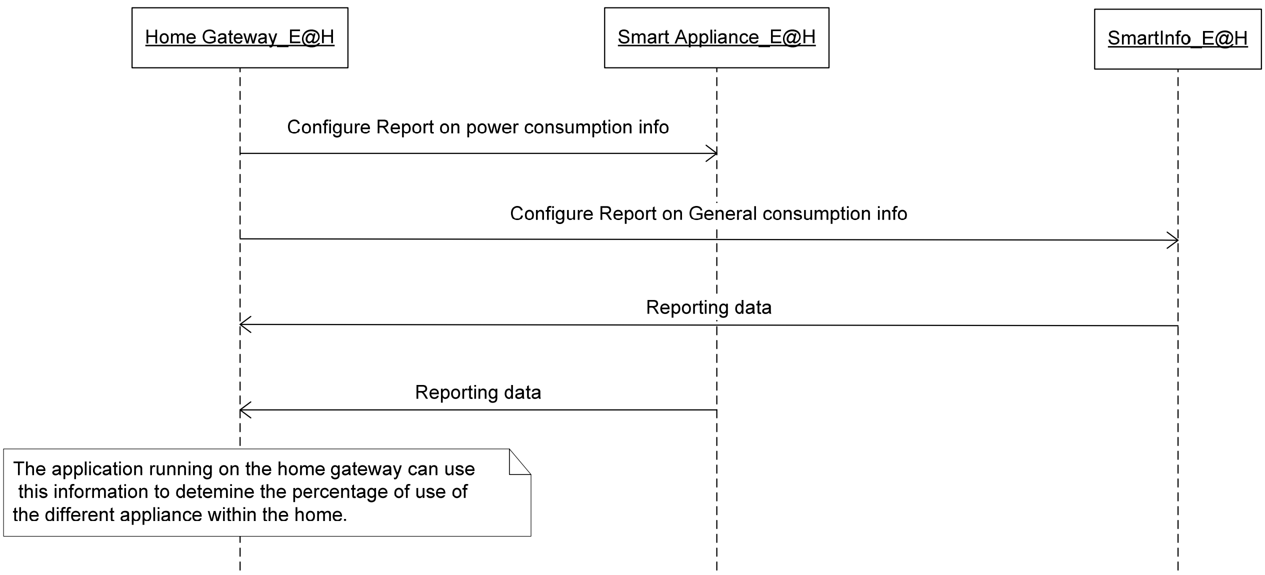


Figure 4 – configuration of energy, power, and price reporting procedure.

In case the Home Gateway is operating in the E@h network it shall acts as a mirror for the information to the other devices on the HAN: that means that the Home Gateway shall maintain up to date data related to energy, power, and energy cost (if required), associated to each device as well as metering data from the Smart Info related to home global consumption. The devices willing to access this information should access the mirrored information in the Home Gateway. That mechanism provides the following main advantages:

- It enables the support of sleeping devices in the network: since devices may sleep in the network, the Home Gateway (always-on device) should buffer the data to be retrieved by other devices in the HAN;
- It reduces the need of broadcast messages enhancing the performance in case of wireless E@h network: the mirroring feature on the Home Gateway enables the other devices to communicate in unicast to the gateway itself, reducing the need of the broadcast messages in the HAN.

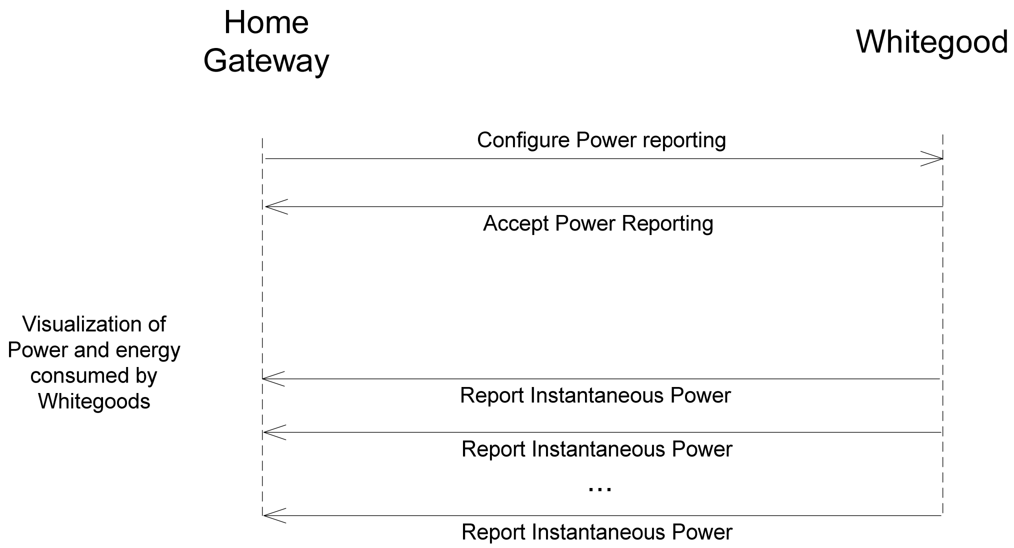


Figure 5 – configuration of instantaneous power reporting on appliances.

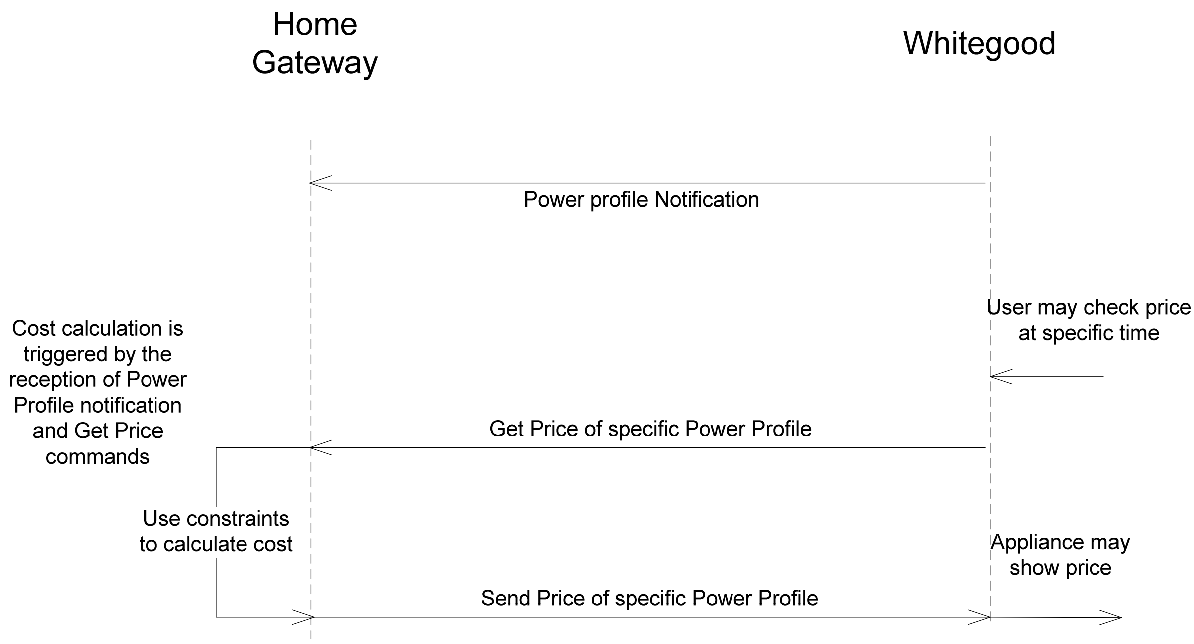


Figure 6 – Visualization of price associated to a power profile

2.4 Appliance regulation

The descriptions of these interactions are reported in different examples and sequence diagrams: the interactions and the message flows represent only example of possible interactions. Please notice that they might be different according to implementations and feature support.

2.4.1 E@h control disabled

In the following example it is described a possible interaction with the user and the expected messages exchanged between the smart appliances and the Home Gateway.

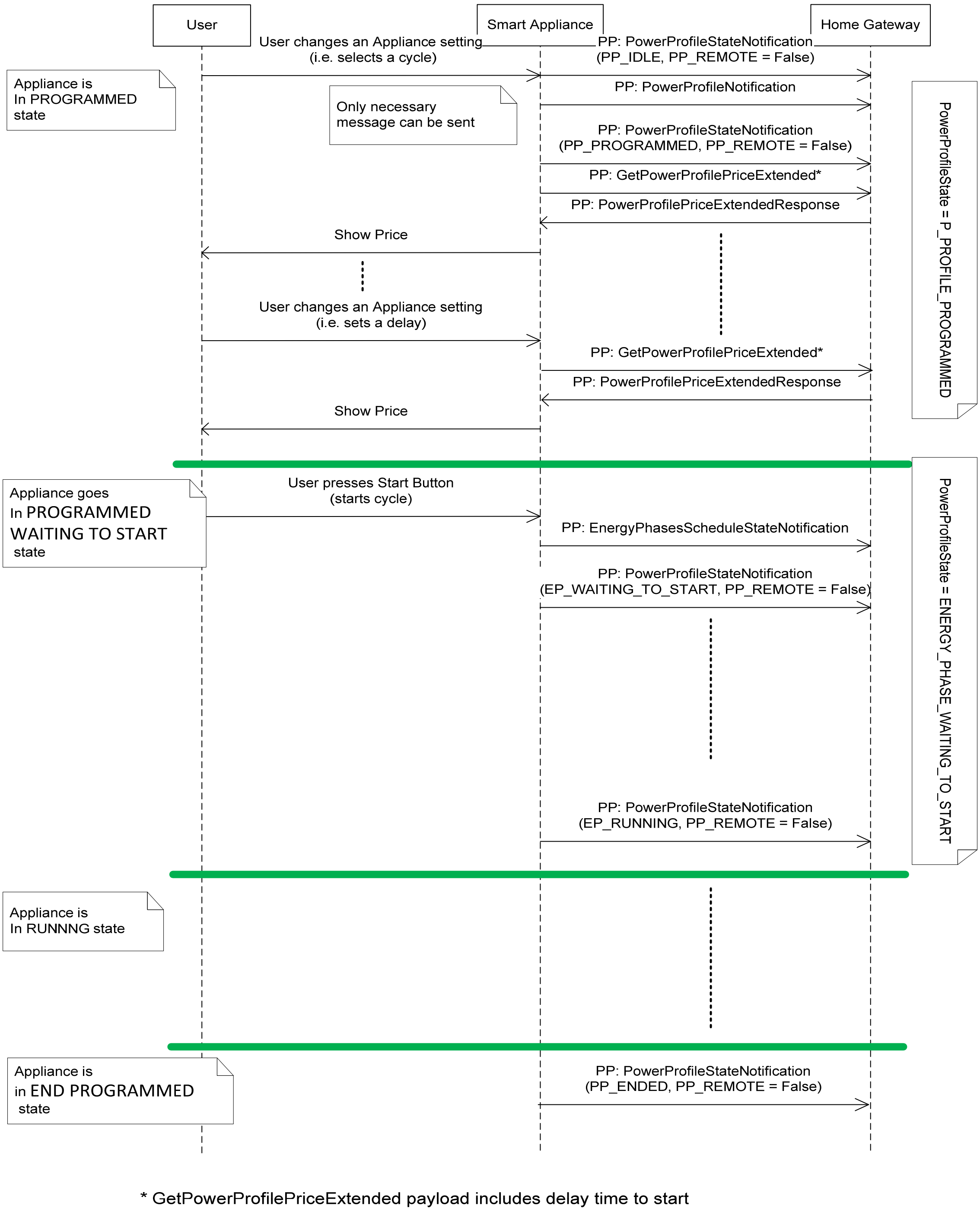
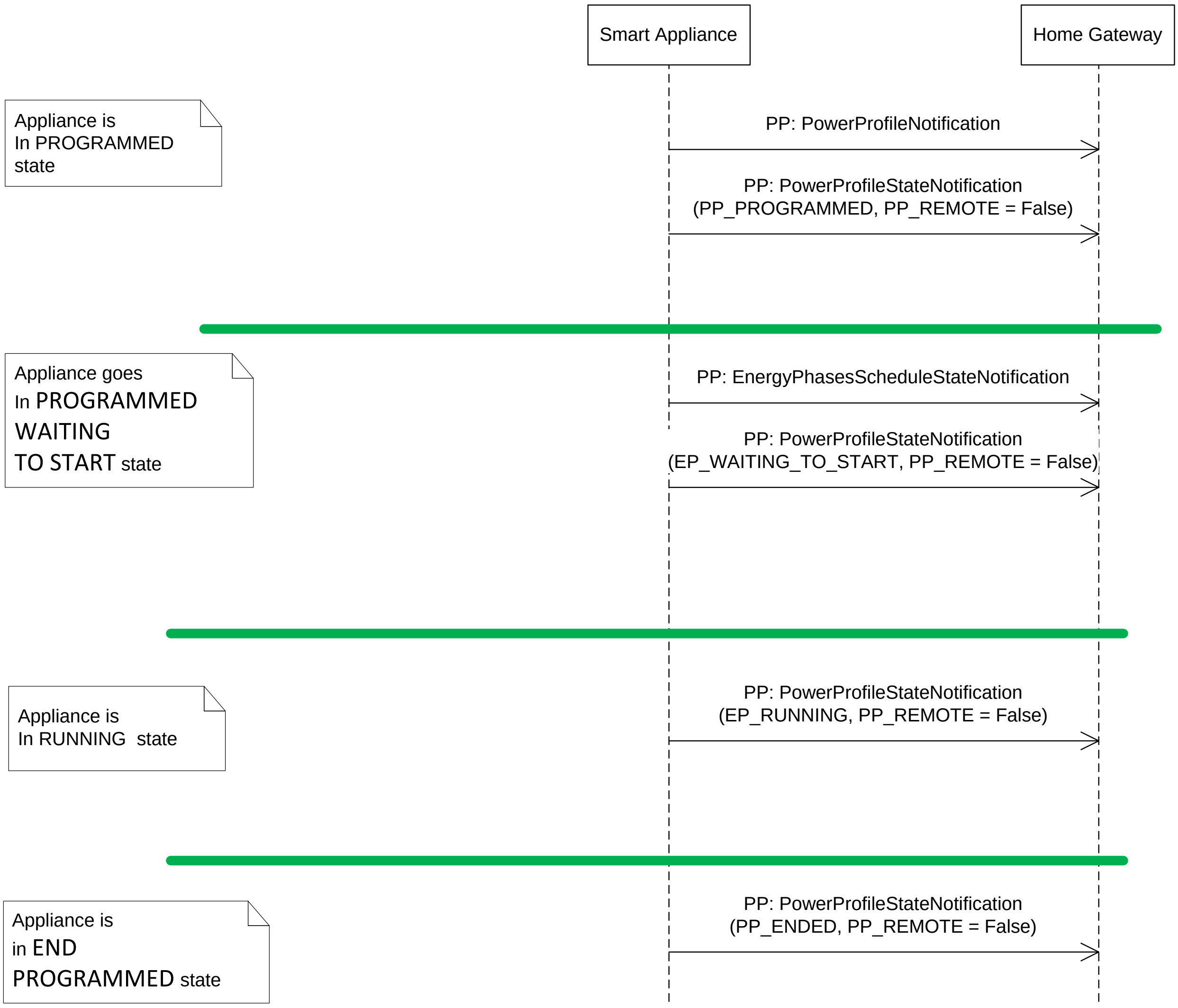


Figure 7 – E@h control disabled: example of sequence diagram with user interaction.



* GetPowerProfilePriceExtended can be generated any time by SA if a PP is active

Figure 8 – E@h control disabled: example of sequence diagram.

When the total instantaneous power used by the house (measured in kW and described by the attribute *InstantaneousDemand* in case of ZigBee) exceeds the contractual limit (described by the attribute *DemandLimit*), we reach an **overload condition:** the HG starts to send periodically to the Appliances (e.g. every 60 seconds) an "Overload Warning" message, an alarm that will be reset by sending once the "End of Overload Warning" message when the total instantaneous power returns below the limit[3].

[3] Issue #194

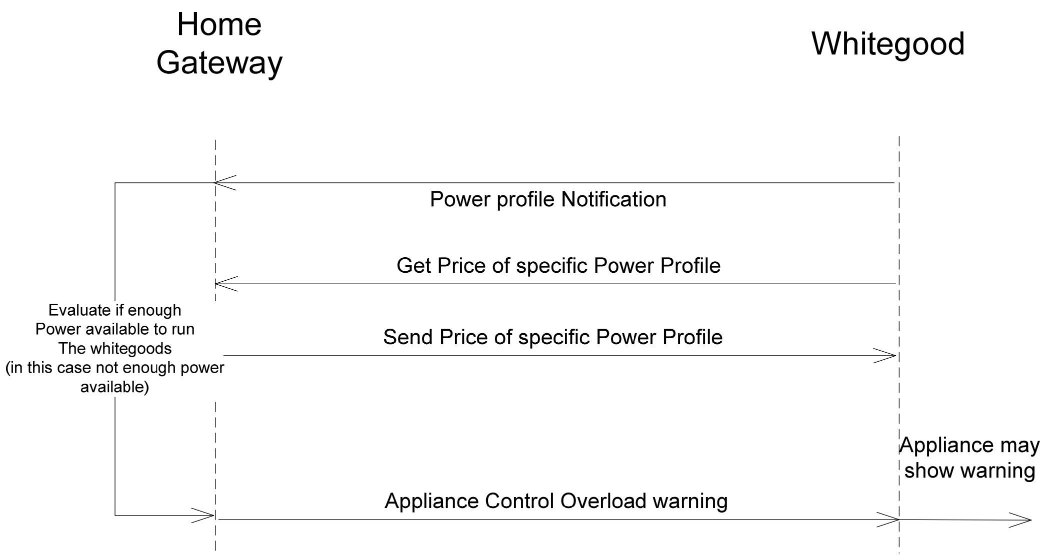


Figure 9 – E@h control disabled: Overload warning

2.4.2 E@h control enabled

In the following example it is described a similar scenario as previously described in 2.4.1, but where the Energy@home control is enabled.

2.4.2.1 Reactive control (overload management)

In Figure 10 is reported an overload management sequence diagram, with reactive control.

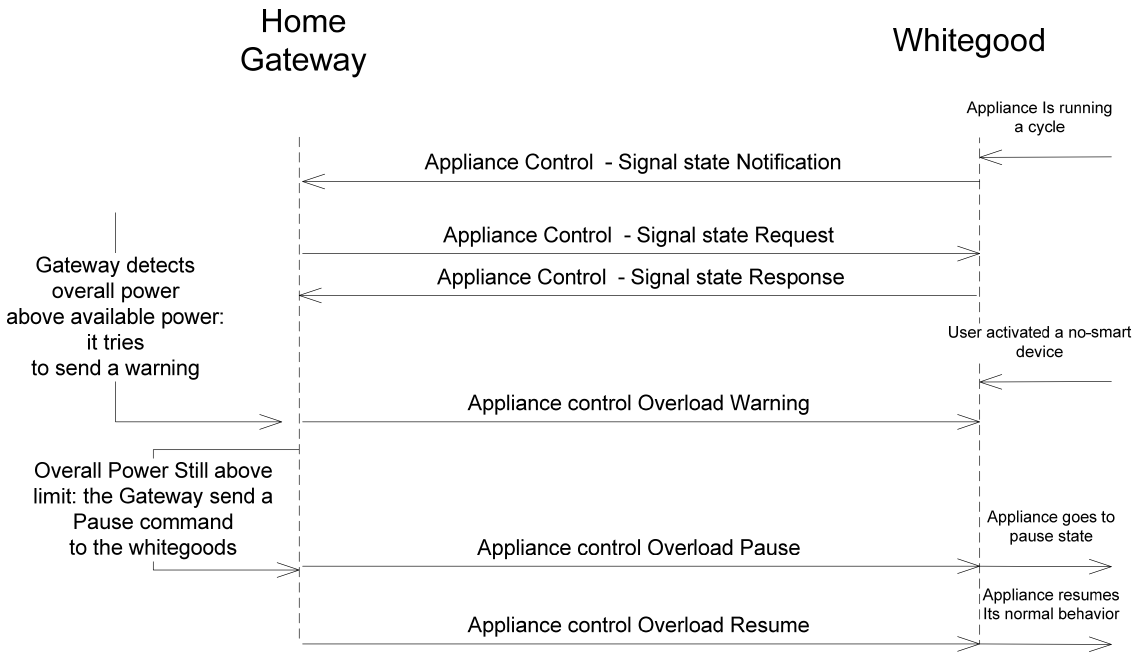
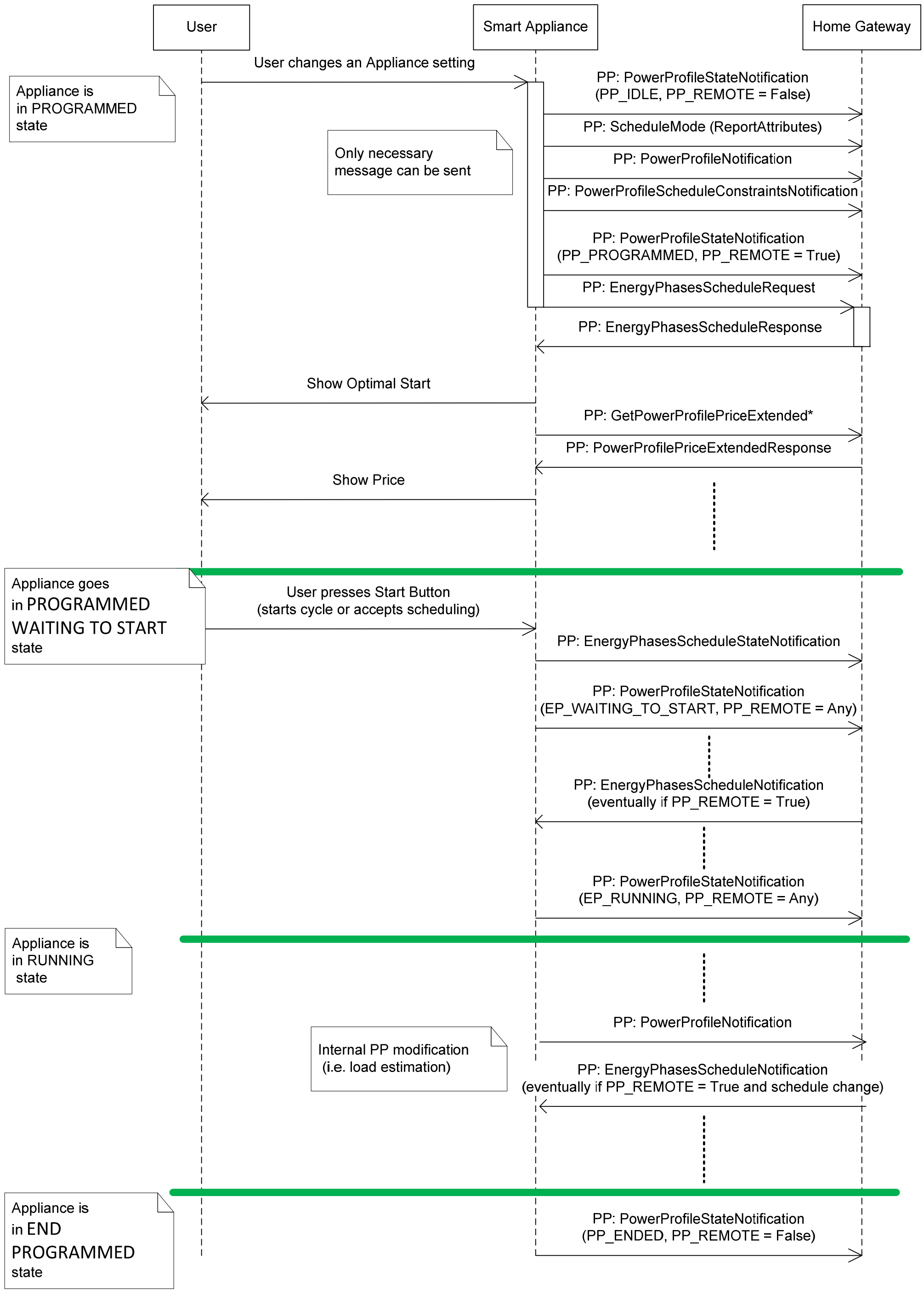


Figure 10 – E@h control enabled: sequence diagram of reactive control (overload management).

2.4.2.2 Pre-emptive control (scheduling)

In Figure 11 and Figure 12 are reported a sequence diagram that shows how the scheduling phase is accomplished in Energy@home.



* GetPowerProfilePriceExtended payload includes delay time to start

Figure 11 – E@h control enabled: example of sequence diagram with user interaction.

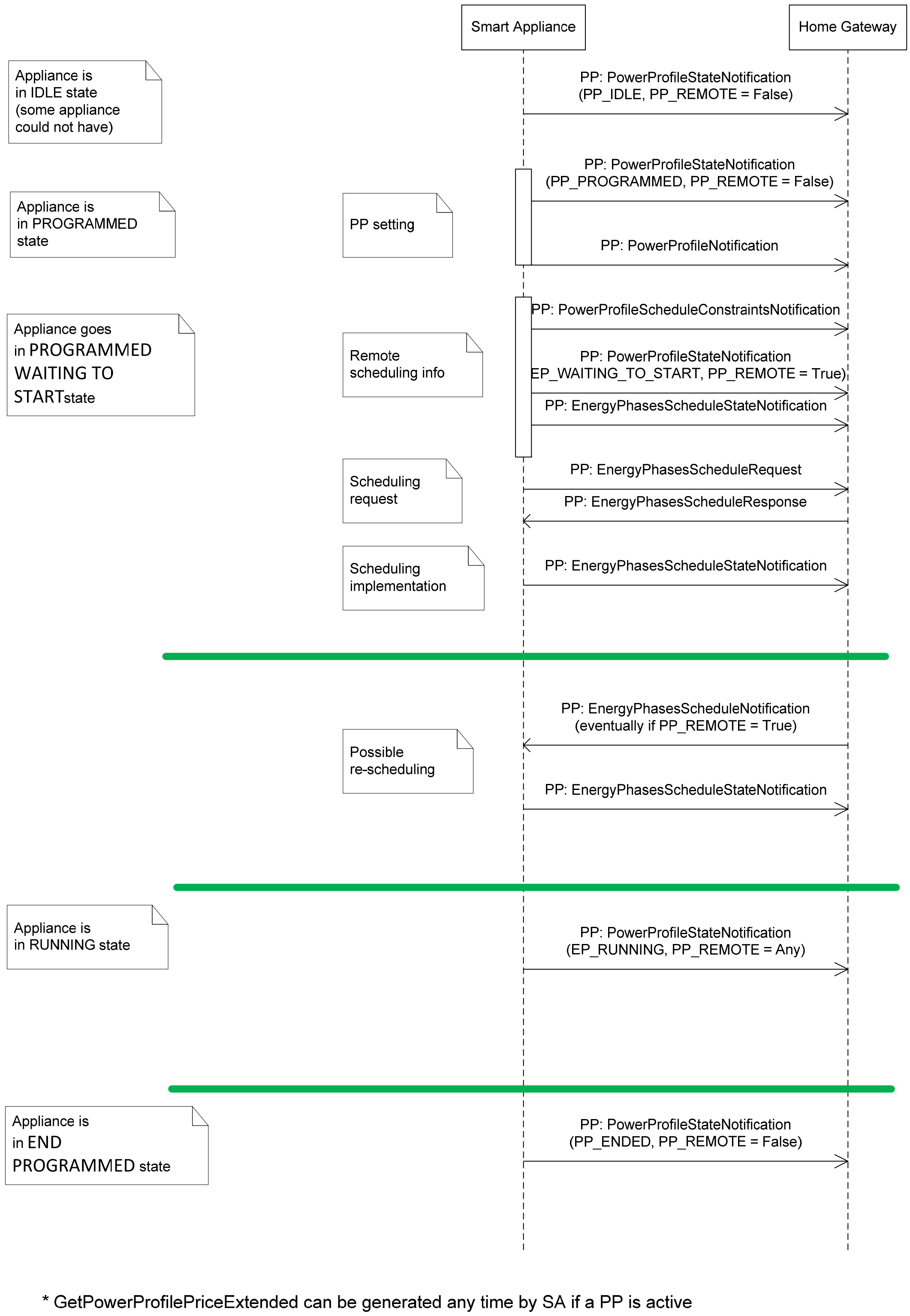


Figure 12 – E@h control enabled: example of sequence diagram

2.5 CEMS algorithms

A typical CEMS algorithm shall perform the following steps:

1. **Pre-emptive phase**: It performs a preventive control whenever possible using the following metrics:
   - Overload avoidance
   - Energy Bill optimization
   - Minimizing the tardiness on an expected appliance tasks
   - Maximize the use of local power generation when available
2. **Reactive phase**: it performs a reactive control on the controllable devices when the following cases occur:
   - Possible overload (above the contractual power)
   - Expected overload (above the power limit)

The general flow of the CEMS is shown in the figure below:

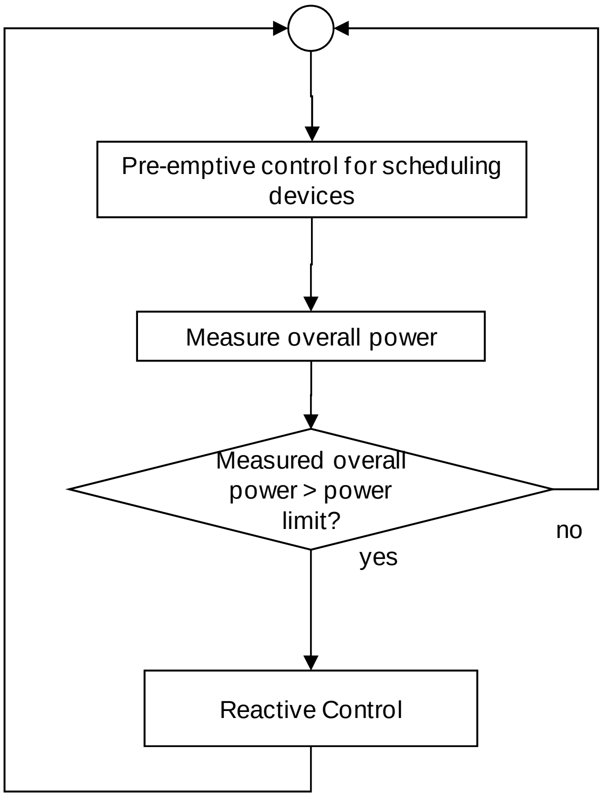


Figure 13: General flow of CEMS

2.5.1 Pre-emptive phase (scheduling)

A fully-compliant implementation of a CEMS is required to implement the scheduling function. This section is informative and it describes possible methods for scheduling smart appliance in order to perform energy management optimization.

Pre-emptive phase

The pre-emptive phase followed by the CEMS system is described in the following figure. The system proceeds with an estimation of the overall power (performed using historical data and the predicted user behavior considering the time of the day); if the estimation is already beyond the power limit of the meter, the System proceeds with the reactive mode.

If the estimation is below the power limit, the system checks if there is any requests by the Smart Appliances or devices to start operating. If there is a request, the system will decide if the scheduling needs to be operated:

1. **locally** on the Home Gateway:
2. **remotely** on the remote platform;
3. **locally** and **remotely** in parallel.

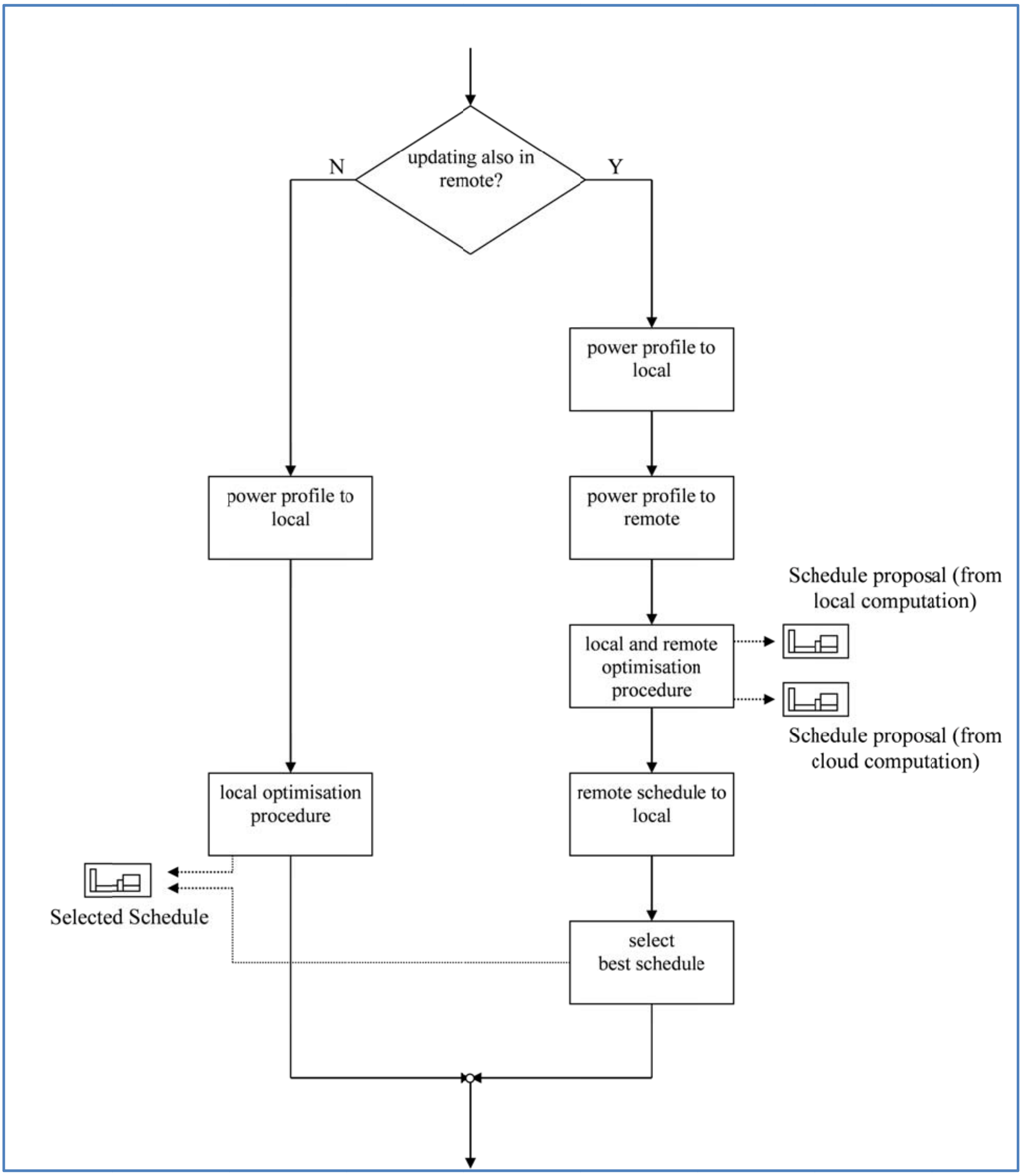


Figure 14: Pre-emptive phase

In the first case the Smart device notifies the gateway with the estimated power of the cycle that is about to start; the gateway then schedules the proposed time to start the device considering the metrics required by the service, according to the algorithm used (see next section). In case of remote scheduling the pre-emptive phase is managed by the scheduling algorithm running in the cloud and the scheduling time for an appliance is delivered to the Home Gateway which distributes the scheduling to the device. In the third case the calculation is started in parallel in the local and remote CEMS and the best results received after a fixed amount of time are taken. The third approach guarantees the best performances and can operate also in case of fault between the communication between the Home Gateway and the remote platform.

Please note that in case of remote scheduling the Smart devices could just send information about the type of energy cycle that is required to be operated since the remote platform could retrieve from stored data and match the appropriate power estimation curve over time; the remote platform could then use this curve to schedule the device and assign the proper time for the device to start according to the metrics required by the service.

Given the problem formulation, the scheduling of Power Profiles, each composed by a set of sequential phases (possibly to be delayed), under energy constraints is classified in the more general family of **Resource Constrained Scheduling Problem** (RCSP), which is known as being an NP-Hard combinatorial optimization problem. For easy problems, exact methods can be exploited, such as Branch&Bound and Mixed Integer Linear Programming (MILP), with back-tracking and constraints propagation to prune the search space. However, in most circumstances, the solution space is highly irregular and finding the optimum is in general impossible. An exhaustive method that checks every single point in the solution space would be infeasible in these difficult cases, since it takes exponential time.
A better approach for solving complex NP-Hard problems that has shown great success is based on **metaheuristic** algorithms. In Annex 2 the Quantum inspired PSO with Lévy flights (QPSOL) algorithm is presented. It guarantees quick reaction over changing conditions and can be used to provide scheduling in limited time (e.g. showing estimated cost on a Washing machine display based on optimized schedule of appliance).

2.5.2 Reactive phase

This section shows an example in how the CEMS algorithm could work, in term of reactive mode, in collaboration with the alerts coming from the DSO meter (see Figure 15).

In general, the CEMS received from the DSO's Smart Meter the total power required by the house (Ptx) and it compares this value with the contractual power (Pc). By default the Smart Info publishes these values every 10 minutes. Only if the Ptx is greater than the 80% of the Pc, the CEMS requests an update for the Ptx. Any additional request must be submitted with maximum frequency of 1 minute. The same scenario can be applied when a new load wishes to start if the CEMS calculates that by adding this new load the total power required exceeds the threshold (i.e. in Italy this values is generally fixed by contract at 3.0 kW or 4.5 kW).
If the consumption detected by the Smart Meter exceeds this limit, an overload alarm is generated and reported to the CEMS ("*TypeAl != 0*"): there could be different status codes, each one describing a specific scenario, but in general a time before the disconnection event, Td, is calculated, as well as the power surplus value, Ps (when TypeAl == 2), equals to Ptx – 1.1Pc. That information allows planning the next action that CEMS must perform to prevent a blackout. In order to optimize the algorithm the E@H system should provide a priority list of all the loads which allows identifying the appliance to be switched off. The algorithm determines the appliances that

can still remain on, since they are considered priorities, while it forces the other loads to reduce their consumptions or, if it is supported, to turn off for a specific time their tasks.

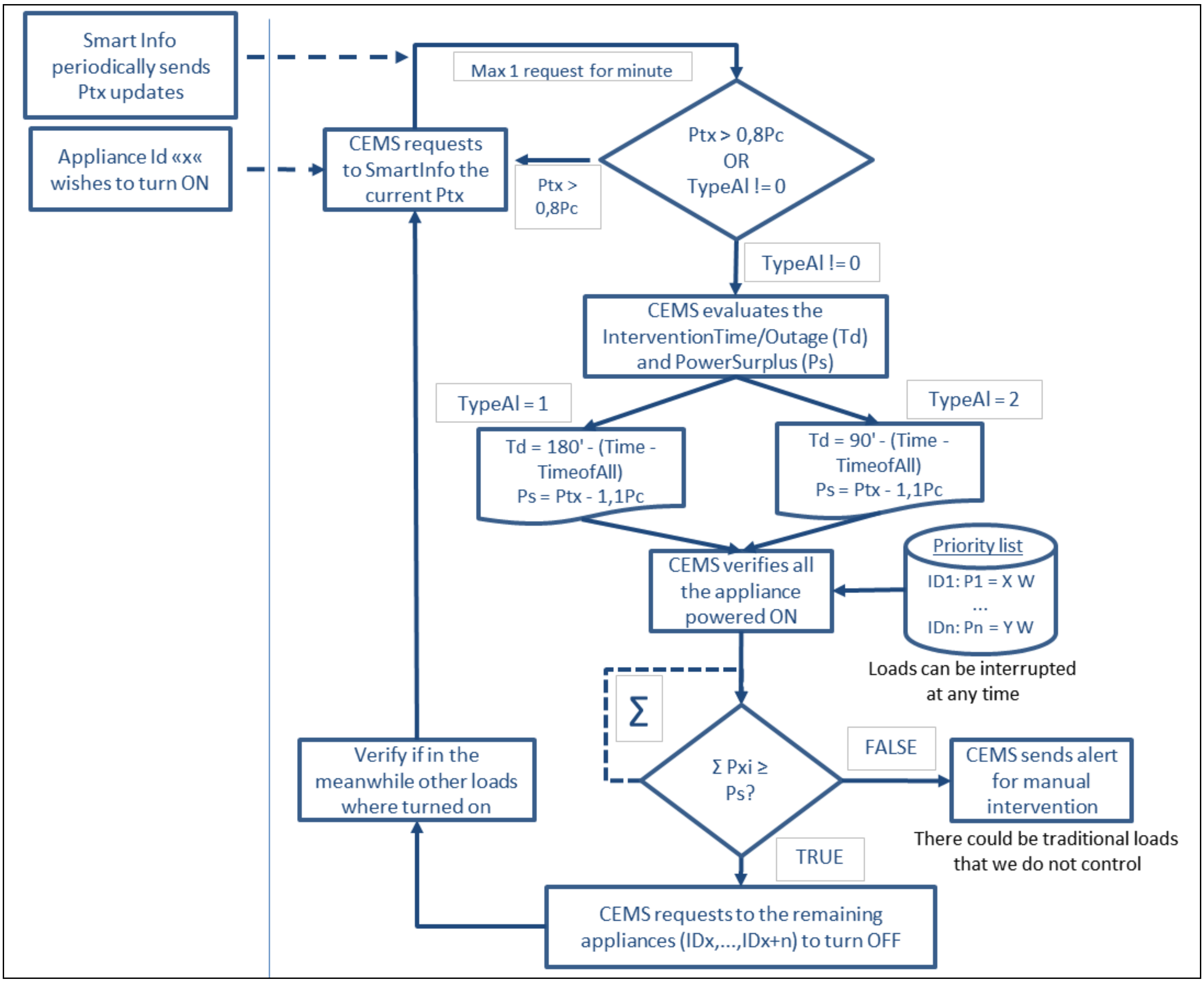


Figure 15 – Example of CEMS algorithm

3 Smart Meters requirements

The following picture describes the standard configuration of residential on-site generation plant (i.e. photovoltaic panel, mini wind turbine, etc…), including both production and primary smart meters.

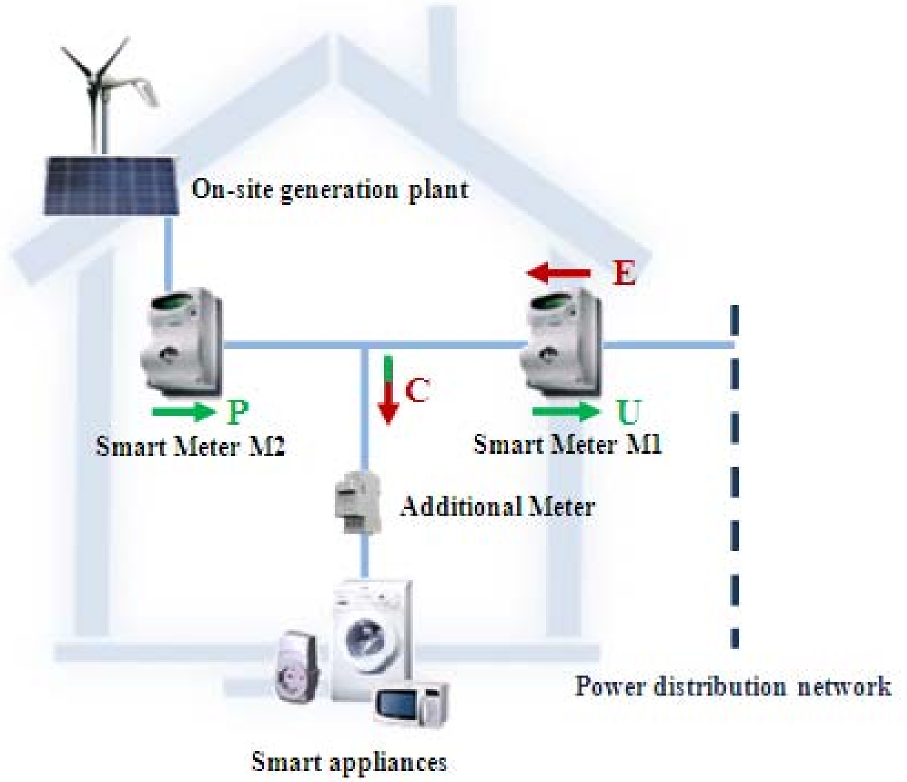


Figure 16 - Use Primary and Production meters in E@h

The energy production of any on-site generation plant is monitored and recorded by a smart meter (in the picture marked with the label M2 and the produced power with the arrow P). In such case the primary smart meter (M1) monitors and records both the energy picked-up from the power distribution network (arrow E) and the energy put into it (arrow U). The home consumption of energy (arrow C) is calculated as the contribution of both a part from the on-site generation plant and from the power distribution network.
To summarize, arrow C is calculated by the expression C = E + (P – U), where:

- E: Primary meter M1 CurrentSummationDelivered
- U: Primary meter M1 CurrentSummationReceived
- P: Production meter M2 CurrentSummationReceived

The instantaneous power data may be different according to the table Data Quality Attribute ID that identifies the data quality.

Device	Data Quality ID
All data is certified	0x0000

Only Instantaneous Power is not certified	0x0001
Only Cumulated Consumption is not certified	0x0002
Not certified data available	0x0003

In the case "All Certified Data", 0x0000, instantaneous power data is monitored from the meter M1 or M2 and the refresh rate will not be in real time.
In the case "Only Instantaneous Power is not certified", 0x0001, instantaneous power data is measured by an additional meter installed on the power line that supplies the user of the client, measuring the vector C in a real-time frequency.
Finally, the next sequence diagram shows how the Home Gateway can configure the smart appliances and Smart Info device to periodically report their data.

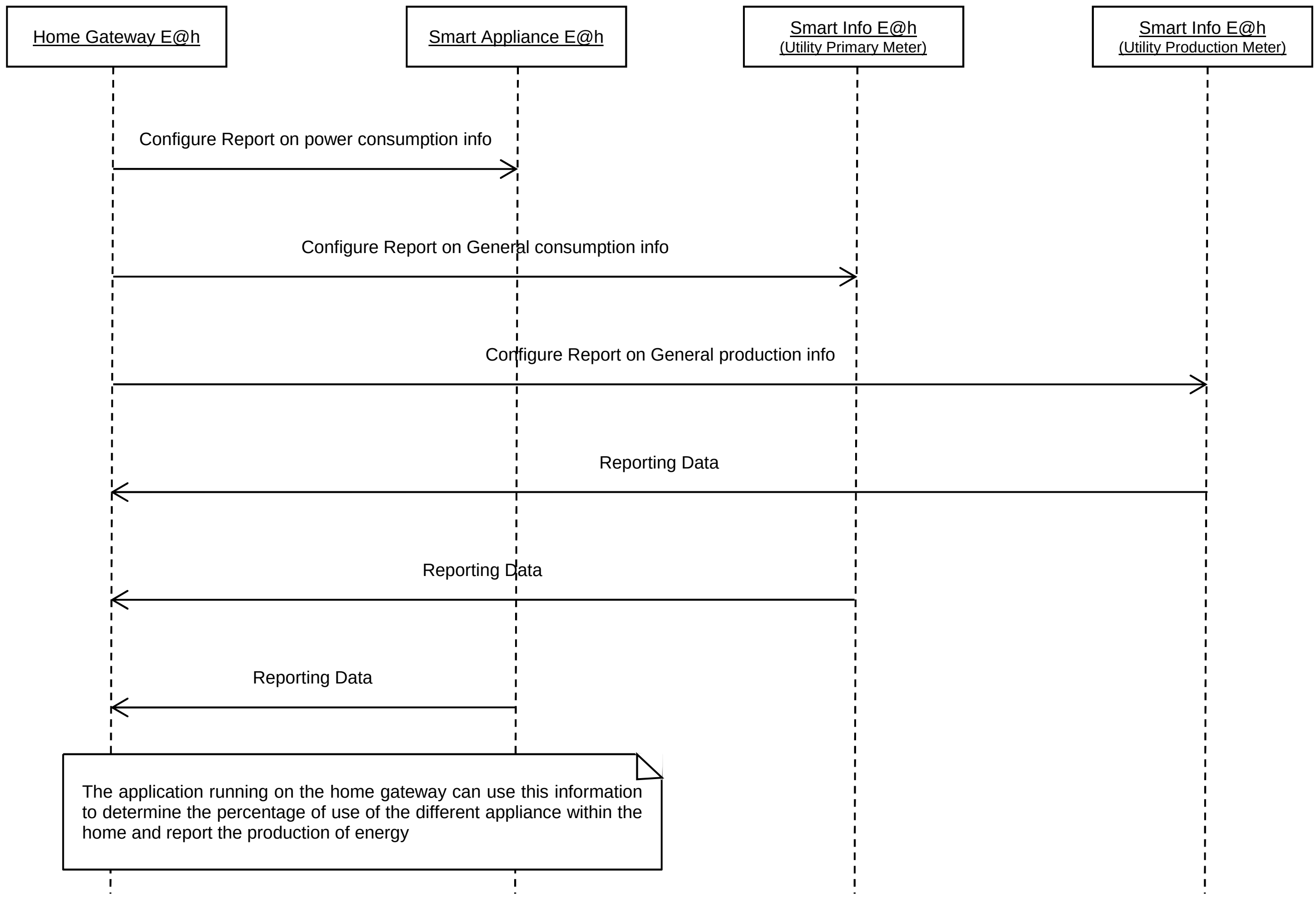


Figure 17 - Management of Production and Primary meter in Energy@home

In annex 3 is reported a possible communication between HAN and an external interface, such as web services, external authorities, and remote systems. With the introduction of the production system in E@h, knowing how much energy the production plant will produce in next days has become essential for consumption peak shaving and load balance purpose. Therefore in the annex is introduced a forecast service needs to constantly download heavy satellite data and to do a complex image elaboration process, so the service has to reside in a remote dedicated server.

3.1 Smart Info attributes

This section aims to describe the Smart Info attributes used in the Energy@home system that perhaps are already mapped in existing ZigBee specification. In the following table is reported a list of DSO Smart Meter fields and the proposed mapping in ZigBee.
Please notice that the "TIME" field requests that the corresponding "TimeStatus" attribute in ZigBee (a bitmask field) shall be set to 0x00, or alternatively to 0x04 if the "Daylight" time is used. It also verifies that the MasterZoneDst is set to 1.

Field	Type	Description	ZigBee Cluster	ZigBee Attribute
E(p)	EEnergy	Total active energy of previous period	Metering (0x0702)	0x0442 PreviousMonthConsumptionDelivered
E(t)	EEnergy	Total active energy of actual period	Metering (0x0702)	0x0000 CurrentSummationDelivered
DATE	EDate	Smart meter date	Time (0x000A)	0x0000
TIME	ETime	Smart meter time	Time (0x000A)	Time (UTC format)
Daylight	EByte	Daylight (disabled/enabled)	Time (0x000A)	0x0001 TimeStatus
Tall	ETimeA	Time of alarm: Time of the last recorded alarm	Reported using the Alarm command (see section 0)	
TypAl	EByte	Type of Alarm		
E-(p)	EEnergy	Total negative active energy of previous period	Metering (0x0702)	0X0441 PreviousMonthConsumptionReceived
E-(t)	EEnergy	Total negative active energy of actual period	Metering (0x0702)	0x0001 CurrentSummationReceived
Total daily active energy current date	EEnergy		Metering (0x0702)	0x0401 CurrentDayConsumptionDelivered
PTx	EPower	Instant power (Average in time Tx, 1 second)	Metering (0x0702)	0x0400 InstantaneousDemand
P-Tx	EPower	Negative Instant power (Average in time Tx, 1 second). Available only if it is measured by smart meter. *[Please note that P-Tx is the field used to measure the SmartInfo production]*	Metering (0x0702)	0x0400 InstantaneousDemand

Pc	EPower	Contractual power	Meter Identification (0x0B001)	0x000D AvailablePower
Pa	EPower	Available Power is 110% Pc	Meter Identification (0x0B001)	0x000E PowerThreshold
POD	EBArray (15)	Point of Delivery	Meter Identification (0x0B001)	0x000C POD
Meter Type Model Type	EWord	• Case Utility primary Meter: 0x0000 • Case Production Meter: 0x0001 • Case Utility Secondary Meter: 0x0002 • Case Private primary Meter: 0x100 • Case Private Production Meter: 0x101 • Case Private Secondary meter: 0x102 • Case Generic Meter: 0x110	Meter Identification (0x0B001)	0x0001 MeterType ID
DataQuality ID	EWord	Smart Info cases: • All Data Certified 0x0000 • Smart Info DIN case: Only Instantaneous Power not certified 0x0001 • Only Cumulated Consumption certified 0x0002 • Not Certified data 0x0003	Meter Identification (0x0B001)	0x0004 DataQualityID
Model	EWord		Meter Identification (0x0B001)	0x0006 Model
Power Unit Mode	EByte	Watt: 0x00 Decawatt: 0x01	Metering (0x0702)	0x0302 Divisor

				Note: • if divisor = 1000 implies "watt" • if divisor = 10000 implies "decawatt"

Table 2 – Smart Info attributes

All the DataTypes used in the Smart Meter are reported in the following table.

DSO format	C ANSI equivalence	Description
EByte	Unsigned char	1 byte coded as required by the application
EShort	Unsigned char	1 byte coded as integer (0-255)
EWord	Short unsigned int	2 bytes coded as required by the application (most significant bit first)
EPower	Short unsigned int	2 bytes used for a short unsigned integer, most significant byte first, used for Power Resolution: 1 W (VAr, for reactive)
EEnergy	Long unsigned int	4 bytes used for a long unsigned integer, most significant byte first, used for Energy Resolution: 1 Wh (VArh, for reactive)
Edate	Structure	Structure 3 bytes long: 1 Day (Values 1..31) 2 Month (Values 1..12) 3 Year (Values 00-99, 00 = 2000)
Etime	Structure	Structure 3 bytes long: 1 hours 2 minutes 3 seconds
EBArray(XX)	Bytes array	String of XX bytes max, null terminated, XX not defined
EtimeA	Structure	Structure 4 bytes long: 1 day 2 hours 3 minutes 4 seconds

Table 3 – DSO Data Types

3.2 Retrieve load profile data

This section describes a procedure adopted by Energy@home in order to retrieve data stored in various E@h devices like Smart Plug or Smart Info which are needed by the CEMS to fill some gaps that could be present in the historical database due to some errors or temporary black out. The same procedure could also be used for billing purposes. In particular the procedure described below depends a lot on the frequency sample used: for example, considering a sample every 15 minutes (each sample is about 2 bytes long) it means having 96 samples per day, and thus depending on the maximum memory available (e.g. 1000 samples) only 10 days can be stored. Clearly, to make the transfer of such data more efficient, samples will be grouped in blocks (each blocks will have 24 samples). The overall procedure consists of:

- A message sent from the CEMS to the SmartInfo/SmartPlug requesting all the blocks available (HistoricalEnergyRequest command)
- SmartInfo internally counts the block number available, for then sending each one (as soon as he retrieve them from the memory). In this phase the device start reading each block for then decide and discard those one not requested until it reaches the first interesting one (which are represented by the “StartTime” field sent in the request). From this moment the SmartInfo can start sending HistoricalDataBlock command containing (n-s) blocks (eventually split in more than one message), where “n” is the total number of stored records and “s” is the number of discarded messages. During this transfer the CEMS periodically send notifications as acknowledge
- Using the “EndTime” field, the SmartInfo is aware if and where to stop to report blocks

Based on those assumptions, we provide below two scenarios and command descriptions depending if the data logs requested are available or not in the Smart Info memory.

3.2.1 Historical data available

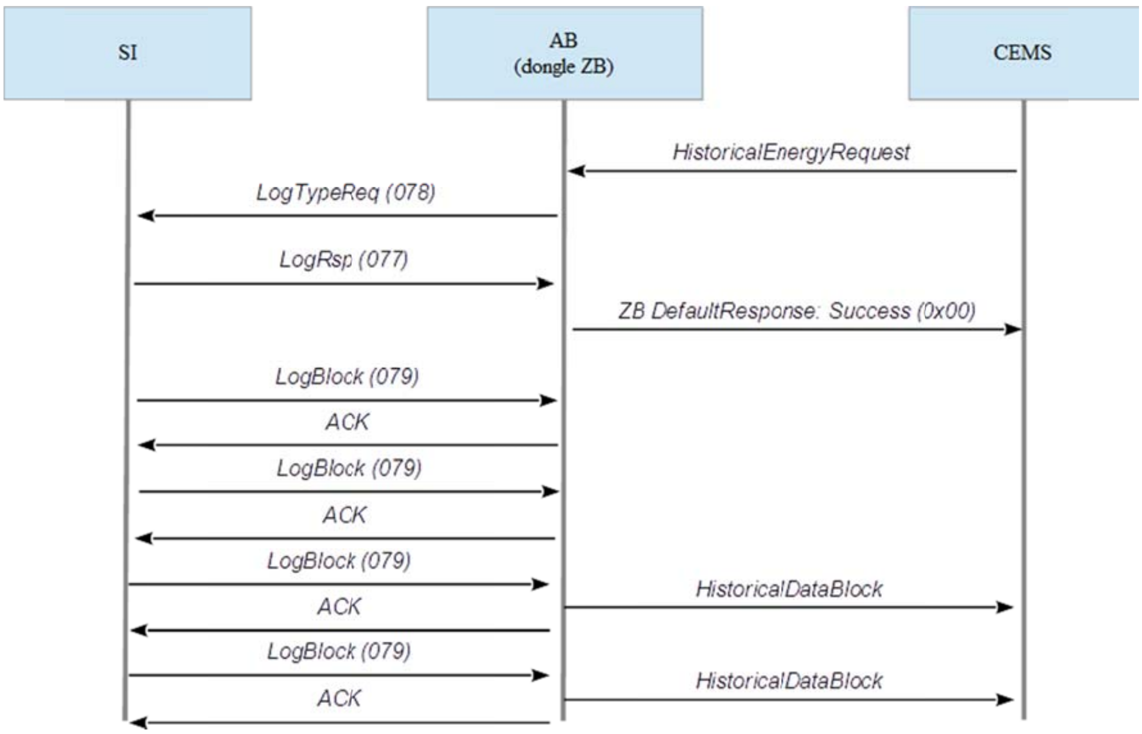


Figure 18 – Retrieve Load Profile Data – Log available

The first message, HistoricalEnergyRequest, is sent by the CEMS with the payload reported in Table 4.

Octets	**1**	**0/4**	**0/4**
Data Type	Unsigned 8-bit integer	UTC time (32 bit)	UTC time (32 bit)
Field Name	Type	Start Time	End Time

Table 4 – Format of HistoricalEnergyRequest Payload.

The field explanation is provided below:

- Type: 8-bit enumeration (it is equals to zero in case of historical consumption, one in case of historical production)
- Start Time : UTC time (32 bit) representing the number of seconds since 1st Jan, 2000
- End Time: UTC time (32 bit) representing the number of seconds since 1st Jan, 2000

The last two fields are optional: if both are missing, then the request is related to all the data available.
When the Smart Info reaches data matching the request (e.g. the data is greater or equal the Start Time field), the dongle can start sending HistoricalDataBlock packages which are formatted as shown in Table 5.

Octets	**1**	**1**	**1**	**4**	**6**	**…**	**4**	**6**
Data Type	8-bit bitmap	Unsigned 8-bit integer	Unsigned 8-bit integer	UTC time (32 bit)	Unsigned 48-bit integer	…	UTC time (32 bit)	Unsigned 48-bit integer
Field Name	Data Indicator	Block Number	Record Numbers	Record Time Stamp 1	Energy value record 1	…	Record Time Stamp N	Energy value record N

Table 5 – Format of HistoricalDataBlock Payload.

The field explanation is provided below:

- Data Indicator: 0 if first block, 1 for following block, 2 for the last block
- Block Number: it indicates the block number (zero is the first block)
- Records Number: number of records in the current block
- Record Time Stamp: UTC Time of record i-th
- Energy Value Record: it reports the Current Summation Delivered/Received

3.2.2 Historical data not available

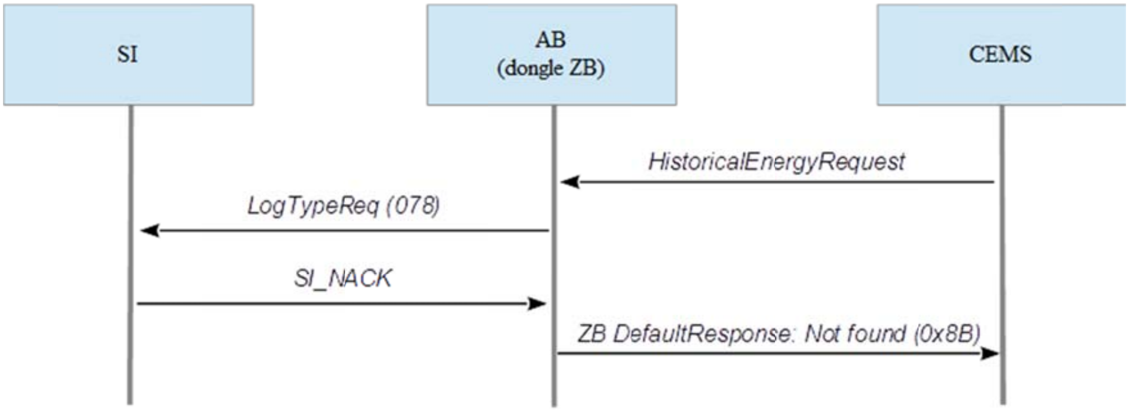


Figure 19 – Retrieve Load Profile Data – Log not available

In this scenario the log available are out-of-range compared to the requested data (for example, the CEMS may be looking for data which are too old and thus not stored anymore in the log data). It could also happen that the Start Time field is too old, but the End Time field is within the range. The correct and expected behavior is:

- If EndTime is too old (or simply it is not present in the request), then just send a ZigbeeDefaultResponse command with value equals to 0x87
- If EndTime field has a valid value, then send all the data starting from the first record available until the slot matching the end time field.

Clearly, if both Start Time and End Time are not present the dongle just sends all the data starting from the first one available.

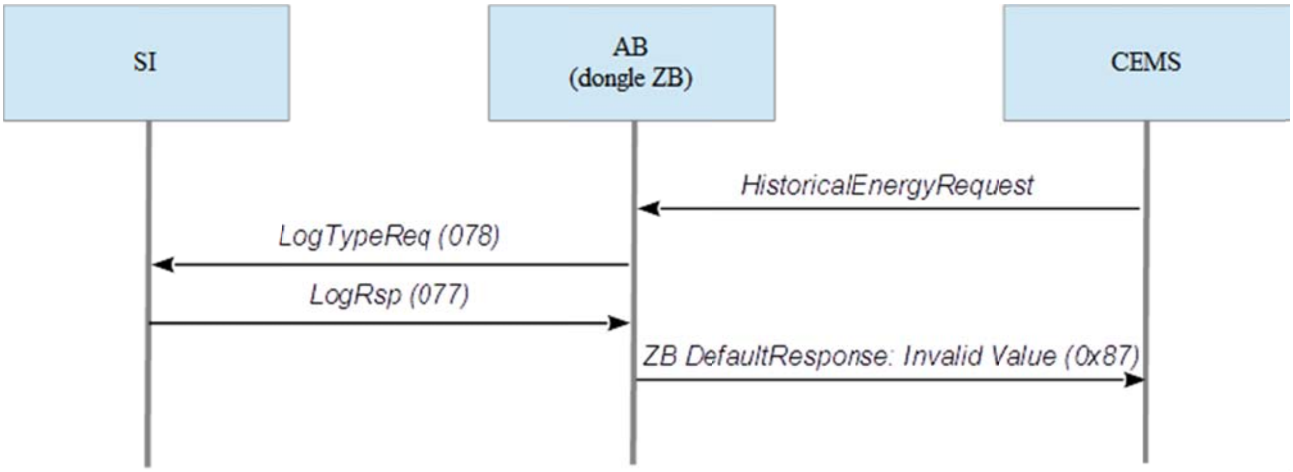


Figure 20 – Retrieve Load Profile Data – Invalid value scenario

4 Protocol specification

The E@h protocol extends the ZigBee Home Automation and Smart Energy profiles. In order to satisfy all the requirements of Energy@home use cases, different new devices and clusters have been included in [R11] and thus here no further information is provided. In Annex 1 is presented the original mapping done between already defined ZigBee clusters and/or CENELEC appliance interworking functional blocks. In the next section are reported the main ZigBee requirements adopted by the Energy@home Association.

4.1 Protocol Basics

The ZigBee application architecture is presented in [R4]. The specific E@h devices can be implemented leveraging on one or more Application Objects (each one relying on its own communication Endpoint), belonging to the ZigBee Application Framework.
ZigBee application objects include a collection of clusters, i.e. a related group of commands and attributes, which together define an interface to specific functionality.

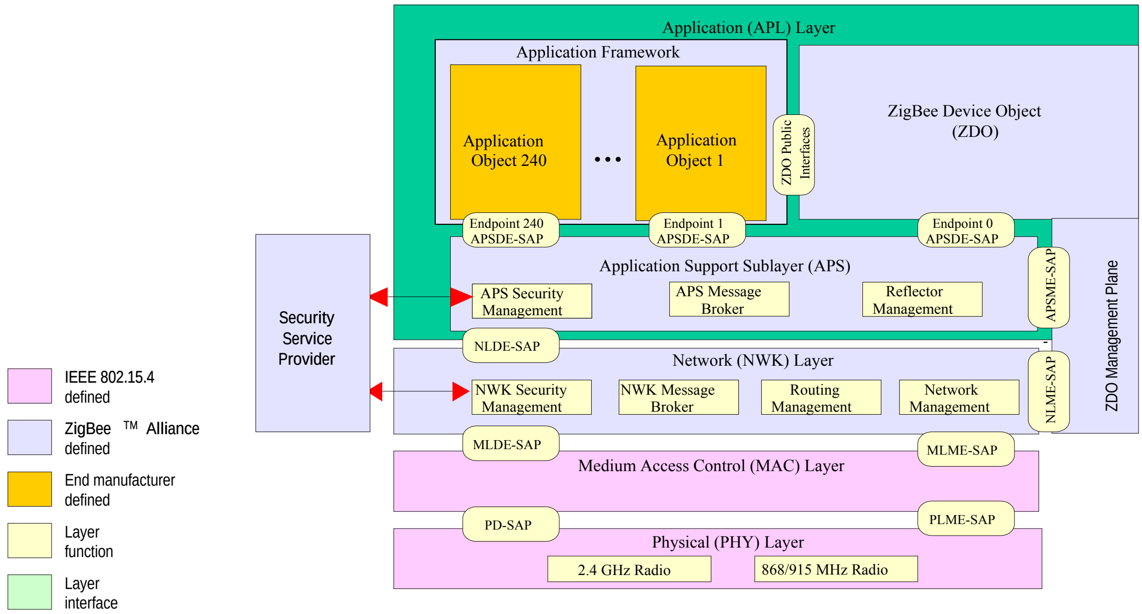


Figure 21 – The ZigBee application architecture.

4.2 Networking

Smart Appliance connectivity is expected to become a standard functionality in the next future. This will enable innovative services through an evolution from the current standalone appliance to the future Smart Appliance. In the scope of E@h project, connectivity and digital domain computation will enable in-house smart power management.

To this purpose, the adoption of several communication protocols, either wired or wireless, has been proposed (Konnex, LonTalk, Ethernet, etc.). ZigBee RF transmission promises to be a feasible solution: it is cost-effective and it is getting even less expensive over time; at the same time it provides the flexibility of a wireless communication and benefits of the worldwide standardization of application profiles. Hence, in the following, ZigBee is referred as the HAN communication technology (see below).

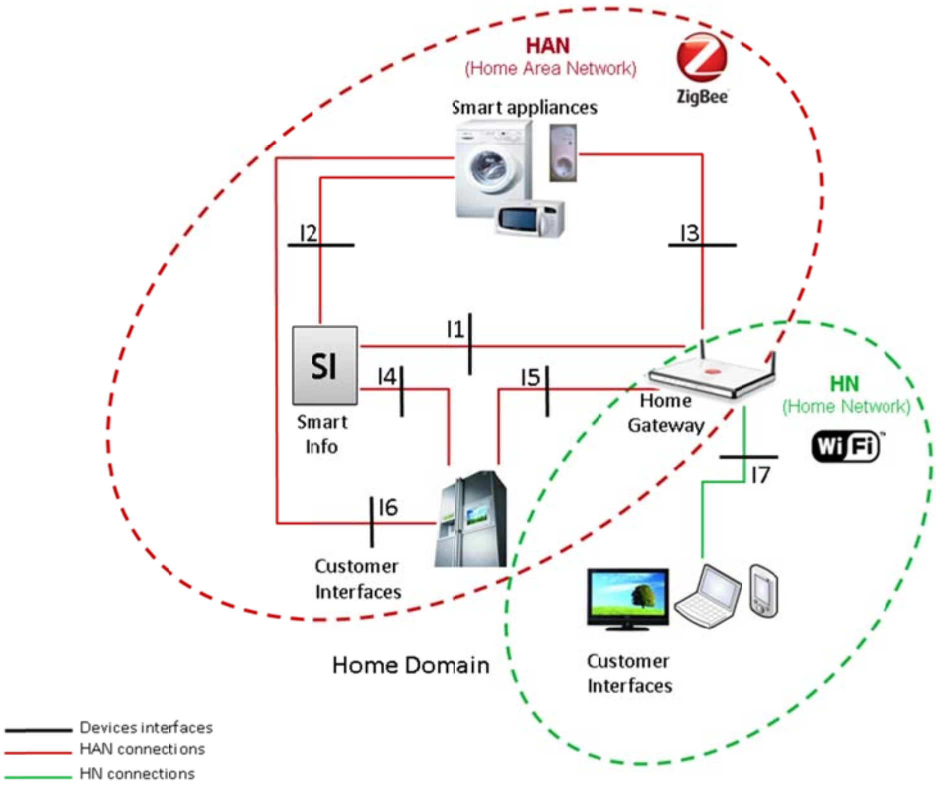


Figure 22 – HAN and HN connections.

The figure represents the user's Home Domain that includes both the HAN and the HN. In this domain all the home devices (i.e. Smart Appliances, Smart Plugs, Home Gateway, Smart Info and Customer Interfaces) can cooperate through some communication mechanism as specified in these technical specifications.
In the figure the Smart Info is the device that enables the Electronic Meter of the DSO to communicate with the HAN, while the Home Gateway is the Telco broadband residential gateway with the extended functionality of gateway between the HAN, the HN and the WAN (i.e. broadband connection to internet). All the depicted interfaces are logical ones and are expected to be implemented through the communication technology specified in this document.

4.3 ZigBee Stack profile

Products that are compliant to this specification shall use stack profile number 0x02 (ZigBee PRO). As a result of the integration of these specification within future versions of ZigBee Home Automation Public profile (ZHA), Energy@home devices shall use of ProfileId= 0x0104[5]. However the recently upgrades done by the ZigBee Alliance regarding the profile interoperability between all the ZigBee PRO application profiles are changing the meaning of this value, and thus we recommend to verify in the future release of the ZigBee Specification (currently at revision 20, [R4]) how to handle this piece of information in order to be fully compatible across all the public ZigBee Application profiles.APS Fragmentation Parameters
When using clusters requiring fragmentation (see cluster definitions) there are application settings from the APS IB that must be defined by the application profile. These parameters are to be set as shown in Table 6 - APS Fragmentation Parameters.

[5] An Energy@home Profile ID = 0xC23C had been reserved for development purposes.

Parameters	Identifier	Type	Value	Description
apsInterframe Delay	0xc9	Integer	50	Standard delay in milliseconds between sending two blocks of a fragmented transmission
apsMaxWindowSize	0xcd	Integer	1	Fragmentation parameter – the maximum number of unacknowledged frames that can be active at once

Table 6 - APS Fragmentation Parameters.

In addition the Maximum Incoming Transfer Size Field in the Node descriptor defines the largest ASDU that can be transferred using fragmentation. For the HA Profile the default value shall be set as described in [R3]. Maximum ASDU size allowed is specified in [R4] and dictated by solution needs and RAM capacities of the communicating devices.

4.4 Commissioning and security

The current E@h commissioning and security procedures are based in two parts, a standard and mandatory one derived from the Home Automation 1.1, and an enhanced mode defined in Home Automation 1.2.

STANDARD MODE:

ZigBee Home Automation 1.1 compatible mode [MANDATORY]:
The startup procedure of the network shall involve the following steps:

1. the network shall be opened by the Home Gateway (i.e. enable permit joining to the routers of the network);
2. each device shall join the network by using the default TC link key;
3. The devices will then receive a network key according the common security mode specified in ZigBee (network key encrypted with the TC link key).

ENHANCED MODE:

ZigBee Home Automation 1.2 installation code procedure [OPTIONAL]:
The startup procedure of the network shall involve the following steps:

1. the network shall be opened by the Home Gateway (i.e. enable permit joining to the routers of the network);
2. each device shall join the network by using a unique TC link key (i.e. same key on the products and the home gateway derived with Hash specified in Smart Energy 1.0 - Matyas-Meyer-Oseas hash function); the TC link key shall be derived from Serial/bar code or other products code (e.g. 2D barcode);
3. the TC link key shall be configured on the home gateway or portal controlling the gateway and derived by the registration of the product code.

The devices will then receive a network key according the common security mode specified in ZigBee (network key encrypted with the TC link key). The network key may change over time according to the security policy of the Home Gateway. If losing synchronization with the proper key the devices shall be able to rejoin using the TC link key.
Devices joining with the STANDARD MODE security might select to downscale features due to the security level and make those features accessible just when joining through the ENHANCED MODE.

No APL link keys are required to be used among the devices to access the information in the E@h network.

4.5 Best practices

Below some general recommendation that shall be taken into account when developing an Energy@home device.

4.5.1 Service Discovery

Commissioning modes

Three different commissioning modes are typically discussed within the ZigBee specification (see [R3]):

- A-mode (automatic mode), which involves automatic commissioning of devices. The A-mode generally allows for minimal (or no) human intervention.
- E-mode (easy mode), which involves the use of buttons or other physical mechanisms on devices to direct devices during commissioning. The E-mode allows for simpler end-user or professional installer commissioning. It usually targets small installations (maximum size: typical home).
- S-mode (system mode), which involves the use of external tools and are typically used by expert installers. The S-mode represents the most complex form of commissioning and includes the highest level of human intervention. It usually targets larger installations such as commercial premises and high-end residential environments.

All E@h devices must support E-mode. E-mode commissioning may be a simple button press or may involve a separate low-cost commissioning tool (like a remote control). The device can use some form of automatic behaviour for instance joining the network upon Power up, but shall still provide the means for the end user to commission the device. S-mode (e.g. using commissioning operated by an interface exposed by the Home gateway) should be possible.

Pair devices

The operation of pairing E@h devices may be operated using easy commissioning mode as defined in [R4]. See ZigBee Home Automation specification for detailed reference on the easy commissioning procedures.
Example: a user would like to pair two devices (for example, a Smart Appliance and a Home Gateway). A button on each device is pressed and the "pairing" is done using the easy commissioning procedures for complex device.

4.5.2 Preferred Channels

When forming a new network, or scanning to join a network, E@h devices should perform a channel scans, possibly using one of the following channels in order to avoid noisy channel and the most common channels used by Wi-Fi: **11, 14, 15, 19, 20, 24, 25**. This will improve the user experience during installation (quicker joining) and possibly improve bandwidth (on average).

4.5.3 Broadcast Policy

Use of Broadcast messages should be minimized as much as possible in order to avoid network flooding.

4.5.4 Frequency Agility

E@h devices shall support frequency agility as defined in ZigBee Specification [R4].

4.5.5 Key Updates

E@h devices shall support "common security model" (i.e. default preconfigured Trust Center link key shall be used to transfer network key if no specific Trust Center Link Key is set through out-of-band mechanism to the E@h device). Network key updates should be limited due to the possibility of end devices missing two key updates.
It is strongly encouraged that key updates should only be initiated by the user via interaction with the Trust Center. Auto updates of security keys pose the risk that battery operated devices will miss two key updates and need to be re-commissioned.

4.5.6 Return to Factory Defaults

In support of a return to factory default capability, E@h devices shall implement the ZDO Management Leave server service. When invoked with a unicast address and the DeviceAddress set to NULL=0x00000000, the device shall implement a NWK Leave. When invoked with a broadcast address and the DeviceAddress set to NULL=0x00000000, the device shall wait the broadcast timeout period to allow the message to propagate through network, then the device shall implement a NWK Leave. Prior to execution of the NWK Leave in either case, processing in the device shall ensure all operating parameters are reset to allow a reset to factory defaults.

4.6 Overload Management notification procedure

This section describes how to implement the Overload Warning notification procedure in ZigBee. The whole use case can be found in [R1].

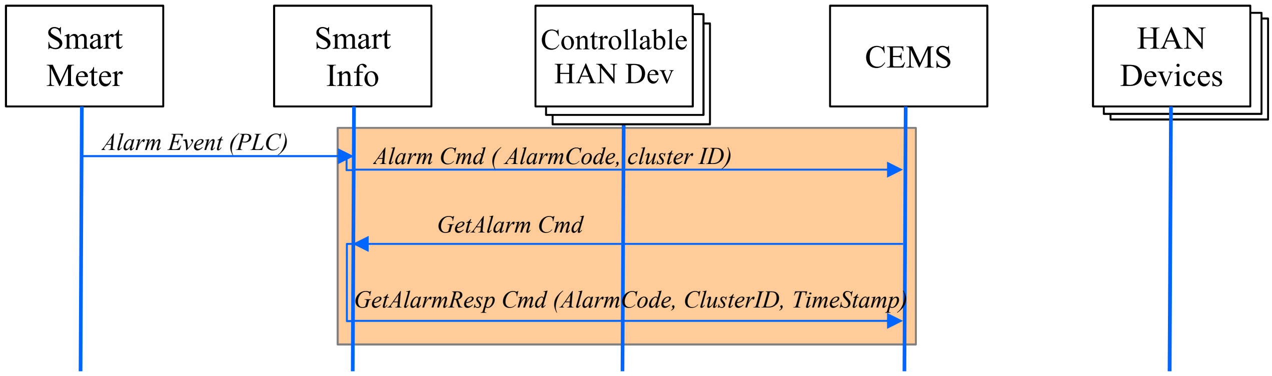


Figure 23 – Overload Management scenario

The first part of the overload warning is generated by the DSO meter, which recognize the limit exceed by a residential user and thus an alarm is sent from the Smart Meter to the Smart Info. This message is sent in a proprietary way.

Overload Warning Notification phase (initiated by Smart Meter)

- The Smart Meter notifies the Smart Info that there is a warning situation through an encoded warning code and relative time stamp.
- Smart Info, via ZigBee Alarm Cluster, notifies the CEMS about a warning situation. The Alarm command payload is composed by the following field:
  - Alarm Code: the alarm codes are defined inside Meter Cluster. See table below for their definition.

Alarm Code	***ZB Meter Cluster definition***	***Use case meaning***

0x86	Limit Threshold Exceeded	First level of overload warning: the standard threshold has been exceeded
0x87	Limit Threshold OK	The threshold is back to the standard value. Power consumption is in a non-warning scenario.
0x88	Limit Threshold Changed	Nth level of overload warning. Alarm escalation due to the overload condition update.

- Cluster ID: Metering Cluster 0x0702

- The CEMS sends to the Smart Info a Get Alarm command (Alarm Cluster) to retrieve information (time stamp) about the latest Alarm Event.
- The Smart Info responds with a Get Alarm Response Command (Alarm Cluster) where, besides Alarm Code, and Cluster ID, provides the time stamp of the alarm event.
- Due to the presence of a time stamp, the Time Cluster should be implemented by Smart Info (synchronized with the Smart Meter one)

Message exchange

Message ID	From	To	Description	Parameters
0x00	Smart Info	CEMS	*Alarm:* Signals an alarm situation on the Smart Info	Alarm Code Cluster ID
0x02	CEMS	Smart Info	*Get Alarm*: Ask the alarm with the earliest time stamp	None
0x01	Smart Info	CEMS	*Get Alarm Response*: It is the response to the *Get Alarm command.* Includes additional information about last alarm event.	Alarm Code Cluster ID Time stamp

The second part of the overload warning is generated by the CEMS, which now has received the overload notification and it needs to report to all the smart appliances about this new state and try to reduce the total power consumed.

4.7 Device Description

All the devices used in the E@h specification and listed in Table 7 are specified in section 7.4 of [R11] and thus we avoid in this section to copy them. In bold the proposal extension covered in this specification document and that are not yet part of the ZigBee Alliance specification.

Device	Device ID
Energy Management System (Home Gateway)	0x0050

Smart Plugs	0x0051
White Goods	0x0052
Meter Interface (Smart Info)	0x0053
ESS (EnergyStorageSystem)	**0x0054**

Table 7 – Devices used in E@h Profile

Thus, only one additional device is currently proposed in the Energy@home specification.

ESS (EnergyStorageSystem)

The ESS (Energy Storage System) is a system composed by an energy StorageUnit (i.e. battery, flywheel, compressed air, etc...), an Inverter or a Power Electronic Unit used to convert the energy stored into electric power, and a Logic Unit acting as system supervisor that provides a communication data interface. It could be part of a renewable energy production inverter or exist as a standalone storage system.

Supported clusters

In addition to those specified in the common cluster, the ESS (EnergyStorageSystem) device shall support the clusters listed in Table 8.

Server Side	**Client Side**
Mandatory	
StorageUnit	
Optional	
Renewable Energy Production	

Table 8 - Clusters Supported by the Metering Device (Smart info)

In the case the ESS (EnergyStorageSystem) cannot provide storage information, it can either loose its function and cease to use the StorageUnit to load/unload energy, or continue to store/use the energy from the StorageUnit on stand-alone/default basis.

4.8 ZigBee Cluster List

The ZCL provides a mechanism for clusters to report changes to the value of various attributes. It also provides commands to configure the reporting parameters. The attributes that a particular ZCL-defined cluster is capable of reporting are listed in the ZCL specification as well. The E@h devices utilize both the clusters specified in the ZigBee Cluster Library [R2] and in the SE and HA specifications ([R11]) whenever possible. The implementation details for each cluster are given in the relative ZigBee specifications. Further specification and clarification are given in this document when necessary.

The clusters used in this profile are listed in Table 9 (in bold the new proposed clusters, that once finalized and tested in Energy@home could be proposed in ZigBee Alliance as well).

Functional Domain	**Cluster Name**	**Cluster ID**
General	Basic	0x0000
General	Identify	0x0003
General	Groups	0x0004
General	Scenes	0x0005
General	On/Off	0x0006
General	Time	0x000A
General	Partition	0x0016
General	Power Profile	0x001a
General	EN50523 Appliance Control	0x001b
Measurement & Sensing	Temperature Measurement	0x0402
Smart Energy	Price	0x0700
Smart Energy	Demand Response and Load Control	0x0701
Smart Energy	Metering	0x0702
Smart Energy	Message	0x0703
Home Automation	EN50523 Appliance Identification	0x0b00
Home Automation	Meter Identification	0x0b01
Home Automation	EN50523 Appliance Events and Alerts	0x0b02
Home Automation	Appliance Statistics	0x0b03
E@h Clusters	***StorageUnit***	***0x0B04***
E@h Clusters	***RenewableEnergyProduction***	***0x0B05***

Table 9 – Cluster used in E@h specification

Please notice that most of those clusters listed in Table 9 are derived from the CENELEC standard: since the EN50523 does not cover all the needed functionalities, some extensions have been introduced.

4.9 ZigBee Extension proposal

In the following sections, the new clusters that could be proposed to the ZigBee Alliance as extension to the current ZigBee Home Automation 1.2 profile specification are presented. The description includes data organization and cluster command definitions, and further revisions are expected before to submit a final version to the ZigBee Alliance.

4.9.1 Metering cluster (application guidelines)

Attribute reporting may be used for sending information in the Reading Information and Meter Status attribute sets. The frequency and timeliness of updating metering data contained in the Metering Cluster Attributes and Profile Intervals is up to the individual Metering device manufacturer's capabilities. As a best practice recommendation, updates of the metering data should not cause delivery of the information to end devices more often than once every 30 seconds. End devices should also not request information more often than once every 30 seconds.

4.9.2 Overload Management

In order to cover the Overload Management scenario explained in section 4.6, the Energy@home approach is to use the already existing Appliance Control cluster defined by the ZigBee Alliance. Below the requested changes to support this new scenario.

Server Commands Received

Command Identifier Field Value	Description	Mandatory / Optional
0x00 – 0x05	No changes from section 9.6.5 of [R3]	-
0x06	Overload Management Event	O
0x07 – 0xff	Reserved	-

Overload Management Event

The Overload Management message is used to send overload warning severity level and related load control commands to a household appliance.

Payload Format

The Overload Management Command payload shall be formatted as illustrated in Figure 24 below.

Octets	4	2	4	2	1
Data Type	Unsigned 32-bit Integer	16-bit Bitmap	UTC Time	Unsigned 16-bit Integer	Unsigned 8-bit integer
Field Name	Issuer Event ID	Device Class	Start Time	Duration (minutes)	Criticality Index

Figure 24 - Overload Management Event Command payload format.

Payload Details

Issuer Event ID: Unique identifier generated by the EMS. The value of this field allows matching of Event reports with a specific Overload Management event. The expected the value contained in this field shall be a unique number managed by upstream systems or a UTC based time stamp (UTCTime data type) identifying when the Overload Management Event was issued.

Device Class: Bit encoded field representing the Device Class to apply the current Overload Management Event. Each bit, if set individually or in combination, indicates the class device(s) needing to participate in the event[6].

Start Time: UTC Timestamp representing when the event is scheduled to start. A start time of 0x00000000 is a special time denoting "now."

Duration (minutes): Duration of this event in number of minutes. Maximum value is 1440 (one day). A duration of 0x00000000 is a special duration denoting instantaneous event.

Criticality Index: This field defines the level of criticality of this event. The action taken by command target devices for an event is based on combination of this value with internal appliance state. Criticality levels are listed in Table 10. Indexes from 0x01 to 0x07 refer to in-home energy management events; indexes from 0x11 to 0x13 refer to smart-grid energy management events

Criticality Index	Index Description	Participation
0x01	Overall power above "available power" level	Voluntary
0x02	Overall power back below the "available power" level	Voluntary
0x03	Overall power above "power threshold" level	Voluntary
0x04	Overall power back below the "power threshold"level	Voluntary
0x05	Overall power will be potentially above "available power" level if the appliance starts	Voluntary
0x06	Overload Pause	Voluntary
0x07	Overload Resume	Voluntary
0x11	Power reduction recommended	Voluntary
0x12	Planned outage	Voluntary

[6] See SE1.1 Demand Response and Load Control Cluster for a mapping proposal.

0x13	Power reduction intervention canceled	Voluntary

Table 10 – Criticality Index values

0x01 – Overall power above "available power" level – When receiving an Overall power above "available power" level Event with 0x01 Criticality Index an appliance shall show the warning state on a display. Generally used with Start Time = 0 and Duration = 0.

0x02 – Overall power back below "available power" level – When receiving an Overall power back below "available power" level Event with 0x02 Criticality Index an appliance is signaled of the end of an Overall power above "available power" level Event and shall resume the normal visualization. Generally used with Start Time = 0 and Duration = 0.

0x03 – Overall power above "power threshold" level – When receiving an Overall power above "power threshold" level Event with 0x03 Criticality Index an appliance shall show the warning state on a display. Generally used with Start Time = 0 and Duration = 0.

0x04 – Overall power back below "power threshold" level – When receiving an Overall power back below "power threshold" level Event with 0x04 Criticality Index an appliance is signaled of the end of an Overall power above "power threshold" level Event and shall resume the normal visualization. Generally used with Start Time = 0 and Duration = 0.

0x05 – Overall power will be potentially above "available power" level if the appliance starts – When receiving an Overall power will be potentially above "available power" level if the appliance starts Event with 0x05 Criticality Index an appliance shall show the warning state on a display. Generally used with Start Time = 0 and Duration = 0.

0x06 – Overload Pause – When receiving an Overload Pause Event with 0x06 Criticality Index an appliance shall move to its "not-mandatory overload pause state" to reduce consumption to its minimum.

0x07 – Overload Resume – When receiving an Overload Resume Event with 0x07 Criticality Index an appliance is signaled of the end of an Overload Pause event and shell resume the normal behavior.

0x11– Power reduction recommended – When receiving Overload Management Event with 0x04 Criticality Level an appliance can move to its "not-mandatory power reduction state" where it moves its power consumption outside the intervention interval as much as possible.

0x12 – Planned outage – When receiving Overload Management Event with 0x08 Criticality Level an appliance do its best to reduce power consumption at a minimum by means of moving in a cycle pause state.

0x13 – Power reduction intervention canceled – When receiving Overload Management Event with 0x0A Criticality Level an appliance is signaled of the end of an intervention interval (referred by means of Issuer Event ID field).

Server Commands Generated

Command Identifier Field Value	Description	Mandatory / Optional
0x00 – 0x01	No changes from section 9.6.6 of [R3]	-
0x02	Overload Management Event Report	O
0x03 – 0xff	Reserved	-

Overload Management Event Report

Payload Format

The Overload Management Event Report command payload shall be formatted as illustrated in Figure 25 below.

Octets	4	2	4	1
Data Type	Unsigned 32-bit Integer	Unsigned 8-bit Integer	UTC Time	Unsigned 8-bit integer
Field Name	Issuer Event ID	Event Status	Event Status Time	Criticality Index Applied

Figure 25 - Overload Management Event Report Command payload format.

Payload Details

Issuer Event ID: Unique identifier generated by the EMS. The value of this field allows matching of Event reports with a specific Overload Management event.

Event Status: Status of Overload Management event.

Value	Description
0x00	Reserved
0x01	Overload Management Event received and scheduled
0x07	The event has been superseded
others	Reserved

Event Status Time: UTC Timestamp representing when the event status occurred. This field shall not use the value of 0x00000000.

Criticality Level Applied: Criticality Level value applied by the device, see the corresponding field in the Overload Management Event Command for more information.

4.9.3 StorageUnit Cluster

4.9.3.1 Overview

This cluster presents attributes and commands for determining basic information about a device and setting about user device information. In particular, the StorageUnit cluster is used to inform the energy available to be used or stored in the StorageUnit inside the ESS, the rate at which it is possible to source or sink that Energy and a number of information defining the StorageUnit. Since the ESS converts electric power into energy suitable to be stored in the StorageUnit (i.e. chemical, Electric, mechanical, thermal etc...), attributes of this cluster will be in W, Wh, Ah, V, A. and Time (i.e. electrical unit of measurements).

4.9.3.2 Server

4.9.3.2.1 Dependencies

None.

4.9.3.2.2 Attributes

The attributes defined in this cluster are listed in Table 11.

Identifier	Name	Type	Range	Unit	Access	Default	Mandatory/Optional	Reportable
0x0000	StorageUnitType	Unsigned 16-bit integer	0=electrical; 1= thermal;	-	Read only	-	M	No

0x0001	Thermal Energy Storage Type DHW	Unsigned 16-bit integer	0=NO; 1= YES;	-	Read only	-	O	No
0x0002	Thermal Energy Storage Type CH	Unsigned 16-bit integer	0=NO; 1= YES;	-	Read only	-	O	No
0x0003	Thermal Energy Storage Type Cooling	Unsigned 16-bit integer	0=NO; 1= YES;	-	Read only	-	O	No
0x0004	FullDeviceCapacity	Unsigned 16-bit integer		1 Wh	Read only	-	M	No
0x0005	FullDeviceCapacity DHW	Unsigned 16-bit integer	-	1 Wh	Read only	-	O	No
0x0006	FullDeviceCapacity CH	Unsigned 16-bit integer	-	1 Wh	Read only	-	O	No
0x0007	FullDeviceCapacity COOLING	Unsigned 16-bit integer	-	1 Wh	Read only	-	O	No
0x0008	StorableEnergy	Unsigned 16-bit integer		1 Wh	Read only	-	M	Yes
0x0009	StorableEnergy DHW	Unsigned 16-bit integer	-	1 Wh	Read only	-	O	Yes
0x000A	StorableEnergy CH	Unsigned 16-bit integer	-	1 Wh	Read only	-	O	Yes

0x000B	StorableEnergy COOLING	Unsigned 16-bit integer	-	1 Wh	Read only	-	O	Yes
0x000C	Min Modulation	Unsigned 16-bit integer		(%)	Read Only		O	No
0x000D	Max Modulation	Unsigned 16-bit integer		(%)	Read Only		O	No
0x000E	ChargeMaxPower	Unsigned 16-bit integer	-	1 W	Read only	-	M	No
0x000F	ChargeMinPower	Unsigned 16-bit integer	-	1 W	Read only	-	M	No
0x0010	DischargePowerLimit	Unsigned 16-bit integer	-	1 W	Read only	-	O	No
0x0011	MaximumChargeCurrent	Unsigned 16-bit integer	-	0.01Ah	Read only	-	O	No
0x0012	MaximumDischargeCurrent	Unsigned 16-bit integer	-	0.01Ah	Read only	-	O	No
0x0013	MaximumChargeVoltage	Unsigned 16-bit integer	-	0.1V	Read only	-	O	No
0x0014	EndOfDischargeVoltage	Unsigned 16-bit integer	-	0.1V	Read only	-	O	Yes

0x0015	BatteryCurrent	Signed 16-bit integer	-	0.01Ah	Read only	-	O	Yes
0x0016	BatteryVoltage	Unsigned 16-bit integer	-	0.1V	Read only	-	O	Yes
0x0017	DHW Energy generation efficiency	Unsigned 16-bit integer	-	(%)	Read only	-	O	No
0x0018	CH Energy generation efficiency	Unsigned 16-bit integer	-	(%)	Read only	-	O	No
0x0019	COOLING Energy generation efficiency	Unsigned 16-bit integer	-	(%)	Read only	-	O	No
0x001A	DHW Heat losses rate	Unsigned 16-bit integer		[kWh/day]	Read only	-	O	No
0x001B	CH Heat losses rate	Unsigned 16-bit integer		[kWh/day]	Read only	-	O	No
0x001C	COOLING Heat losses rate	Unsigned 16-bit integer		[kWh/day]	Read only	-	O	No
0x001D	DHW DeltaSetPoint	Unsigned 16-bit integer		1 K	Read only	-	O	No
0x001E	CH DeltaSetPoint	Unsigned 16-bit integer		1 K	Read only	-	O	No
0x001F	COOLING	Signed		1 K	Read	-	O	No

	DeltaSetPoint	16-bit integer			only			

Table 11 – Attributes for the StorageUnit cluster

4.9.3.2.2.1 StorageUnitType Attribute

StorageUnitType is an unsigned 16-bit and contains information about the type of the Storage unit making difference between a thermal and electrochemical storage.

4.9.3.2.2.2 ThermalEnergyStorageType Attribute

ThermalEnergyStorageType is an unsigned 16-bit and contains information about capabilities, in case of a thermal storage unit, of storing energy in different modalities (DHW, CH and Cooling).

4.9.3.2.2.3 FullDeviceCapacity Attribute

FullDeviceCapacity (for storage unit like thermo devices it will be split into DHW, CH and Cooling) is an unsigned 16-bit and contains the size of the ESS. This value represents the amount of energy that can be actually stored in the ESS free to be used. FullDeviceCapacity may differ from the nominal storage capacity because of aging, thermal stress, system wear-out.

4.9.3.2.2.4 StorableEnergy Attribute

StorableEnergy (for storage unit like thermo devices it will be split into DHW, CH and Cooling) is an unsigned 16-bit and contains the quantity of energy actually storable in the system and eventually available to be used-up. Using a ReadAttribute command the client device can be informed on the quantity of energy (if any) storable in the StorageUnit. Based on this and other information the CEMS algorithm can decide to store more energy in the StorageUnit. The energy value can be also considered in order to have a comprehensive economic balance.

4.9.3.2.2.5 MinModulation Attribute

Min Modulation is an unsigned 16-bit expressed in percentage and defines the minimum value allowed for machine modulation. The minimum value is not necessary 0, in some situations thermal machines could have limitations on minimum value.

4.9.3.2.2.6 MaxModulation Attribute

Max Modulation is an unsigned 16-bit expressed in percentage and defines the maximum value allowed for machine modulation. The maximum value is not necessary 100, in some situations thermal machines could have limitations on maximum value.

4.9.3.2.2.7 ChargeMaxPower Attribute

ChargeMaxPower is an unsigned 16-bit and contains the maximum instantaneous power that the StorageUnit can manage when sinking energy from the grid/Renewable production plant. Using a ReadAttribute command the client device can get the maximum electric power the ESS can sink by the StorageUnit. Based on this information the CEMS algorithm can use the StorageUnit as load of a given power that can be activated for a minimum time given by EnergyStorable/ChargeMaxPower. If the ESS StorageUnit is a battery, a more accurate estimation of the power can be done by the product of the “MaximumChargeCurrent” and the “EndOfDischargeVoltage” attributes.

4.9.3.2.2.8 ChargeMinPower Attribute

ChargeMinPower is an unsigned 16-bit and contains the minimum instantaneous power that the StorageUnit can manage when sinking energy from the grid/Renewable production plant. This attribute will be used in case of a modulating StorageUnit.

4.9.3.2.2.9 **DischargePowerLimit Attribute**

DischargePowerLimit is an unsigned 16-bit and contains the maximum instantaneous power that the StorageUnit can deliver sourcing energy to the load/grid. Using a ReadAttribute command the client device can get the maximum electric power that an ESS can deliver from the StorageUnit. Based on this information and the AvailableEnergy information, the CEMS algorithm can estimate how long a given load can be sustained by the energy stored in the ESS. Please note that if the ESS StorageUnit is a battery, a more accurate estimation of the power can be done by a product of the "MaximumDischargeCurrent" and the "EndOfDischargeVoltage" attributes.

4.9.3.2.2.10 **MaximumChargeCurrent Attribute**

MaximumChargeCurrent is an unsigned 16-bit and contains, only for Battery storage, the maximum charging current the Battery Unit can manage when charging.

4.9.3.2.2.11 **MaximumDischargeCurrent Attribute**

MaximumDischargeCurrent is an unsigned 16-bit and contains, only for Battery storage, the maximum current the battery can manage when discharging.

4.9.3.2.2.12 **MaximumChargeVoltage Attribute**

MaximumChargeVoltage is an unsigned 16-bit and contains, only for Battery storage, the maximum voltage the battery can reach when charging.

4.9.3.2.2.13 **EndOfDischargeVoltage Attribute**

EndOfDischargeVoltage is an unsigned 16-bit and contains, only for Battery storage, the minimum voltage the Battery can reach during discharge

4.9.3.2.2.14 **BatteryCurrent Attribute**

BatteryCurrent is a signed 16-bit and contains, only for Battery storage, the actual battery current value – for monitoring porpoise only.

4.9.3.2.2.15 **BatteryVoltage Attribute**

BatteryVoltage is an unsigned 16-bit and contains, only for Battery storage, the actual battery voltage value – for monitoring porpoise only.

4.9.3.2.2.16 **EnergyGenerationEfficiency Attribute**

EnergyGenerationEfficiency (split into DHW, CH and Cooling) is an unsigned 16-bit and defines the efficiency for thermal energy generation in CH-Cooling-DHW.

4.9.3.2.2.17 Heat losses rate Attribute

Heat losses rate (split into DHW, CH and Cooling) is an unsigned 16-bit and defines for a storage unit (for example DHW tank, house) the rate of energy losses.

4.9.3.2.2.18 DeltaSetPoint Attribute

DeltaSetPoint (split into DHW, CH and Cooling) can be unsigned/signed 16 bit and defines the capability to store more energy into thermo device in comparison to the normal working mode.

4.9.3.2.3 Commands Received

The commands IDs for the StorageUnit cluster are listed in Table 12.

Command Identifier Field Value	Description	Mandatory/Optional
0x00	storeAvailableEnergyRequest	O
0x01	useStoredEnergyRequest	O

Table 12 – Received Commands for the StorageUnit cluster.

4.9.3.2.3.1 *storeAvailableEnergyRequest command*

This basic message is used to store a given energy in the StorageUnit of the ESS. The command has PowerRate as payload. The command can store energy as power for a given time: PowerRate indicates the power/percentage of modulation in case of thermo machines at which the CEMS wants to store a given energy (i.e. CEMS may want to store 1kWh of energy in the form of “1kW PowerRate” for 1 hour instead of “500W PowerRate” for 2 hours, depending on its load management algorithm).
As PowerRate can be expressed in percentage in order to drive power for thermo machines, as soon as the PowerRate payload assumes zero value it doesn’t mean device switched off (it will correspond to minimum machine working mode, in other words ChargeMinPower value). From here the need to use the command with a double function (binary values, 1 for start and 0 for stop)...
In case the CEMS gives a thermo device the storeAvailableEnergyRequest command it uses PowerRate in percentage (a value between Min and Max modulation) and select the right value by estimating how much power the thermo device should absorb (by mean of Power rate [%] and ChargeMax Power and ChargeMinPower). CEMS will monitor the energy exported into the grid and will adjust the PowerRate value in order to reach zero value for energy given to the grid. It makes no sense to give the power consumption feedback to the CEMS from the thermo device because it will give estimation, not really measured and it is not precise as required.
If the StorageUnit cannot store energy at the given PowerRate, it will execute the command at the higher possible PowerRate. This command has a payload command reported on Table 13.

Octets	**2**
Data Type	Unsigned 16-bit integer
Field Name	PowerRate

Table 13 – Format of storeAvailableEnergyRequest Payload.

In case of usage on thermo devices this command has another payload command reported on Table 10.

Octets	**2**
Data Type	Signed 16-bit integer
Field Name	CH [1], DHW [2], Cooling [3]

Table 10 – Format of storeAvailableEnergyRequest Payload (thermo device).

4.9.3.2.3.1.1 **Effects on Receipt**

On receipt of this command, the device shall generate a storeAvailableEnergyResponse message (see 5.3.1.2.4.1).

4.9.3.2.3.2 *useStoredEnergyRequest command*

This basic message uses part of the energy stored in the ESS StorageUnit to serve a load or the grid (even if it is not used for EES like thermo devices). The command as a "PowerRate" as payload. The command can dispose of the energy stored as power for a given time: PowerRate indicates the power at which the CEMS wants to extract from the StorageUnit a given energy (i.e. CEMS may want to sink 1kWh of energy in the form of "1kW PowerRate" for 1 hour instead of "500W PowerRate" for 2 hours, depending on its load management algorithm). The CEMS algorithm should check that the PowerRate is less than the DischargePowerLimit attribute (see 5.3..1.2.2.4).
If the StorageUnit cannot source energy at the given PowerRate, it will execute the command at the higher possible PowerRate. If the PowerRate is "0" the command will not be executed.
This command has a payload command reported on Table 14.

Octets	**2**
Data Type	Unsigned 16-bit integer
Field Name	PowerRate

Table 14 – Format of useStoredEnergyRequest Payload.

4.9.3.2.3.2.1 **Effects on Receipt**

On receipt of this command, the device shall generate a useAvailableEnergyResponse message (see 5.3.1.2.4.1).

4.9.3.2.4 Commands Generated

The command IDs generated by the StorageUnit server cluster are listed in Table 15.

Command Identifier Field Value	**Description**	**Mandatory/Optional**
0x00	storeAvailableEnergyResponse	O
0x01	useStoredEnergyResponse	O

Table 15 – Generated Commands IDs for the StorageUnit cluster.

4.9.3.2.4.1 *storeAvailableEnergyResponse command*

This basic message is used to transfer energy from the Renewable Energy Production or from the Grid into the StorageUnit. This command has a payload command reported on Table 16

Octets	**1**	**2**
Data Type	8-bit Enumerator	Unsigned 16-bit integer

Field Name	Status	PowerRate

Table 16 – Format of storeAvailableEnergyResponse Payload.

The Status field can have one of the enumerator values reported in Table 17.

Value	Status Description
0x00	Charging
0x01	Discharging
0x02	General Fault
0x03	Not executable
0x04 – 0xFF	reserved

Table 17 – Status values for the storeAvailableEnergyResponse command

The PowerRate payload confirm or correct the PowerRate payload of the command: if the payload of the command exceeds the hardware possibilities, in the command response PowerRate reports the PowerRate of the executed command (i.e. the maximum possible PowerRate). When Status has value 0x02 – 0xFF (see Table 13) the payload value is "don't care" (see next section).

4.9.3.2.4.1.1 Effects on Receipt

On receipt of this command, the device shall check that the command is been completely executed or be informed that is been partially executed (the returned payload is different from what requested in the command) or just ignore. If the Status has value between 0x02 to 0xFF (i.e. a fault communication, see Table 13) the device shall log the event, communicate the faulty condition to the user or just ignore.

4.9.3.2.4.2 *useStoredEnergyResponse command*

This basic message is used to extract energy from the StorageUnit to feed the Grid or the home loads. This command has the same payload command of storeAvailableEnergyResponse command, reported on Table 16. This command is not used for thermo devices.

4.9.3.2.4.2.1 Effects on Receipt

On receipt of this command, the device shall check that the command is been completely executed or be informed that is been partially executed (the returned payload is different from what requested in the command). If the Status has value between 0x02 to 0xFF (i.e. a fault communication, see Table 13) the device shall log the event, communicate the faulty condition to the user or just ignore.

4.9.3.3 Client

4.9.3.3.1 Dependencies

None.

4.9.3.3.2 Attributes

The client cluster has no attributes.

4.9.3.3.3 Commands Received

The client receives the cluster specific commands generated by the server.

4.9.3.3.4 Commands Generated

The client generates the cluster specific commands received by the server, as required by the application.

4.9.4 RenewableEnergyProduction Cluster

4.9.4.1 Overview

The RenewableEnergyProduction cluster is used to report basic information on the energy production plant useful to a domestic power management. This cluster presents attributes and commands for determining basic information about a device and setting user device information.

4.9.4.2 Server

4.9.4.2.1 Dependencies

None.

4.9.4.2.2 Attributes

The attributes defined in this cluster are listed in Table 18.

Identifier	Name	Type	Range	Unit	Access	Default	Mandatory /Optional	Reportable
0x0000	GridVoltage	Unsigned 8-bit integer	-	0.1V	Read only	-	O	No

0x0001	GridCurrent	Unsigned 16-bit integer	-	0.01A	Read only	-	O	No
0x0002	GridPower	Unsigned 16-bit integer	-	1W	Read only	-	M	No
0x0003	GridFreq	Unsigned 8-bit integer	-	0.01Hz	Read only	-	O	No
0x0004	ActualAppliedPowerLimit	Unsigned 16-bit integer	-	1W	Read only	-	O	No
0x0005	NominalPower	Unsigned 16-bit integer	-	1W	Read only	-	M	No
0x0006	SystemStatus	Unsigned 64-bit integer	-	--	Read only	-	M	No
0x0007	PartNumber	Unsigned 64-bit integer	-	--	Read only	-	O	No
0x0008	Version	Unsigned 64-bit integer	-	--	Read only	-	O	No
0x0009	CumulatedEnergyReading	Floating point Single Precision[7]	-	--	Read only	-	O	No

Table 18 - Attributes for the RenewableEnergyProduction cluster

4.9.4.2.2.1 GridVoltage Attribute

GridVoltage is an unsigned 8-bit and contains the mean grid voltage value.

4.9.4.2.2.2 GridCurrent Attribute

GridCurrent is an unsigned 16-bit and contains the mean current fed into the grid.

4.9.4.2.2.3 GridPower Attribute

GridPower is an unsigned 16-bit and contains the actual Power injected to the grid.

[7] DataType 0x39 (4 octets length)

4.9.4.2.2.4 GridFreq Attribute

GridFreq is an unsigned 8-bit and contains the grid AC frequency.

4.9.4.2.2.5 ActualAppliedPowerLimit Attribute

ActualAppliedPowerLimit is an unsigned 16-bit and it is used to inform if the inverter is "derating" its MPPT power for internal reasons or external command.

4.9.4.2.2.6 NominalPower Attribute

NominalPower is an unsigned 16-bit and represent the nominal inverter power. It is a constant characteristic of the inverter.

4.9.4.2.2.7 SystemStatus Attribute

SystemStatus is a 5 byte attribute and contains the overall status of the inverter.

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4
Global State	Inverter State	DC/DC channel 1 state	DC/DC channel 2 state	Alarm

Table 19 – Content values for the SystemStatus attribute

The content value for each of those bytes in presented in the following table.

Global State		Inverter State		DC/DC channel x state		Alarm	
1	Waiting (sun/Grid)	**0**	Stand By	**4**	Input Over Current	**0**	No alarm
2	Checking Grid	**1**	Checking Grid	**6**	Input Over Voltage	**1**	Sun Low
6	Run	**2**	Run	**7**	Input low	**2**	Input over current
9	Ground fault	**3**	Bulk Over Voltage	**9**	Bulk Over Voltage	**3**	Input under voltage
15	Leakage fault	**4**	Output over current	**14**	Ground Fault	**4**	Input over voltage
31	Temperature fault	**6**	Bulk Under Voltage	**15**	Inverter Failure	**7**	Bulk over voltage
115	Arc fault	**10**	Grid Over Voltage			**9**	Output over current
		15	Leakage failure			**11**	Bulk under voltage
		16	DC/DC failure			**13**	Grid failure
		26	DC injection			**23**	Ground fault
		46	Grid Failure			**21**	Inverter failure
						31	DC injection error
						32	Grid Over voltage

						33	Grid Under voltage
						34	Grid over frequency
						35	Grid under frequency
						38	R iso low
						48	Under Temperature
						67	Anti-islanding
						68	DC fuse failure
						79	Arc fault
						81	Module door open

Table 20 - List of values for the SystemStatus attribute

4.9.4.2.2.8 PartNumber Attribute

PartNumber is an unsigned 8-byte and contains an 8 char string defining the part number of the inverter.

4.9.4.2.2.9 Version Attribute

Version is an unsigned 8-byte and contains an 8 char string with additional information on the inverter model and its setting.

4.9.4.2.2.10 CumulatedEnergyReading Attribute

CumulatedEnergyReading is a 32-bit floating point and contains the lifetime cumulated Energy produced by the inverter.

Byte 0	Byte 1	Byte 2	Byte 3
En3	En2	En1	En0

Table 21 - Content field for CumulatedEnergyReading attribute

En (4 bytes) is the cumulated energy reading expressed in Wh, with En3 being the most significant byte and En0 the less significant byte. Energy values are coded as follows:

$$Energy = En3 * 2^{24} + En2 * 2^{16} + En1 * 2^{8} + En0$$

4.9.4.2.3 Commands Received

There are no commands received for this cluster.

4.9.4.2.4 Commands Generated

There are no commands generated for this cluster.

4.9.4.3 Client

4.9.4.3.1 Dependencies

None.

4.9.4.3.2 Attributes

The client cluster has no attributes.

4.9.4.3.3 Commands Received

The client receives the cluster specific commands generated by the server.

4.9.4.3.4 Commands Generated

The client generates the cluster specific commands received by the server, as required by the application.

Annex 1 - ZigBee and CENELEC mapping

Several use-cases have already been defined [R1], relying on HAN and HN connectivity. Each use case requires the implementation of several functions (e.g. product identification, statistics collection, alert management, etc.). The following table includes all the interesting tasks with a preliminary mapping with already defined ZigBee clusters and/or CENELEC appliance interworking functional blocks. See [R8] and [R9]for more details.

Scenario	E@h feature requirement	Coverage in ZigBee	Coverage in EN50523
1	Visualization of current energy and power data + cost.	ZigBee Cluster Library Metering Cluster Price Cluster	Not supported
2	Visualization of historical data.	ZigBee Cluster Library Metering Cluster	Potentially COLLECT DIAGNOSIS DATA MID can be used
3	Alarm	ZigBee Cluster Library Alarm Cluster	SIGNAL EVENT/STATE MIDs which support Alert Event OID management
4	Other energy information	ZigBee Cluster Library Message Cluster	Not supported
5	Home Domain Overload management	ZigBee Cluster Library Metering Cluster Demand Response&Load Control Cluster	EXECUTE COMMAND MIDs and SIGNAL STATE MIDs covers statements and status of SA
6	Optimize energy cost in case of time-based prices contract	ZigBee Cluster Library Metering Cluster Price Cluster	Not supported
7	Demand response	ZigBee Cluster Library Price Cluster Demand Response&Load Control Cluster	EXECUTE COMMAND MIDs covers statements to SA

Table 22 – Mapping between ZigBee clusters and/or CENELEC appliance functional blocks

According to the preliminary analysis, the E@h use-cases could be fulfilled implementing several functions embedded into a single Application Object. The same table reports also the potential correspondences between ZigBee and CENELEC concepts/terminology which will be deeply analysed in the next paragraphs.

The clusters implemented in the Smart Appliances could leverage on the ZigBee Home Automation (HA) profile. Essential HA or SE clusters, related with electrical appliances functionalities, are implemented (e.g. Identify, Basic, Group, etc.). The same end-point includes clusters, derived from

Smart Energy profile, which will be added to monitor electrical appliance energy consumption (e.g. Metering cluster).

CENELEC functionalities described in [R6]-[R7] not covered by existing ZigBee clusters but useful for E@h project, are implemented in private (potentially, in a near future, public) dedicated clusters. Moreover, manufacturer specific tasks could be embedded in a private cluster as well.

The ZigBee Alliance provides a Cluster Library (ZCL) [R2]which is intended to act as a repository for cluster functionality that is developed by ZigBee. A developer implementing a profile should use the ZCL to find relevant cluster functionality that can be incorporated into the new, even if private, profile. This also allows ZigBee profiles to be developed with more of an object oriented style approach.

Throughout the ZCL, a client/server model is employed. Typically, the entity that stores the attributes of a cluster is referred to as the server of that cluster and an entity that affects or manipulates those attributes is referred to as the client of that cluster. However, if required, attributes may also be present on the client of a cluster. The E@h-defined clusters described below follow, as much as possible, the ZCL approach.

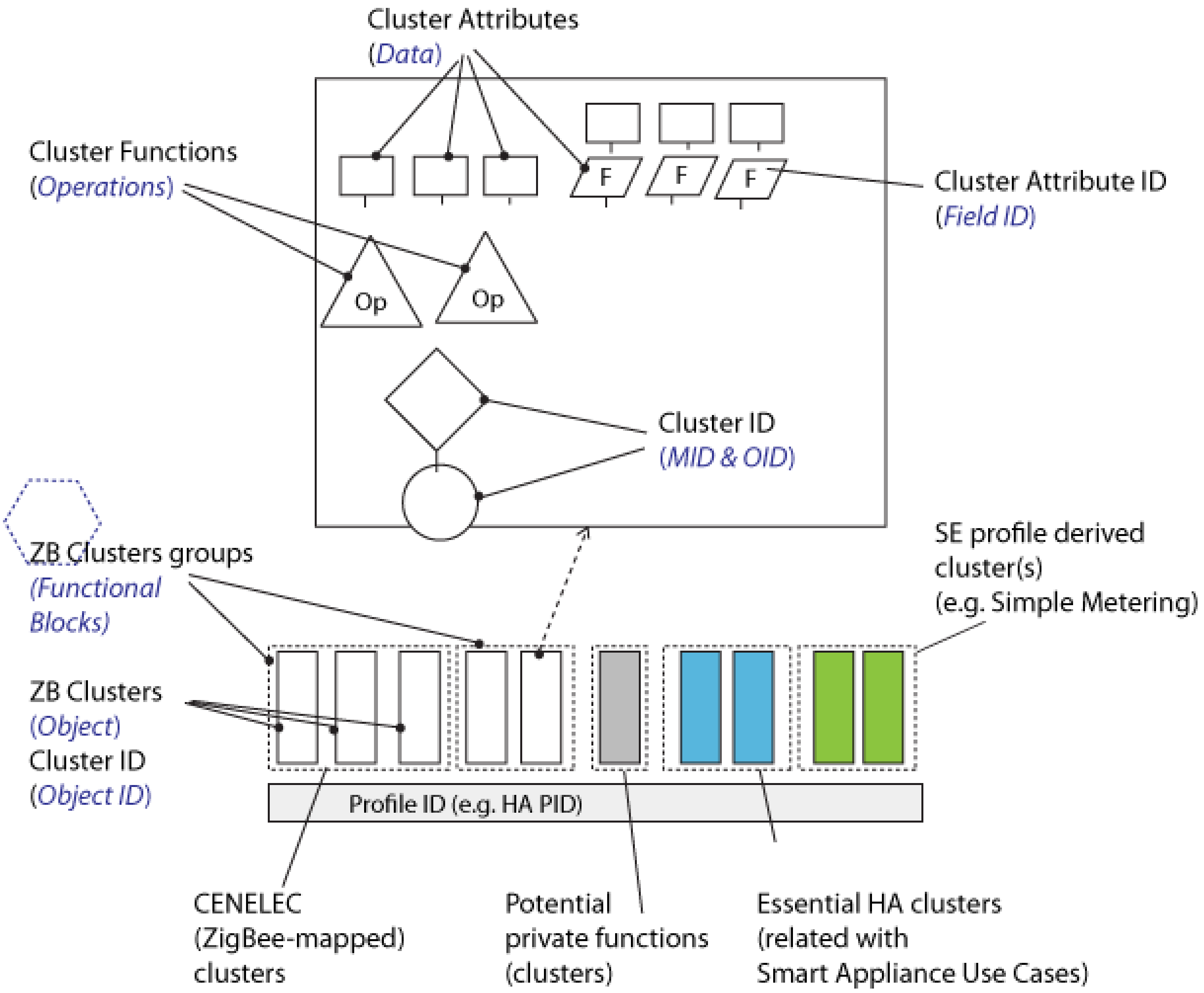


Figure 26 - Architecture of Smart Appliance ZigBee application layer and CENELEC mapping on ZigBee protocol.

Potentially, Smart Appliances could be configured as a new device in the E@h profile, i.e. generic "White Goods" device or more detailed sub-categories, as depicted in the following (i.e. according to CENELEC specifications). In the following tables, a potential mapping of CENELEC networking concepts on ZigBee protocol is proposed.

Concepts	**ZigBee Protocol Mapping**
OID	Cluster ID
OID Data	Cluster attributes
MID value field	ZB cluster command with data parameter field
MID individual transmission	ZB individual transmission
MID group transmission	ZB group transmission or, alternatively, individual transmission to all linked devices
MID broadcast transmission	ZB broadcast transmission
Functional Block	Group of clusters

Primitives	**Addressing**	**ZigBee Protocol Mapping**
Change value primitive	Individual	Individual Write request ("Write attributes" command, Command Identifier Field Value: 0x02) on ZB attribute
	Group	Group Write request on ZB attribute to linked devices
	All	Broadcast Write request on ZB attribute to all devices
Get value primitive	Individual	Individual Read request ("Read attributes" command, Command Identifier Field Value: 0x00) on ZB attribute
	All	Broadcast Read request on ZB attribute
Return value primitive	Individual	Individual "Read attribute response" command (Command Identifier Field Value: 0x01) related to read ZB attribute
Send value primitive	Individual	Individual Report attribute request ("Report attributes" command, Command Identifier Field Value: 0x0a) on ZB attribute
	Group	Individual Report attribute request to linked devices
	All	Individual Report attribute request to linked devices

Annex 2 – QPSOL algorithm

In this annex the QPSOL (Quantum inspired Particle Swarm with Lévy flights) algorithm is presented. Please notice that Telecom Italia owns a patent on this algorithm, published on August 7th 2014, publication number WO2014117861 A1, PIR request number PCT/EP2013/052047. For more information please see [R13]. More detailed description of the QPSOL algorithm can be found at www.thinkmind.org/download.php?articleid=iccgi_2014_1_30_10119.

After several experimental and simulated alternative metaheuristic approaches, the proposed algorithm is a variant of the PSO algorithm that can be described as Quantum inspired PSO with Lévy flights (QPSOL). The algorithm tries to capture and exploit some of the best characteristics of various algorithms. The result being an algorithm that provides a good balance between exploration and exploitation that gives quasi-optimal solutions within a very short time even with limited computing power. In fact, it can run efficiently on a Home Gateway (HG) with low power embedded system running a Java Virtual Machine in the OSGi framework. The two main assumptions of the QPSOL algorithm are:

- First, as in Quantum PSO, particles have no mass and move around their attractor within a probability distribution.
- Secondly, rather than follow the quantum physics that uses the exponential distribution, in QPSOL particles move according to the nature-inspired Lévy distribution. From our experiments and simulations, the quantum inspired PSO, coupled with the Lévy distribution, has proven to outperform the classical PSO and traditional QPSO.

For our purposes, the Lévy distribution coefficient α chosen in QPSOL is actually the Cauchy coefficient $\alpha = 1$. The Cauchy random generator is much simpler than the more general algorithm for Lévy generation and that is a determining factor in runtime execution. Since the random generation needs to be executed for an umpteen number of times (i.e. the dimension of the problem, by the number of particles in the swarm, by the number of iterations of the algorithm), the computing speed of the random generation is of paramount importance. From our experiments, within a given time limit allotted to the algorithm to find a solution, the Cauchy version of the algorithm is able to execute almost twice the number of iterations than the general Lévy version. Therefore, even if there was an optimal coefficient α that provides better results for the same number of iterations, it will be outperformed by the Cauchy variant that with more allowed iterations finds better solutions. Since Cauchy is simply a special case of the general Lévy distribution, henceforth we will continue to refer to the algorithm as a Quantum PSO with Lévy flights QPSOL.

QPSOL for Scheduling Appliances

As any population based metaheuristic algorithm, each particle represent a complete solution to the problem, i.e. a complete schedule for all the Power Profiles of the appliances. Since each Power Profile is itself composed by a sequence of phases, we model each particle (complete solution) as a set of N sub-particles, where N is the number of Power Profiles and where each sub-particle represents the schedule for the energy phases of that Power Profile.

Below we report the pseudo code of the evolution of the sub-particles in the swarm and it represents the core of the QPSOL algorithm.

Procedure: nextRandomFlight

```
void nextRandomFlight(ProfileScheduleSubparticle bestParticle)
```

Parameters

bestParticle - ProfileScheduleSubparticle

Returns Void

Pseudocode

```
Set globalBestPositions Array to the best Particle's best Positions Array
Initialise currentMaxSlack to profileSlackInterval
Initialise phaseMaxDelay to profileSlackInterval
For each i iterating over all Phases of the Profile
	If i is greater than 0 (i.e. for all Pahses other than the firts one)
		Set phaseMaxDelay to the minimum between currentMaxSlack, and Phase(i)'s MaxAlowedDelay
		If phaseMaxDelay
			Set i of phasesCurrentPositions to 0
			continue;
		EndIf
	EndIf
	Initialise r to a random real number uniform in [0,1]
	Initialise attractor to r multiplied by Phase(i)'s currentBestPositions(i) plus ( 1 minus r ) multiplied by Phases(i)'s globalBestPositions(i)
	Initialise c to a random real number with Cauchy distribution
	Initialise step to c multiplied by (attractor minus Phase(i)'s currentPositions(i))
	Set Phase(i)'s currentPosition to attractor plus step
	If Phase(i)'s currentPosition is less than 0 or greater than phaseMaxDelay
		Set Phase(i)'s currentPosition to 0
	EndIf
	Subtract to currentMaxSlack the new updated Phase(i)'s currentPosition
EndFor
Set tardiness to profileSlackInterval minus currentMaxSlack
```

Annex 3 - Production forecast acquisition system

This section reports a possible communication between HAN and an external interface, such as web services, external authorities, and remote systems. With the introduction of the production system in E@h, knowing how much energy the production plant will produce in next days has become essential for consumption peak shaving and load balance purpose. Therefore this section introduces a forecast service needs to constantly download heavy satellite data and to do a complex image elaboration process, so the service has to reside in a remote dedicated server.

Use case scenario

In this paragraph we will describe the interaction between E@h CEMS and a forecast service, which is composed by two main steps:

- Plant registration: the plant is registered in the forecast service. This means that forecast service needs some relevant plant parameters in order to compute a production forecast, such as nominal power, location …
- Forecast acquisition: once registered, CEMS can periodically invoke the forecast service to obtain expected production values that the CEMS can show to the home user or stored to make decisions about consumption peak shaving and load balancing.

Plant registration

In the registration phase, the CEMS GUI provides a registration form that the home user or the plant installer can fill with relevant plant information.
Data inserted in web form are sent to the forecast service invoking a specific web method. In this way the service collects all the necessary data to start the forecast computation process.
Registration form data can be categorized in two areas: **general information** and **plant information**. The registration web form asks the user for the data shown in the following tables.

General information			
Plant unique ID (DSO ID)			
Provider URL			
Working start date			
Plant address			
Address		House number	
CAP			
City		District	
Longitude		Latitude	
Plant referent			
Name and Surname			
Telephone			
E-mail			

Figure 27 - General information plant

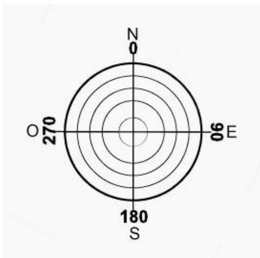
Plant information	
PNI – Nominal power [kWp]	
Inverter model (brand/model no.)	
Number of MPPTs For each MPPT, the following table must be compiled	
MPPT n	
Number of Homogeneous fields **Homogeneous field**: set of PV modules with the same tilt and azimuth For each Homogeneous field, the following table must be compiled	
HOMOGENEOUS FIELD n	
Title	
Azimuth (south = 180°, east = 90°)	
Modules model type (brand/model no.)	
Number of strings	
Number of modules for each string	

Figure 28 – Plant Registration form

When the user fill the registration form and press the “submit” button in the interface, the CEMS wraps all the compiled fields in a web request and sends the request to the Forecast Service, as in the following sequence diagram.

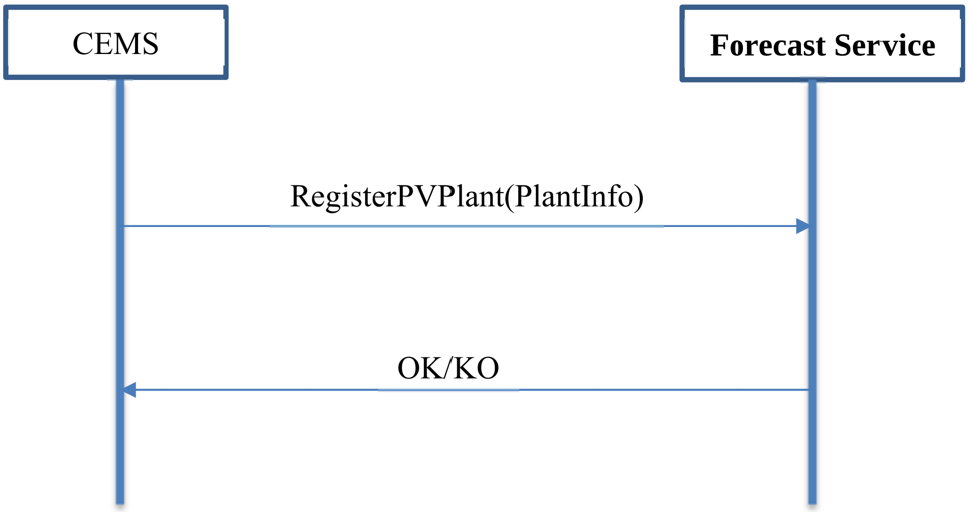


Figure 29 - Sequence diagram CEMS/Forecast service

Forecast Service reply with the result of the registration process. IF succeeded, CEMS is now able to make forecast prediction requests with its unique ID with which it has registered in the registration form.

Forecast data acquisition

Once registered, CEMS starts periodically the forecast data acquisition process: the CEMS makes a request to the Forecast Web Service asking for the expected plant power of the next hours.
Forecast service returns a sequence of expected powers in a specific date time that is stored by CEMS in a database to let it be available by user when he/she requests the expected plant production information. The Forecast service typically returns 72 power values, once an hour for the next 72 hours.

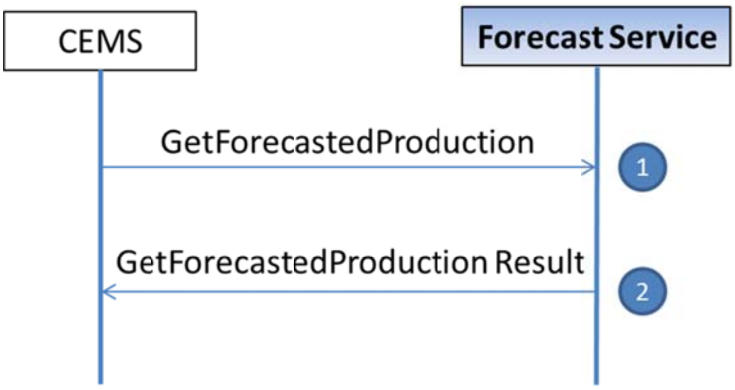


Figure 30 – Forecast Data Acquisition message exchange

Data exchanged in this sequence diagram are described in the following tables.

Message ID	From	To	Description	Parameters
GetForecasted Production	CEMS	Forecast Service	CEMS asks the forecast service for the current PV power	• String **plant_UID** • String **quantityType** • DateTime **date**

GetForecasted Production Result	Forecast Service	CEMS	Forecast service returns the expected plant power	• String Provider • DateTime **created** • TimeInterval **validFor** Sequence of: • `String` **`quantityType`** • `DateTime` **`timestamp`** • `Double` **`value`**

Below a description of the GetForecastedProduction request and response parameters is reported as well.

Plant_UID	Plant unique ID, as passed to the Forecast Service at registration time. This ID corresponds to the id that ENEL assigns to the PV Plant when deployed
quantityType	The quantity to which the CEMS wants the forecast. Actually only the Current Production Power can be retrieved (written in shorter form as **pac)**, but in the next future also energy, irradiance and other environmental parameters could be retrieved)
date	Day in which the forecast process is executed. Typically is today, but CEMS could also need forecast elaborated in previous days to store historical forecasts

Figure 31 - Description of the GetForecastedProduction request parameters

Provider	Name of the provider of the forecast service
Created	Forecast creation timestamp
validFor	Interval of the forecasted values
quantityType	The forecasted quantity
Timestamp	The timestamp to which the forecasted value is associated
Value	The forecasted value

Figure 32 - Description of the GetForecastedProduction response parameters

Communication protocols

To communicate externally with the CEMS, the most used communication protocols in the web services implementations currently used in Energy@home are **SOAP** and **REST**:

- **SOAP** is a communication protocol that wraps message written in XML with some custom SOAP custom tags, and sends these wrapped messages over HTTP protocol using HTTP POST method.

- **REST** is a different communication protocol that uses HTTP GET method to read values from server, and HTTP POST method to insert/write values in the server (instead of SOAP that uses exclusively HTTP POST), and sends messages written in plain XML format or JSON format.

In Energy@home, both protocols are supported, and in next paragraphs we show how messages defined in are exchanged using SOAP and REST.

SOAP

RegisterPVPlant Request

```
POST http://forecast-service.eu/webservice.asmx HTTP/1.1
Content-Type: text/xml; charset=utf-8
SOAPAction: "http://forecast-service.eu/RegisterPVPlant"
Host: forecast-service.eu

<?xml version="1.0" encoding="utf-8"?>
<soap:Envelope xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
  <soap:Body>
      <RegisterPVPlant xmlns="http://www.energy-home.it">
            <Plant_UID>string</Plant_UID>
            <start_date>string</start_date>
            <Address>string</Address>
            <number>int</number>
            <CAP>int</CAP>
            <city>string</city>
            <district>string</district>
            <latitude>double</latitude>
            <longitude>double</longitude>
            <name>string</name>
            <surname>string</surname>
            <telephone>int</telephone>
            <email>string</email>
            <plant>
                  <pni>double</pni>
                  <inv_model>string</inv_model>
                  <mppt_num>int</mppt_num>
                  <mppt>
                        <field_num>int</field_num>
                        <field>
                              <tilt>double</tilt>
                              <azimuth>int</azimuth>
                              <module_model>string</module_model>
                              <string_num>int</string_num>
                              <module_num>int</module_num>
                        </field>
                        <field>
                              ...
                        </field>
                        ...
                  </mppt>
                  <mppt>
                        ...
                  </mppt>
                  ...
            </plant>
      </RegisterPVPlant>
</soap:Body>
</soap:Envelope>
```

RegisterPVPlant Response

```
HTTP/1.1 200 OK
```

GetForecastedProduction request

```
POST http://forecast-service.eu/webservice.asmx HTTP/1.1
Content-Type: text/xml; charset=utf-8
SOAPAction: "http://forecast-service.eu/GetPlantForecast"
Host: forecast-service.eu

<?xml version="1.0" encoding="utf-8"?>
<soap:Envelope xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
  <soap:Body>
        <GetPlantForecast xmlns="http://www.energy-home.it">
                <plant_UID>string</plant_UID>
                <quantityType>string</quantityType>
                <date>string</date>
        </GetPlantForecast>
</soap:Body>
</soap:Envelope>
```

GetForecastedProduction response

```
HTTP/1.1 200 OK

<?xml version="1.0" encoding="utf-8"?>
<soap:Envelope xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
  <soap:Body>
    <GetPlantForecastResponse xmlns="http://www.energy-home.it">
     <provider>string</provider>
     <created>string</created>
     <validFor>string</validFor>
     <ForecastValueSet>
        <ForecastValue>
            <quantityType>string</quantityType>
            <timestamp>string</timestamp>
            <value>double</value>
        </ForecastValue>
        <ForecastValue>
            <quantityType>string</quantityType>
            <timestamp>string</timestamp>
            <value>double</value>
        </ForecastValue>
        …
      </ForecastValueSet>
     </GetPlantForecastResponse>
   </soap:Body>
</soap:Envelope>
```

REST (XML version)

RegisterPVPlant Request

```
POST {ROOT_URL}/RegisterPVPlant HTTP/1.1
Content-Type: text/xml; charset=utf-8
Host: forecast-service.eu

<?xml version="1.0" encoding="utf-8"?>
<RegisterPVPlant xmlns="http://www.energy-home.it">
      <Plant_UID>string</Plant_UID>
      <start_date>string</start_date>
      <Address>string</Address>
      <number>int</number>
      <CAP>int</CAP>
      <city>string</city>
      <district>string</district>
      <latitude>double</latitude>
      <longitude>double</longitude>
      <name>string</name>
      <surname>string</surname>
      <telephone>int</telephone>
      <email>string</email>
      <plant>
            <pni>double</pni>
            <inv_model>string</inv_model>
            <mppt_num>int</mppt_num>
            <mppt>
                  <field_num>int</field_num>
                  <field>
                        <tilt>double</tilt>
                        <azimuth>int</azimuth>
                        <module_model>string</module_model>
                        <string_num>int</string_num>
                        <module_num>int</module_num>
                  </field>
                  <field>
                              ...
                  </field>
                        ...
            </mppt>
            <mppt>
                        ...
            </mppt>
                  ...
      </plant>
</RegisterPVPlant>
```

RegisterPVPlant Response

```
HTTP/1.1 200 OK
```

GetForecastedProduction request

```
GET
{ROOT_URL}/getforecastedproduction?plant_UID=string&quantityType=string&date=st
ring HTTP/1.1
Host: forecast-service.eu
```

GetForecastedProduction response

```
HTTP/1.1 200 OK
```

```
<GetPlantForecastResponse xmlns="http://www.energy-home.it">
    <provider>string</provider>
    <created>string</created>
    <validFor>string</validFor>
    <ForecastValueSet>
            <ForecastValue>
            <quantityType>string</quantityType>
            <timestamp>string</timestamp>
            <value>double</value>
        </ForecastValue>
        <ForecastValue>
            <quantityType>string</quantityType>
            <timestamp>string</timestamp>
            <value>double</value>
        </ForecastValue>
            …
      </ForecastValueSet>
</GetPlantForecastResponse>
```

Glossary - Terms and Abbreviations

Term	Description
AG	See HG.
Appliance Power Profile	The Appliance Power Profile is a data structure containing information about the energy consumption of an appliance (load profile related to its cycles) and some other useful information for load shifting or load shedding its usage.
APL	ZigBee Application Layer
APS	ZigBee Application Support Sublayer
ASDU	ZigBee Application Service Data Unit
CEMS	Community Energy Management System, the aggregator of the HAN data
Customer Interfaces	An appliance or Smart Info User Interface extension. Its goal is having a remote, more verbose, portable, remote, user friendly, configurable device. It could be a physical device or, more commonly, it is only a logical component, which can be visualized by a PDA, a pc or a Smart Phone (connected in the HAN or HN). Typical implementations are through Web pages or custom software written for each of these devices.
Demand-side Management	Demand side management (DSM) entails actions that influence the quantity or patterns (load profile) of use of energy consumed by end users, such as actions targeting reduction of peak demand during periods when energy-supply systems are constrained. Noticeably techniques are load shifting and load shedding.
DSO	In electrical power business a Distribution System Operator is an operator that carries and delivers electricity to the consumer from the TSO's distribution lines.
Energy Cost Algorithm	Algorithm, to obtain the price of energy at a given time (e.g. € per kWh from 08:00 to 19:00) replicating the conditions applied by the Energy Retailer. The Energy Cost Algorithm to get the price could be quite complex, and, in any case, defined by each Energy Retailer. The Energy Cost Algorithm shall receive as inputs a Power Profile, either actual or estimated, and all the needed metering data.
Energy Regulation Algorithm	Energy Regulation Algorithm is any procedure which defines the strategy for coordinating Smart Appliances behaviour, in order to reach energy consumption or cost optimization and to guarantee the overall performance of the system, using as inputs the global energy consumption, its cost, Appliances Power Profile and their status. Main control techniques involved in the Energy Regulation algorithm are load shifting and shedding.

Energy Retailer	Companies that participate in the retail energy market providing a service (energy) to the end user.
HA	ZigBee Home Automation Public Application Profile
HAN	Home Area Network: it is a residential local area network, usually characterized by low throughput. It is typically used for communication between devices within the home such as sensors, smart plugs, smart thermostats and household appliances. It can be a Wireless network (e.g. ZigBee) or wired (e.g. Power Line Communication). This is often referred to as PAN (Personal area network)
HG	Home Gateway: it is the gateway between the HAN, the HN and the WAN (e.g. internet). It is able to interface Smart Appliances and Customer Interfaces through the communication protocol(s) used in the HAN and HN (ZigBee, Wi-Fi, etc.) and to provide a broadband connection to internet (usually via a standard ADSL connection). Moreover, the Gateway is able to collect energy data, from the Smart Info and from the user's appliances, and publish them in the HN and WAN.
Home Domain	It identifies a boundary of the wired/wireless communication system (HAN and HN), covering Smart Appliances, Customer Interfaces, Smart Info and Home Gateway. This boundary is usually the customer's House.
Home Domain Overload	Condition which takes place when aggregated home load exceeds a given power limitation. Power limitation can be determined by different causes according to the regulation in place. For example, in South Europe countries, domestic connections are subject to a maximum contractual power (e.g. 3kW). Note that maximum contractual power limitation process is managed by the Meter, which the only actor is entitled to sense threshold exceeding and to perform needed action. In some circumstances, the Meter will open the breaker immediately, without emitting any alarm. In other countries, the limitation is imposed by physical limitation of the home equipment and apposite safety devices are installed to prevent the overload.
Home Energy Monitor	A Home Energy Monitor is a device providing the consumer a prompt and convenient feedback on electrical (or other) energy use. These devices may also display cost of energy, estimates of greenhouse gas emissions, near real time consumption of some electrical loads inside the house. Usually its display is remote from the measurement point and portable inside the house, communicating with the sensor and the Home Electricity Meter using a wired (e.g. power line communications) or wireless methodology.
HN Home Network	A Home Network is a residential local area network, typically characterized by high throughput. It is used for communication between digital devices typically deployed in the home, usually personal computers, printers, gateways. The home network can be wireless (e.g. Wi-Fi) or wired (e.g. Ethernet).

Load Profile	Load profile is the variation in the electrical load versus time. A more specific definition is the Power Profile, which takes into account the power used by the load.
Load Shedding	Energy utilities' method of reducing demand on the energy generation system by temporarily rationing distribution of energy to different geographical areas; this can be done by forcing the switch off of some electric loads in the grid or by reducing the power consumption of some of those (thus altering their load profile). The most drastic kind of load shedding are rolling blackouts, the last resort measure used by an electric utility company in order to avoid a total blackout of the power system. Smart Appliances could significantly help to avoid these last resort measures, reducing temporarily their power consumptions: load shedding could be performed by the appliance control logic itself changing its power consumption profile (load profile) during its working operations. This action implies information coming from the Utility through the Smart Grid to the Smart Appliance in order to signal the need, carrying usually also a severity level. Their performances should not be greatly or noticeably affected by the load shedding operation (it belongs to the Demand Side Management techniques).
Load Shifting	Load Shifting is an electric load management technique that aims to shift the pattern of energy use of a device (load profile), moving demand from the peak hours to off-peak hours of the day. It belongs to the Demand Side Management techniques. In the Smart Appliance context, the load could be each single electric load of the appliance or, more generally and commonly, the overall working cycle of the appliance (which consists of a complex sequence of activation of those single loads, in order to achieve the needed performance of the machine)
MID	CECED Message Interaction Description
OID	CECED Object Identifier
Peak Demand or Peak Load	Peak demand or peak load are terms used in Demand Side Management describing a period in which electrical power is expected to be provided for a sustained period at a significantly higher than average supply level. Peak demand fluctuations may occur on daily, monthly, seasonal and yearly cycles.
Power Profile	Power profile is the variation of power consumption of an electrical load versus time, thus specifying the [[Load Profile]] concept. It will vary according to customer type (typical examples include residential, commercial and industrial), temperature and holiday seasons. In the Smart Appliances context, the more specific concept of Appliance Power Profile is used.
SE	ZigBee Smart Energy Profile Specifications

Smart Appliance	It is an appliance connected in the HAN and equipped with some intelligence to cooperate with the other home actors in order to provide new services to the consumer, like for instance energy consumption awareness, demand response, etc. The Smart Appliance plays an active role in the home system complying with the system policies, satisfying the user wishes and always assuring its best performance. Most of these technologies imply some information transfer from the Smart Grids to the Smart Appliance (thus a communication channel within the HAN and outside the Home Domain) and an additional control and supervision logic (inside and/or outside the appliance).
Smart Info SI	This device enables the communication between the electronic meter and the HAN. It is the element, provided by the DSO, which provides energy information into the HAN. Published data are a sub-set of those already available inside the Home Electricity Meter, hence the Smart Info acts like a proxy of the meter...
Smart Plug	Device provided with a HAN interface (e.g. ZigBee) that typically has a power meter able to calculate the power/Energy consumption of the connected load and is typically provided with a Relay that can be used to remotely power on/off the load.
TOU	Time of Use
TC	ZigBee Trust Center
TSO	Transmission System Operator. In electrical power business, a transmission system operator (TSO) is an operator that transmits electrical power from generation plants to regional or local electricity distribution operators (DSO).
WAN	Wide area Network: it is a computer network that covers a broad area (i.e., any network whose communications links cross metropolitan boundaries) This is different than personal area network (PANs), Local area network (LANs) which are usually limited to a room, building, campus respectively.
ZCL	ZigBee Cluster Library