Energy@home Data Model

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Acknowledgements

This document is the result of the activities inside the Energy@home Standardization Committee. 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.

Change history

The following table shows the change history for this specification.

Revision	Description
0.1	Original draft coming from E@h data model, version 0.9.
1.0	Final version

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Scope

This document describes the Energy@home data model, representing the functionalities specified in the Energy@home use cases document [R1], independent on the underlying communication technology. The definition of this data model was inspired by the IEEE P2030.5 specification, a representation model coming from the CIM approach.

This document will introduce some proposal extensions that ZigBee SEP2[1] and IEEE P2030.5 could consider to expand the current data model in a future release.

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 24 members from different industries: the electrical system industry (Enel and Edison), household appliances manufacturers (Electrolux, Indesit Company, and Whirlpool), telecommunications (Telecom Italia and Vodafone), ICT companies (Altran), micro-electronics vendors (Freescale, Renesas and ST Microelectronics), building automation companies (Urmet), insurance and assistance companies (Assurant, Europ Assistance) and a company for the inverter and storage systems (ABB), as well as research institutes (Istituto Superiore Mario Boella) and small/medium-sized companies (iEm, Flexgrid, Eurotherm, MAC, Gemino, Apio, Alyt).

[1] The original specification for IEEE P2030.5 has been provided by the ZigBee Alliance within a dedicate working group called SEP2.

The Energy@home 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.

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.

Related Documents

[R1] Energy@home project, *"Energy@home Use Cases"*, Rev. 2.0, May 2014

[R2] ZigBee Application Framework Working Group, ZigBee document 075123, *"ZigBee Cluster Library Specification"*, October 19, 2007.

[R3] ZigBee Standards Organization, *"ZigBee Home Automation Public Application Profile-Version 1.1"*, February 8, 2010.

[R4] ZigBee Technical Steering Committee (TSC), ZigBee Document 05-3474-20, *"The ZigBee Specification"*.

[R5] ZigBee Standards Organization, ZigBee document 075356r14, *"ZigBee Smart Energy Profile Specification"*, May 29, 2008.

[R6] BSI British Standards, document BS EN 50523-1:2009, *"Household appliances interworking - Part 1: Functional specification"*, July 2009.

[R7] BSI British Standards, document BS EN 50523-2:2009, *"Household appliances interworking - Part 2: Data structures"*, July 2009.

[R8] Indesit Co, *"Use Cases: Smart Appliances Requirements and Data Structures"*, Rev. 1.0, March 22, 2010.

[R9] Indesit Co, Telecom Italia, *"Energy@home, ZigBee and EN50523"*, Rev. 1.0, March 22, 2010.

[R10]ZigBee Standards Organization, ZigBee document 075356r15*"ZigBee Smart Energy Profile specification"*, Rev. 15 December 1, 2008.

[R11]ZigBee Alliance, *"ZigBee Home Automation Public Application Profile-Version 1.2"*, public available on March 2014

[R12]CEN-CENELEC-ETSI, "Smart Grid Coordination Group – Sustainable Processes", public available at http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/xpert_group1_sustainable_processes.pdf

1. System Architecture

Following the European roadmap for the implementation of the Smart Grid[2], 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]).

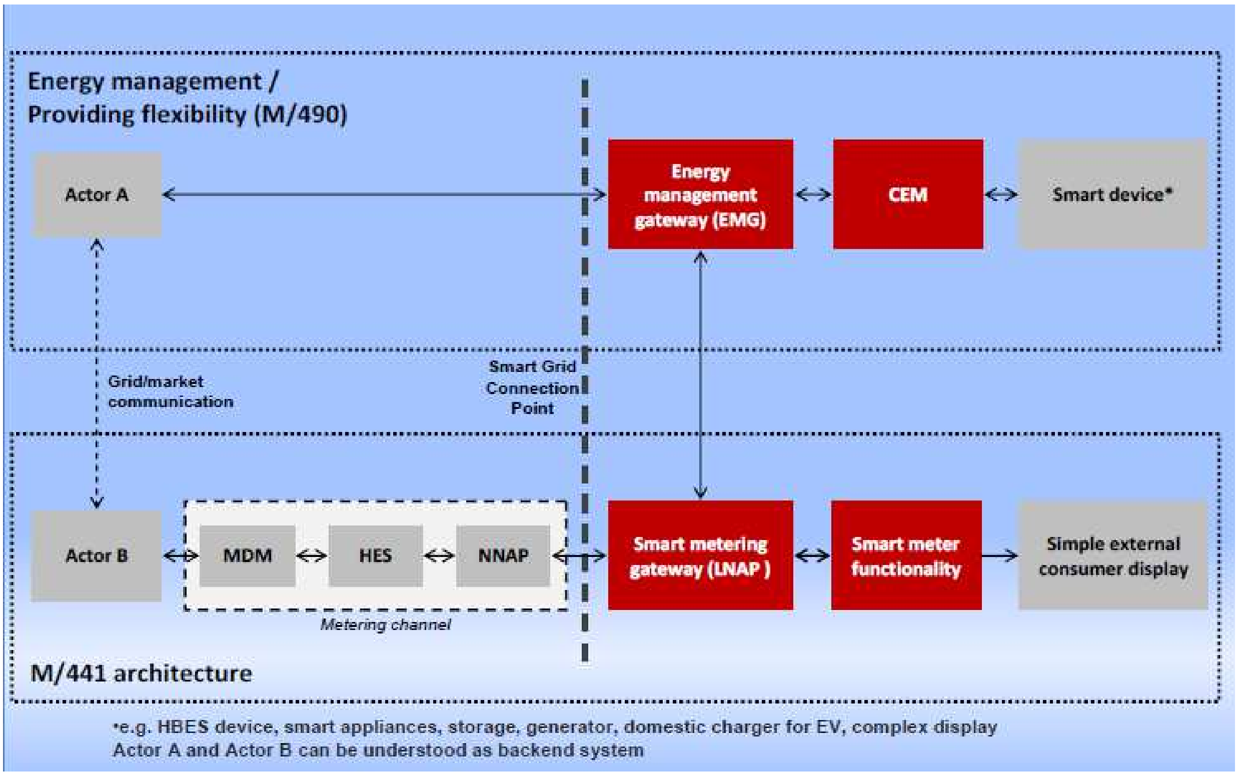


Figure 1: Flexibility functional architecture

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 ongoing collaboration activities and interests of the Energy@home members.

2 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

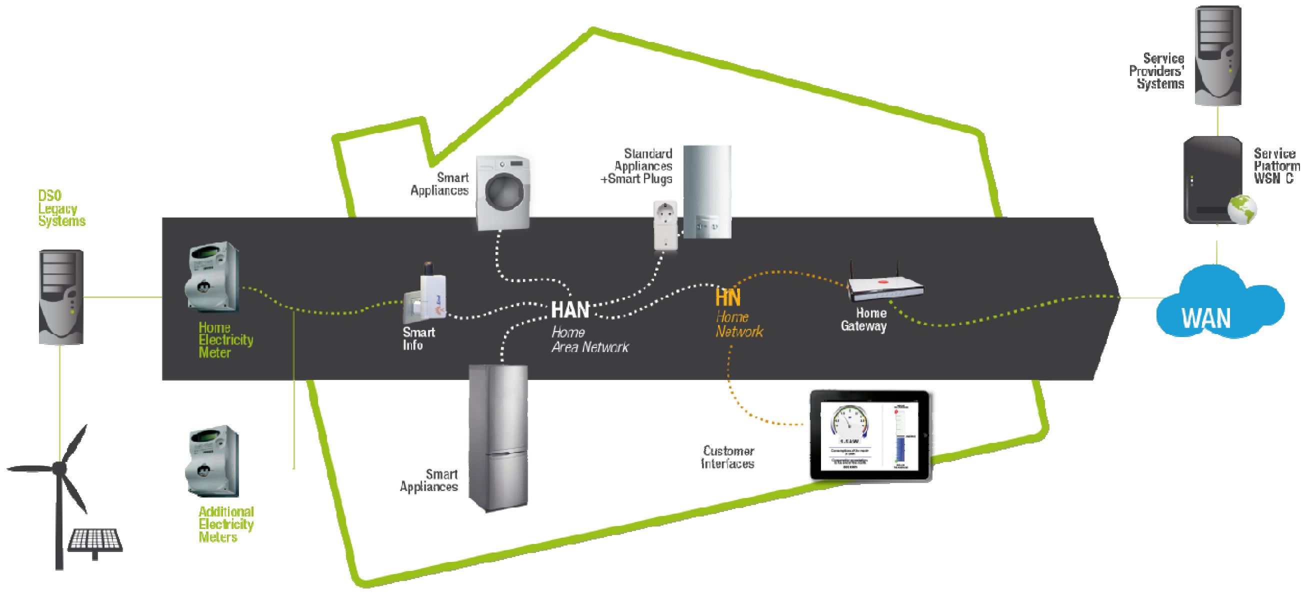


Figure 2: Energy@home architecture

In a Home Domain, that includes both the HAN (Home Area Network) and the HN (Home Network), all the actors (home devices, CEMS, Smart Info and Customer Interfaces) can cooperate through communication mechanism. The aim of Energy@home is to identify and describe the requirements of indoor platform and it is expressly out of the scope the definition of the other interfaces and services provided outside the Home Domain.

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 tunneling 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 four 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 behavior 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 behavior, shall assure the result of the washing cycle.
- **Smart plugs.** They're able to provide remote metering and to be remotely controlled. They 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 behavior
  - 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. E@H data model

One of the priority requirements for the implementation of the Smart Grid (including in this definition also the systems that compose it, like the "Home Area Network") is the "interoperability" qualification. A current definition of this concept, according to IEEE 610, is *"interoperability is the ability of two or more networks, systems, applications, components or devices from the same vendor, or different vendors, to exchange and subsequently use that information in order to perform required functions"*.
The basic degree of interoperability is related to the meaning/semantic of the exchanged information, and it's usually expressed by a Data Model or Ontology. In order to reach a full interoperability at device/system level, in addition to the semantic level it's also necessary to define interoperability at syntactical level, that is usually associated with technological solution (i.e. communication protocol).
The choice to base the E@h data model on SEP2, was the natural evolution of the original E@h selection of the ZigBee specification, mainly motivated by its technological characteristic (i.e. low energy consumption). The SEP2 option was recently reinforced by the IEC decision to base the future data model of IEC-62746 standard related to the interface between the Customer domain and the Smart Grid, on the "IEC-Common Information Model" or "CIM", that also constitute the building block of the SEP2 specification. In that way, the main concepts expressed by "CIM", could applied both inside the customer domain and at the interface between the Grid and the Customer.
In order to fulfil the functional requirements related to E@h use cases, the association proposes its own extensions to SEP2 data model, based on concept related to the European Standard EN50523. Thus, in the next paragraphs the data model proposed by Energy@home is described to represents the outcome of the analysis and integration of the Energy @ home 2.0 Specification[3] in the corresponding SEP2 Function Sets. In particular, for each new Function Sets (FS) generated from scratch, an integration hypothesis in SEP2 is presented and, subsequently, the resources and attributes of each FS are introduced and described in detail.
Please notice that the text and proposal shown below are currently under revision together with the ZigBee Alliance[4] and IEEE P2030.5 and thus future changes and adaptions are expected.

The XSD file is public available at the following URL: www.energy-home.it/Documents/2015-02-dm/. In provides a syntactical representation of a set of messages related to this data model, allowing an automatic validation of conformance of XML data. For completeness, at the same URL a UML file generated using the Enterprise Architect software is available for public download.

[3] Please note that this document has been adopted by the ZigBee Alliance and all the new devices and clusters have been included in the latest version of the ZigBee Home Automation profile 1.2 specification.

[4] Document number docs-14-0250-03

2.1. Monitoring and Control FS

The Energy@home Association wishes to introduce new concepts in IEEE P2030.5 (Draft Standard for Smart Energy Profile 2.0 Application Protocol) to support smart appliance monitoring and control, as well as extend existing function sets to fully support interaction with the Italian smart meter. From here on all the change proposals are highlighted using the “E@h” tags (see for example the next figure).

Regarding monitoring and control functionalities, the data model definition started from the Appliance Control cluster defined inside the ZigBee Home Automation spec, which is quite simple; it has then been extended in order to allow more complex interactions. An example of a possible interface which will be supported is shown in the following figure.

The following description (paragraphs 2.1.1, 2.1.2 and 2.1.3) illustrates the needed information, expressed in an informal way (i.e. not using Smart Energy Profile 2.0 UML modelling). Based on these requirements, a SEP 2.0 extension has been defined and will be illustrated in paragraph 2.1.4.

2.1.1. Initialization phase

This phase is needed to retrieve some general information, listed in the following.

- Available working mode list

It is the list of the working mode available for a specific machine presented as a pair of unique identifier and machine selector position

Working mode Number	**ID**
1	0x0011
2	0x013F
..	…
16	0x5678

- Parameter list & setting mode (min, max, allowed value between min-max)

Each parameter is associated to a type that defines the way the values are represented.
Every type of table has the same header containing the parameter ID, the Unit Code, the Description String and Permissions. The Unit Code is the code that represents a measure unit type.
Permissions can be: “read only”, “write only” or “read and write”

Following two example of Type 0 table (starting value, step, number of set points) and type 1 table containing all the possible values (number of set points, value for each set points).

Type 0 Step example

Parameter ID	**Unit Code String**	**Value Format (Type)**	**Description String**	**Permissions**	**Num Set points**	**Min Value**	**Step**
0x0203	"celsius"	0	"temperature"	read and write	10	0	10
0x0218	""	0	""	read and write	2	0	1
0x001	""	0	"Appliance Status"	read only			

Type 1 Table example

Parameter ID	**Unit Code String**	**Value Format (Type)**	**Description String**	**Permissions**	**Num Set points**	**SP 1 Val**	**SP 2 Val**	**SP 3 Val**	**SP 4 Val**
0x0212	6 (RPM)	1	"spin"	read and write	4	0	600	800	1200

Type 2 Boolean example

Parameter ID	**Value Format (Type)**	**Description String**	**Permissions**
0x0263	2	"door status"	read only

Type 3 Date example

Same as Type 2, with Value Format 3.

- Parameter to parameter compatibility

For each parameter could be represented the incompatibility with each other parameter and what kind (if they shall be reset, set to default value, set to maximum value, ...) through a table like this:

Action	**Affected parameters**	**Expressions list**	**Max Value**

Where:

- **Action** = reset to OFF value /disabled/set to MaxValue/set to default value
- **Affected parameters** = ID of parameters to which apply the action
- **Max value** = maximum value to be used in case of action = set to MaxValue
- **Expressions list** = expressions to evaluate to execute the action as defined in the following table

Parameter ID	**Value**	**Math operator**	**Logical connective**

Where:

- **Parameter ID = ID of the parameter whose current set point has to be compared with the Value, according with the math operator**
- **Math operator can be: ==/ !=/>/</set points above value/set points below value**
- **Logical connective: could** be used to connect different expressions, can be AND/OR

- Working mode data

One or more sets of enabled parameters must be associated to each working mode.
We need n tables for each working mode because different values of some parameter could be associated with different allowed ranges of value for the other parameters.
For each parameter in the set, the following data must be provided

Parameter ID (mandatory)	**Default Value** (mandatory)	**Max Value** (optional)	**Min Value** (optional)	**Avoided Values List** (optional)

Parameter ID = unique ID of the parameter (i.e. temperature)
Default Value = default value of the parameter
Max Value = maximum value that the parameter could be set (if not specified, the maximum value is the one specified in the parameter definition of the initialization phase)
Min Value = minimum value that the parameter could be set (if not specified, the minimum value is the one specified in the parameter definition of the initialization phase)
Avoided Values List = a list of values that can't be set (not admitted)

- The sets of value allowed for each working mode, defined for each working mode #ID (following 2 example of possible tables):

Working mode #1(set 0)	Parameter ID	Default Value	Max Value	Min Value
Temperature	0x0203	40	90	0
Spin	0x0212	1200	1200	0
….	….	….	….	….

……

Working mode #1(set n)	Parameter ID	Default Value	Max Value	Min Value
Temperature	0x0203	40	40	0
Spin	0x0212	1200	1200	0
….	….	….	….	….

The sets above are selected according to the conditions defined in another table . The set 0 is the default set and it is selected when no condition is true.
The condition table has the following format:

Enabled # Set	**Expressions list**

Where
Expressions list = expressions to evaluate to enable a set as defined in the following table

Parameter ID	**Value**	**Math operator**	**Logical connective**

Where

- **Parameter ID =** ID of the parameter whose current set point has to be compared with the **Value**, according with the math operator
- **Math operator** can be: ==/ !=/>/</set points above value/set points below value
- **Logical connective**: could be used to connect different expressions, can be AND/OR

- <u>the strings associated to each working mode, parameter and value</u>

They could be retrieved directly from the device or shared beforehand through tables like the following, where some ID could be standard and others could be custom. There should be a table for each supported language.

ID	**Working mode Name**
0x0011	Cotton 20°
0x0012	Cotton 40°
0x0013	Cotton 60°
…	
0x013F	Synthetics
…	
0x5678	Mix 30 min
0x4823	Super Freezer
0x6512	Super Cool

ID	**Parameter Name**
0x0203	Temperature
0x0212	Spin
0x0218	Prewash
…	
0x0240	Dirty
0x0220	Iron Min

ParameterID: 0x0240	
Value	**Value Name**
1	Low
2	Medium
3	High

2.1.2. Product Status (Monitor phase)

A product status notification can be sent automatically by the device or after a request. That notification contains all the information related to the current state of the appliance. The product status is defined as single data block, because all the properties are strictly related each other.

The information are represented by ParameterID, Current Value and optionally by Max and Min Value that the parameter can assume.

Parameter name	**ParameterID**	**Current Value**	**Max Value**	**Min Value**

2.1.2.
2.1.2.
2.1.2.
2.1.2.
2.1.2.
2.1.2.

			(optional)	(optional)
Temperature	0x0203	40	90	0
Spin	0x0212	400	1200	200
Prewash	0x0218	2	2	1
Appliance Status	0x0001	3	-	-
Remote Control	0x0002	1	-	-
Working mode	0x0003	5	-	-
Start Time	0x0004	dd/mm/yy, hh/mm	-	-
Time to end	0x0005	dd/mm/yy, hh/mm	-	-
Working Mode Duration	0x0006	120	-	-
Water Forecast	0x0007	9	-	-
Execution Phase	0x0008	6	-	-
Energy Consumption Forecast	0x0009	1000	-	-
Door Status	0x0010	1	-	-

Some information (e.g. working mode duration, estimated energy, water consumption), that are calculated from the appliance after setting other parameters (e.g. working mode, temperature, spin, etc…) could be requested only after having sent those parameter settings and will be communicated with the same tag representation.

2.1.3. Control actions (Control phase)

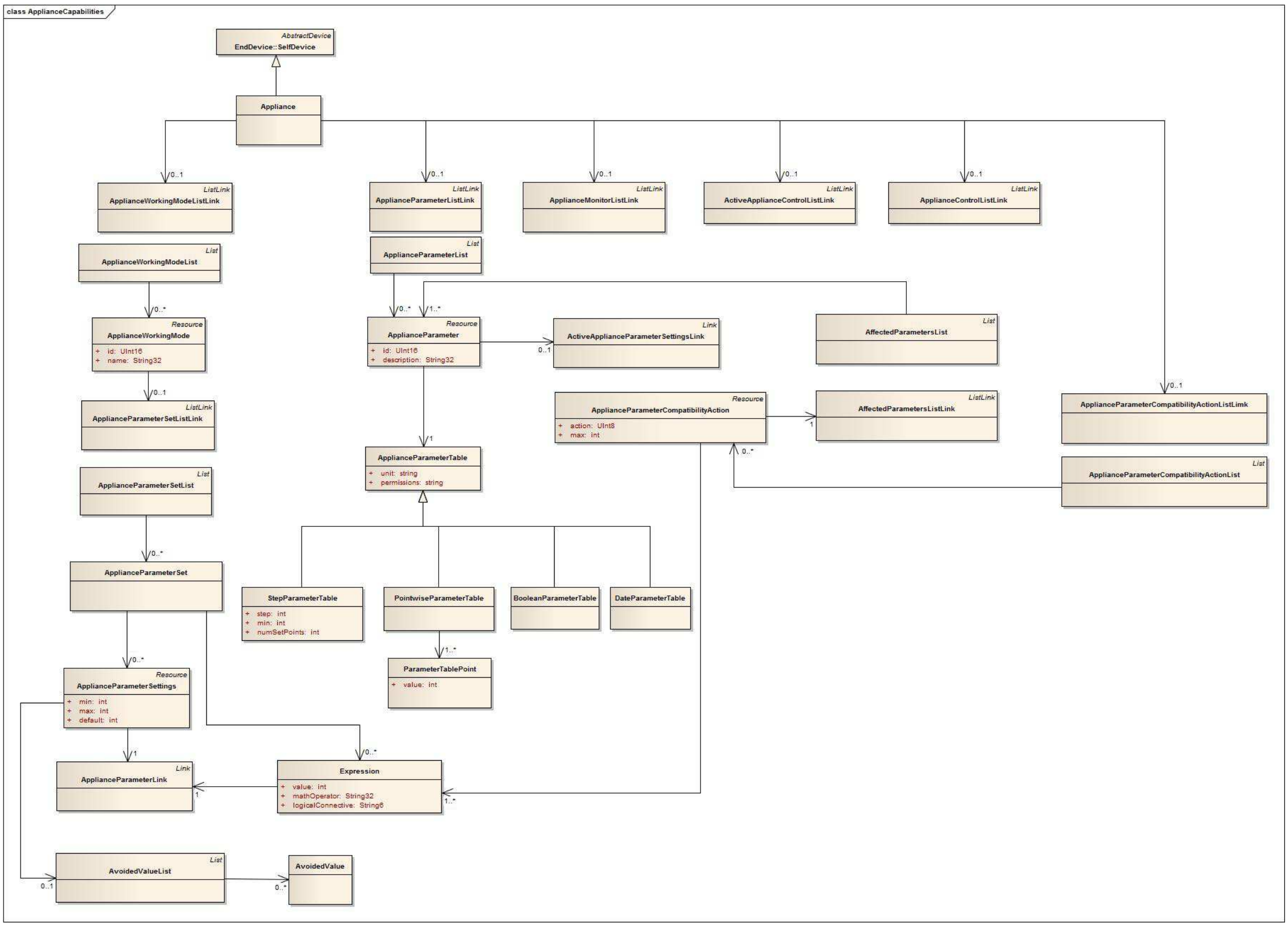
We can use the same parameter representation to describe the list of control actions toward the machine, such as command actuation or the setting of working modes and parameters. The control actions are defined as single data block, because all the actions are strictly related each other and it should be possible to apply them as a single one. The information are represented by the ParameterID and the value to be set.

Parameter name	ParameterID	Value
Command	0x0001	6
Working Mode	0x0002	8
Temperature	0x0203	30
Spin	0x0212	600
Prewash	0x0218	1

Control actions are only valid for parameters with write permission.

2.1.4. SEP 2.0 UML model

In order to control and monitor smart appliances a new Function Set called "ApplianceManagement" is proposed. The data model describing the 'initialization phase' described in paragraph 2.1.1 is shown in the following figure[5].



The class "Appliance" is defined as a specialization of "SelfDevice", and it is linked to controls, measurements, available working modes and parameters. More in detail, an Appliance is linked to a list of 'ApplianceWorkingMode' resources, each representing a particular working mode (e.g. 'Synthetics', 'Mix 30', 'SuperCool'), and to a list of 'ApplianceParameter' resources each representing a particular function (e.g. 'Temperature', 'Spin', 'Prewash', 'Iron Min'). Each ApplianceParameter is described by an 'ApplianceParameterTable', which can be either a 'StepParameterTable' (type 0 table in the language of paragraph 2.1.1), 'PointwiseParameterTable' (type 1 table), 'BooleanParameterTable' (type 2 table) or 'DateParameterTable' (type 3 table). Moreover, each ApplianceParameter may be referenced by a number of 'ApplianceParameterCompatibilityAction' objects, describing function-to-function compatibility. The sets of function set points allowed for each working mode are described by 'ApplianceParameterSet' objects.

Regarding the 'control phase' and 'monitoring phase', a class called "ApplianceParameterState" is defined, which is shown in the following diagram. It can be used to represent the actual parameter values (by means of the 'ApplianceMonitor' class) and to set new values (by means of the 'ApplianceControl' class).

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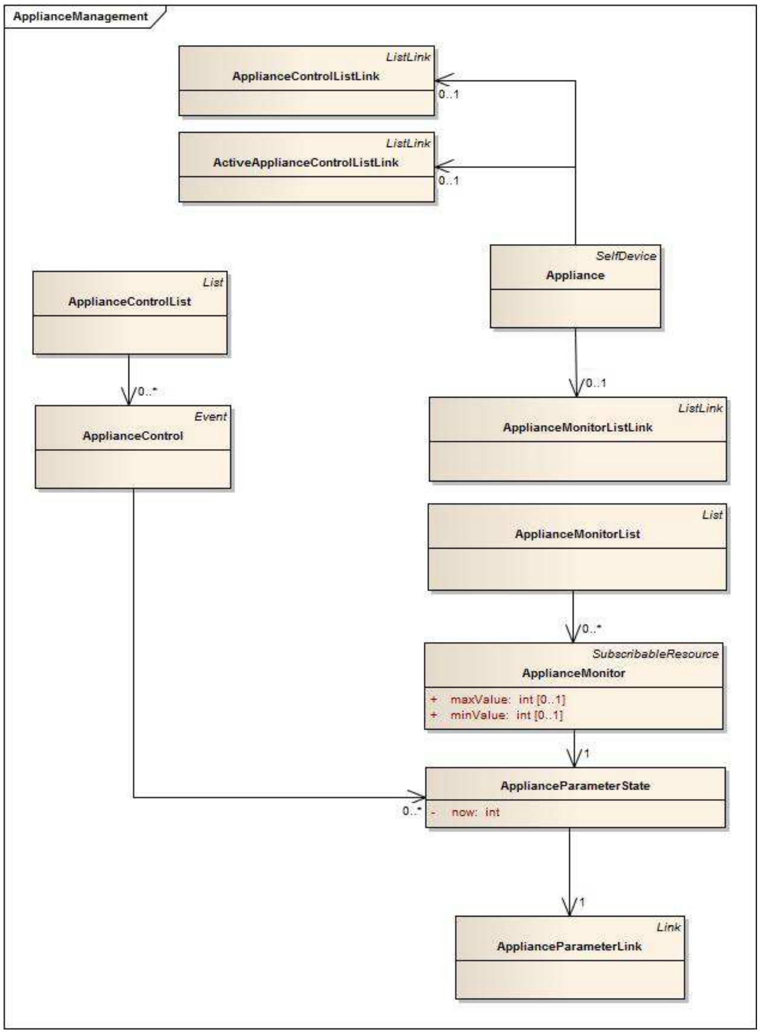
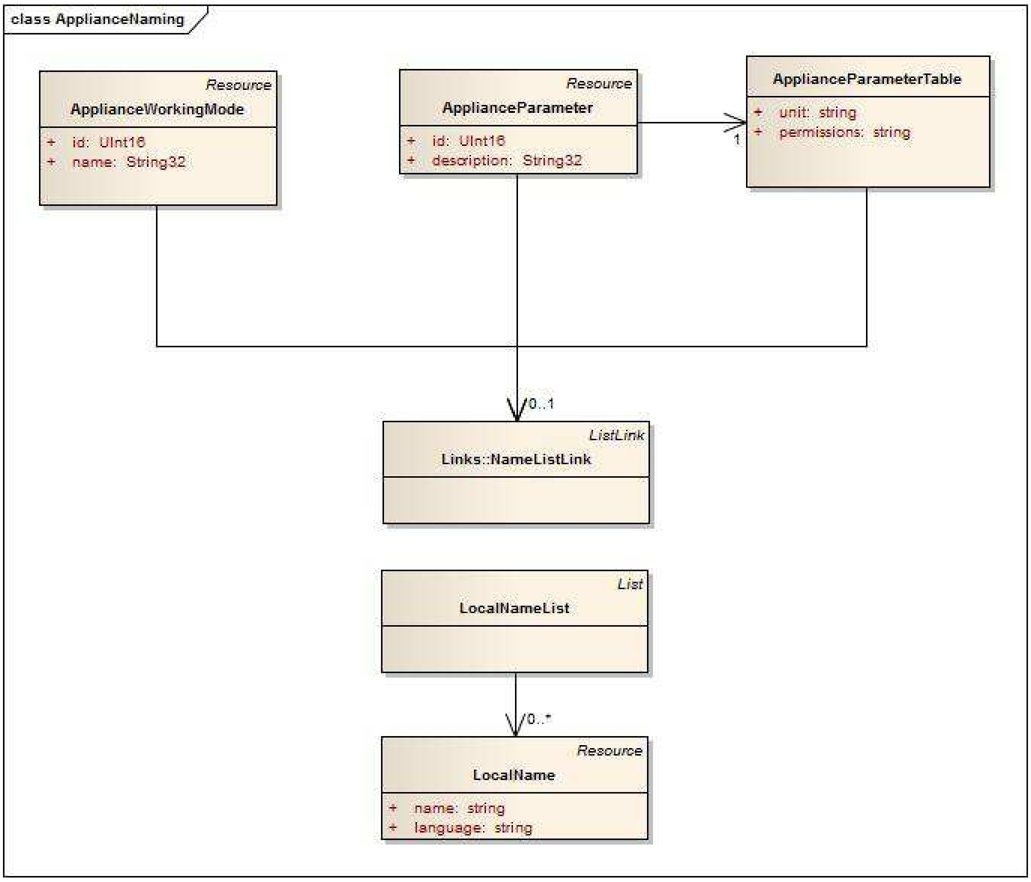
[5] Unfortunately the picture is quite small, however it can be seen very well by downloading the files as described in Chapter 4.



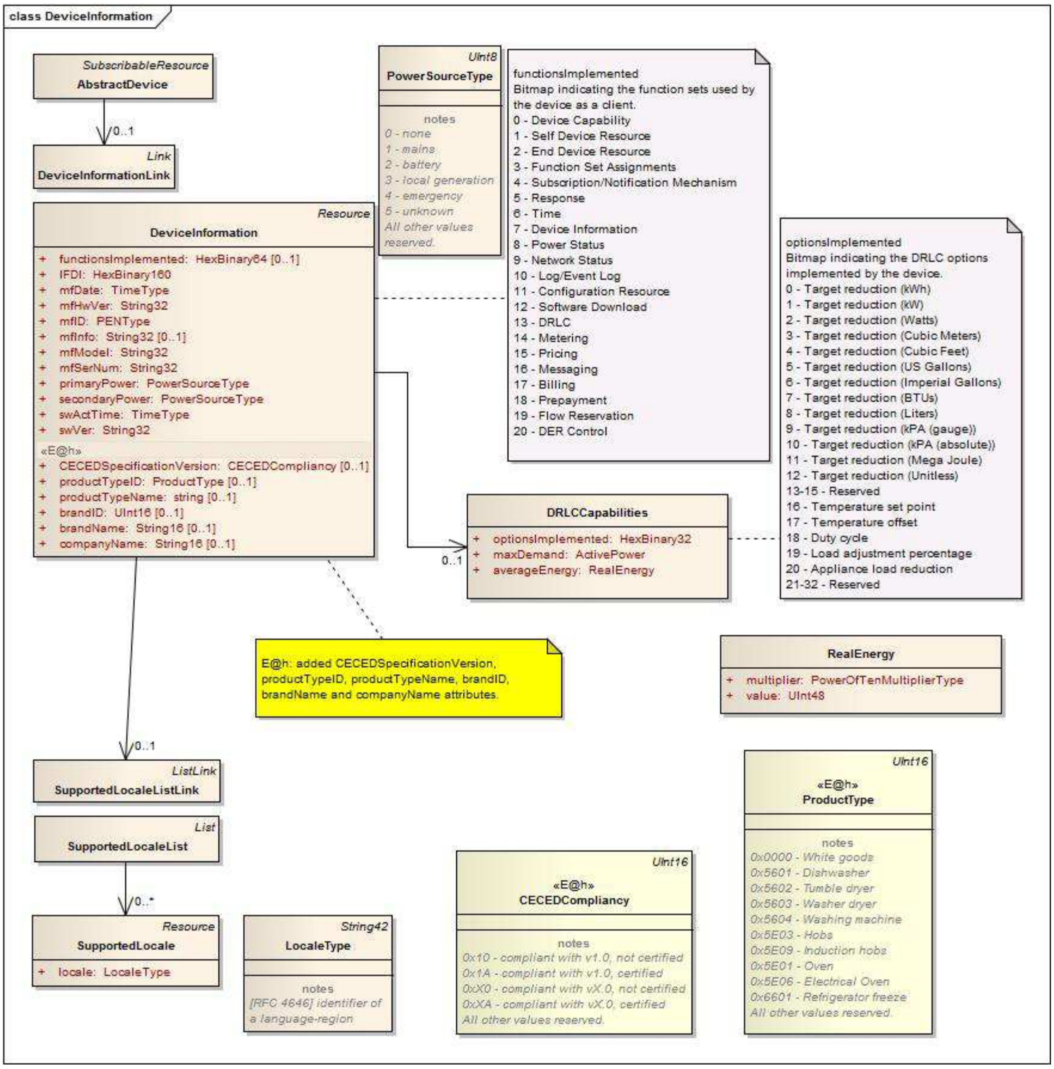
Regarding the strings associated to each working mode, parameter and value, a generic class called 'LocalName' has been defined, as shown in the following figure.


class ApplianceNaming
Resource
ApplianceWorkingMode
+ id: UInt16
+ name: String32
Resource
ApplianceParameter
+ id: UInt16
+ description: String32
ApplianceParameterTable
+ unit: string
+ permissions: string
1
0..1
ListLink
Links::NameListLink
List
LocalNameList
0..*
Resource
LocalName
+ name: string
+ language: string

2.2. Device Information Function Set

The ApplianceIdentification attributes[6] should be harmonized within the DeviceInformation resource and thus few additional attributes are presented (reported in the next figure):

- **CECEDSpecificationVersion**: Attribute that defines the CECED reference documentation (see the CECEDCompliancy class for the possible values of this field).
- **productTypeID**: Unique identifier of the appliance type (see the ProductType class for the possible values of this field).
- **productTypeName**: Appliance type label (e.g. dishwasher, washing machine etc.).
- **brandID**: Unique identifier of the brand of this appliance (a company may own many different brands, for example Procter&Gamble holds Ariel, Bounty, Braun etc.).
- **brandName**: The brand name of this appliance.
- **companyName**: The company name of this appliance (for example, Procter&Gamble).



To better clarify the need of those extra attributes and how they will work together with the existing fields please consider the following example (new attributes in **bold**):

<DeviceInformation href="/edev/1/di" xmlns="http://zigbee.org/sep">

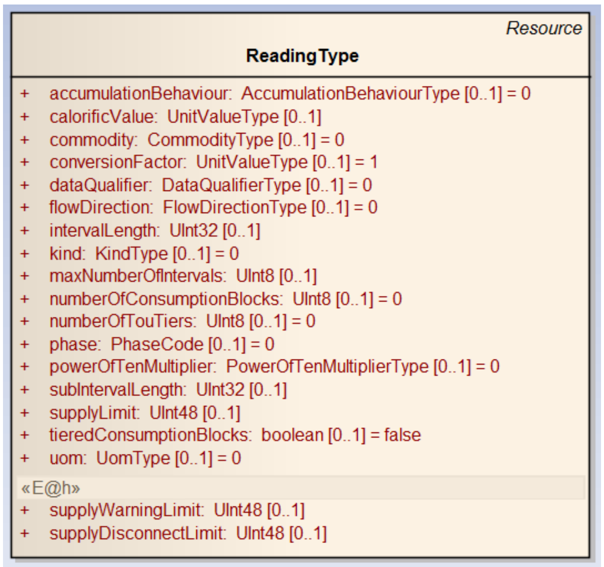
[6] Relate to EN50523 standard

<mRID>APPLIANCE</mRID>
<description>Smart appliance description</description>
<CECEDSpecificationVersion>16</CECEDSpecificationVersion>
<mfID>478</mfID>
<companyName>Procter and Gamble</companyName>
<brandID>50000</brandID>
<brandName>Oral-B</brandName>
<mfModel>ABBCCAA</mfModel>
<mfSerNum>123456</mfSerNum>
<productTypeID>5</productTypeID>
<productTypeName>White goods</productTypeName>
<mfHwVer>10</mfHwVer>
<swVer>1.4</swVer>
<lFDI>3E4F45AB31EDFE5B67E343E5E4562E31984E23E5</lFDI>
<mfDate>1379869200</mfDate>
<primaryPower>1</primaryPower>
<secondaryPower>0</secondaryPower>
<swActTime>1379869201</swActTime>
</DeviceInformation>

As you can notice, the ‘CECEDSpecificationVersion is only a reference to a specific release and it is also optional so it may be omitted. Then the manufacturerID (mfID) is correlated with a text description of the company (companyName), which could be redundant since the same information can be taken from the web, however for different scenarios it could be easier to retrieve the name directly from the smart appliance (again, this is an optional field). Then, a BrandId and BrandName are required to distinguish the particular branch of the company (similar to the Procter and Gamble example) and similar for the productTypeId (and name), which are different from the msModel and/or serialNumber since they describe something more similar to the DeviceId used in ZigBee PRO rather than something free like “ZYZ1234”.

2.3. Metering Function Set

The additional attributes required by Energy@home are shown in the following figure. Please notice that those attributes are taken from the Smart Energy profile (release 1.2) and thus those are not new request strictly coming from the E@h Association.



For this FS, two new attributes have been added in the ReadingType resource:

- **supplyWarningLimit**: supplyLimit can be used to identify the meter's contractual limit. supplyWarningLimit identifies a threshold (higher than supplyLimit) that will trigger a warning, possibly after a fixed amount of time.
- **supplyDisconnectLimit**: supplyDisconnectLimit identifies a threshold (higher than supplyWarningLimit) that will trigger a disconnect action, possibly after a fixed amount of time.

To get an idea of a possible usage of these attributes, it is worth to remind how the overload is regulated in Italy, by using as an example a typical contract with 3 kW contracted peak power[7]:

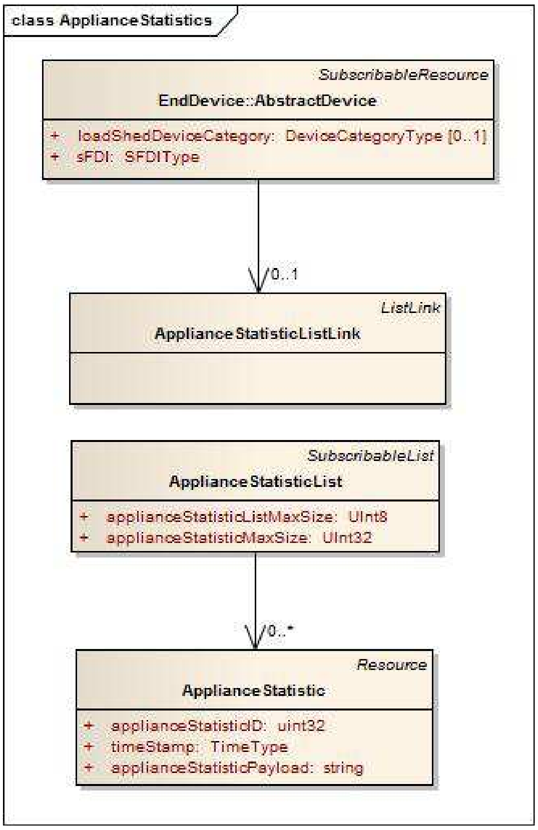
- The meter allows for an excess of 10% of the contracted peak for an unlimited amount of time, i.e. no warning up to 3.3kW of absorbed power (clearly some extra cost could be charged in the bill).
- The meter allows for a current absorption between 3.3 kW and 4.1 kW (i.e. +25%) for a limited amount of time (let’s say 10 minutes), after this time the breaker disconnects. During this period the meter alerts the customer that it should reduce its total energy consumption
- The meter allows for a current absorption above 4.1 kW for a very short amount of time (usually 2 minutes), after this time the breaker disconnects[8]

[7] We expect that other countries adopt a similar algorithm since those enhancements have been introduced from SE1.0 to SE1.2 without any inputs from E@h.

[8] if the meter measures a current absorption higher than 14 kW, for safety reasons, the breaker immediately disconnects

2.4. Appliance Statistics Function Set

A new function set called ApplianceStatistics has been added, in order to collect arbitrary statistics data from appliances.



The meaning of the fields defined inside the ApplianceStatistics class is the following:

- **applianceStatisticID**: 32-bit unsigned integer which defines unique identification for appliance statistic.
- **timeStamp**: time/date at which appliance statistic was generated.
- **applianceStatisticPayload:** Free field used for arbitrary appliance statistic data.

Moreover, two attributes have been included in ApplianceStatisticList:

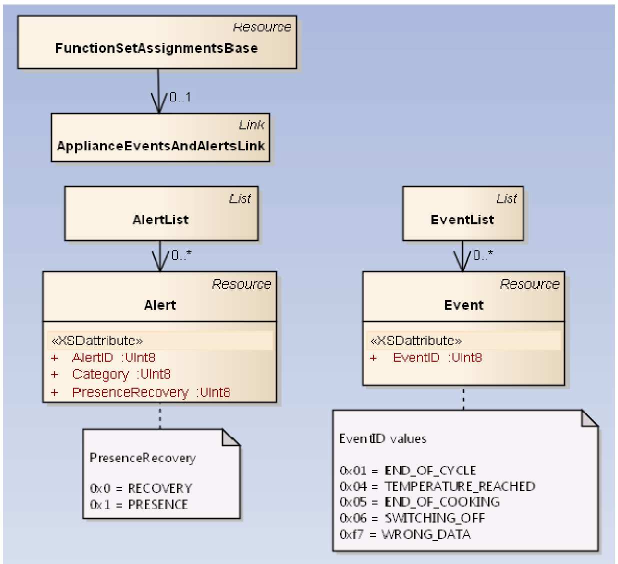
- **applianceStatisticMaxSize**: 32-bit unsigned integer which defines the maximum size of an appliance statistic that can be transferred.
- **ApplianceStatisticListMaxSize**: 8-bit unsigned integer which defines the maximum number of appliance statistics available in the server side.

Thanks to those enhancements it is possible to distinguish between a generic log used for just for statistics and a logEvent, sent to report a warning or something that requires taking an action. This modify will introduce a variable length in how a log can be sent, but since this extension is optional the manufacturer can ignore it, or set LogListMaxSize equals to zero to have no effect from the original version.

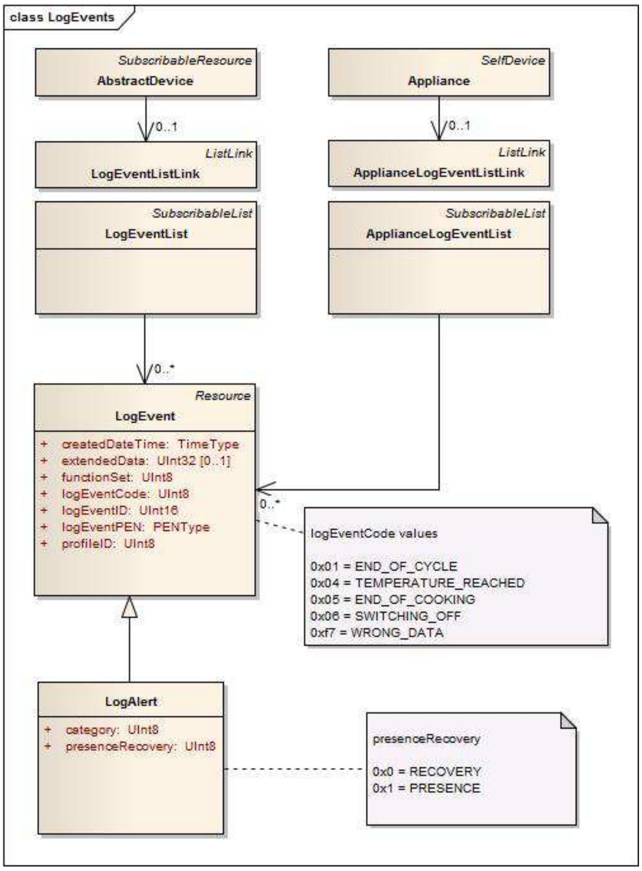
2.5. EN50523 Appliance Events and Alert Function Set

As shown in the following picture, the previous version of the E@h specification defined a new FS to cover this functionalities, however it seems that:

- Events are already defined in LogEvents FS, so we could just define new values for "logEventCode".
- Alert can be considered as particular type of events



As consequence, it is possible to integrate everything in the already defined LogEvents FS, obtaining something like this:



The new logEventCode values should be those one listed in the figure next to the LogEvent class (e.g. END_OF_CYCLE etc.), where the alerts could be considered as particular case of event (composed of a “category” and a “flag” to indicate the “presence” or “recovery”).
The “category” attribute has the following description: 8-bit unsigned integer which defines the category of the alert (0x1 = warning, 0x2 = danger, 0x3 = failure).
The “presenceRecovery” attribute has the following description: 8-bit unsigned integer which defines a presence/recovery flag, indicating if the alert has been detected or recovered (0x0 = recovery, 0x1 = presence).

2.6. Power Profile Function Set

The power Profile Function Set is an extension of the Power Profile Cluster defined inside ZigBee Home Automation 1.2, and in the following description it will be called **Extended Power Profile**: general principles and concepts related to the original Function Set can thus be found in the Home Automation 1.2 document. In particular, the set of commands received by the server side of the Power Profile Cluster in Home Automation 1.2 are shown in the following table.

Command Identifier Field Value	Description	Mandatory Optional
0x00	PowerProfileRequest	M
0x01	PowerProfileStateRequest	M
0x02	GetPowerProfilePriceResponse	M
0x03	GetOverallSchedulePriceResponse	M
0x04	EnergyPhasesScheduleNotification	M
0x05	EnergyPhasesScheduleResponse	M
0x06	PowerProfileScheduleConstraintsRequest	M
0x07	EnergyPhasesScheduleStateRequest	M
0x08	GetPowerProfilePriceExtendedResponse	M

The set of commands generated by the server side of the Power Profile Cluster in Home Automation 1.2 are shown in the following table.

Command Identifier Field Value	Description	Mandatory Optional
0x00	PowerProfileNotification	M
0x01	PowerProfileResponse	M
0x02	PowerProfileStateResponse	M
0x03	GetPowerProfilePrice	O
0x04	PowerProfilesStateNotification	M
0x05	GetOverallSchedulePrice	O
0x06	EnergyPhasesScheduleRequest	M
0x07	EnergyPhasesScheduleStateResponse	M
0x08	EnergyPhasesScheduleStateNotification	M
0x09	PowerProfileScheduleConstraintsNotification	M
0x0A	PowerProfileScheduleConstraintsResponse	M
0x0B	GetPowerProfilePriceExtended	O

With respect to this model, the proposed Extended Power Profile describes the forecasted energy consumption using four levels of classes hierarchically ordered as follows:

1. Extended Power Profile
2. Power Profile
3. Modes
4. Phases

Phase: is the minimum resolution time step. Every phase can be only (eventually) shifted in time or paused. This are the unique flexibility features the class can offer. The phase is described by the following parameters:

- **EnergyPhaseID**: The EnergyPhaseID field indicates the identifier of the specific energy phase described by the Power Profile. This is a sequential and contiguous number ranging from 1 to the maximum number of phases belonging to the Power Profile.
- **MacroPhaseID**: The MacroPhaseID field represents the identifier of the specific phase (operational-displayed) described by the Power Profile. This reference could be used in conjunction with a table of ASCII strings, describing the label of the functional phase. This table is not described in the contest of the Power Profile because it may be not functionally linked with energy management.
- **Expected Duration**: lasting time of single phase, each unit is a minute;
- **Peak power**: max power absorption within single phase, each unit is a Watt;
- **Energy**: energy consumption within a phase, each unit is Watt per hours. The Energy values fulfills the following equation:

$$\boldsymbol{Energy \leq PeakPower(Watt) * ExpectedDuration(sec)}$$

- **Max overload pause**: the time that the device can be paused in that phase, each unit is a minute;
- **Max activation delay** : max shift time allowed in delay for single phase, each unit is a minute;
- **Max anticipation**: this field allows the anticipation of the phase if (and only if) the previous phase has the energy set to 0 Wh, each unit is a minute.

Mode: represents one way to deliver the task between different options. One mode is composed by a sequence of many phases and its duration depends on mode's phases configuration. The mode parameters are:

- **Mode ID**: identification code for Modes used by the CEMS in the reply;
- **Repetition number**: number of repetitions declared for each Mode. It allows to create multiple repetitions for mode chosen by CEMS;
- **Phases number**: number of phases available within a single mode.

PowerProfile: a Power Profile represents a task that a device must perform. Each Power Profile can provide one or more modes to deliver its task. The *Power Profile* parameters are:

- **PowerProfile ID**: identification code for PowerProfile used by the CEMS in the reply;
- **Mix Enable**: flag used to allow/avoid mix between different modes within the same Power Profile;
- **Alternative modes number**: the number of modes provided to perform the Power Profile;
- **Min Power Profile delay**: the time span between the end time of the previous Power Profile and the start of the next one, each unit is a minute;
- **Duration**: the time span between the start and the end of the same Power Profile, each unit is a minute; if this parameter is not specified the duration of the Power Profile is determined by the duration of the mode selected by the CEMS. If specified the CEMS builds a sequence

of many modes until the declared time expires. If the last mode isn't finished yet, the Power Profile will stop anyway.

A visual example of this structures is shown in the following figure.

Extended Power profile

Power Profile number	2

Power Profile

Power Profile ID	1
Mix enable	true
Alternative modes number	3
Min Power Profile Delay [min from previous end time]	0
Duration [min] (optional)	960

Modes

		MODE 0	MODE 1	MODE 2
	MODE ID	0	1	2
	Repetition number	1	1	1
	Phases number	2	2	2
Phase 1	EnergyPhaseID	1	1	1
Phase 1	MacroPhaseID			
Phase 1	Expected Duration [min]	15	30	25
Phase 1	Energy [Wh]	300	300	300
Phase 1	Peak power [W]	1200	600	720
Phase 1	Max overload pause [min]	10	10	10
Phase 1	Max delay [min]	5	5	5
Phase 1	Max ant. [min]	10	10	10
Phase 2	EnergyPhaseID	2	2	2
Phase 2	MacroPhaseID			
Phase 2	Expected Duration [min]	45	45	45
Phase 2	Energy [Wh]	0	0	0
Phase 2	Peak power [W]	0	0	0
Phase 2	Max overload pause [min]	0	0	0
Phase 2	Max delay [min]	5	5	5
Phase 2	Max ant. [min]	0	0	0

Power Profile

Power Profile ID	2
Alternative modes number	2
Mix enable	true
Min Power Profile Delay [min from previous end time]	0
Duration [min] (optional)	480

Modes

		MODE 0	MODE 1
	MODE ID	0	1
	Repetition number	1	1
	Phases number	2	2
Phase 1	EnergyPhaseID	1	1
Phase 1	MacroPhaseID		
Phase 1	Expected Duration [min]	15	8
Phase 1	Energy [Wh]	150	80
Phase 1	Peak power [W]	600	600
Phase 1	Max overload pause [min]	10	10
Phase 1	Max delay [min]	5	5
Phase 1	Max ant. [min]	10	10
Phase 2	EnergyPhaseID	2	2
Phase 2	MacroPhaseID		
Phase 2	Expected Duration [min]	45	30
Phase 2	Energy [Wh]	0	0
Phase 2	Peak power [W]	0	0
Phase 2	Max overload pause [min]	0	0
Phase 2	Max delay [min]	5	5
Phase 2	Max ant. [min]	0	0

-
-
-
-

The power profile scheduling information is used by the CEM to tell the appliance the proposed scheduling for the appliance power profiles modes and energy phases. The appliance uses this same structure to tell the CEM the current scheduling. The data structures used are the following:

Power Profile Schedule properties

Properties	Type	Optional	Description
Power Profile Schedule List	Array	No	List of scheduled appliance power profiles.

Power Profile Schedule List

Properties	Type	Optional?	Description
Power Profile Schedule Mode List	Array	No	List of scheduled appliance power profiles modes. The device will execute this Modes list in sequence. If “Mix Enable” option is false, the array is composed by a single element.
Min Power Profile Delay	Number	No	The time span between the end time of the previous Power Profile and the start of the next one, each unit is a minute.

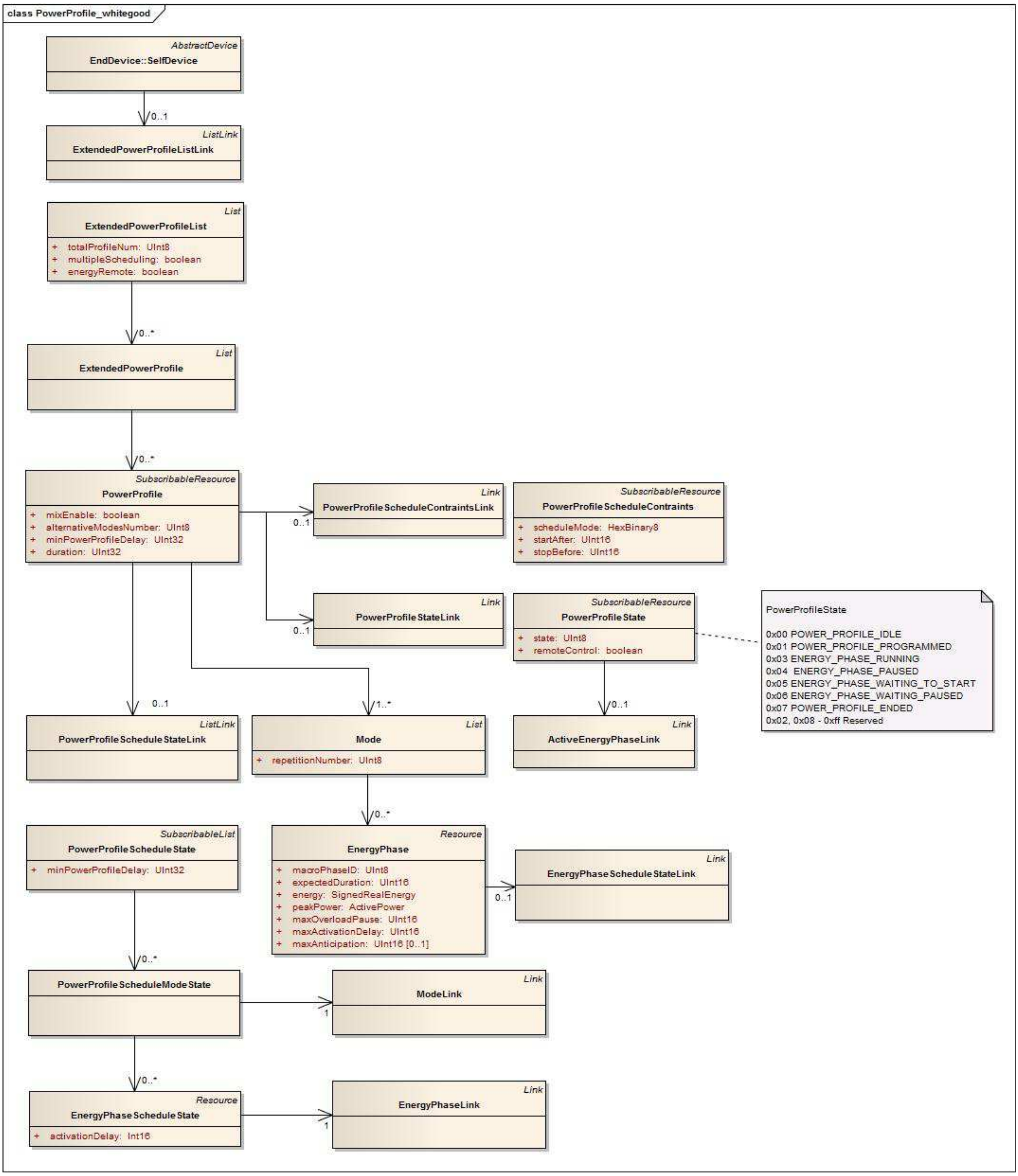
Power Profile Schedule Mode List

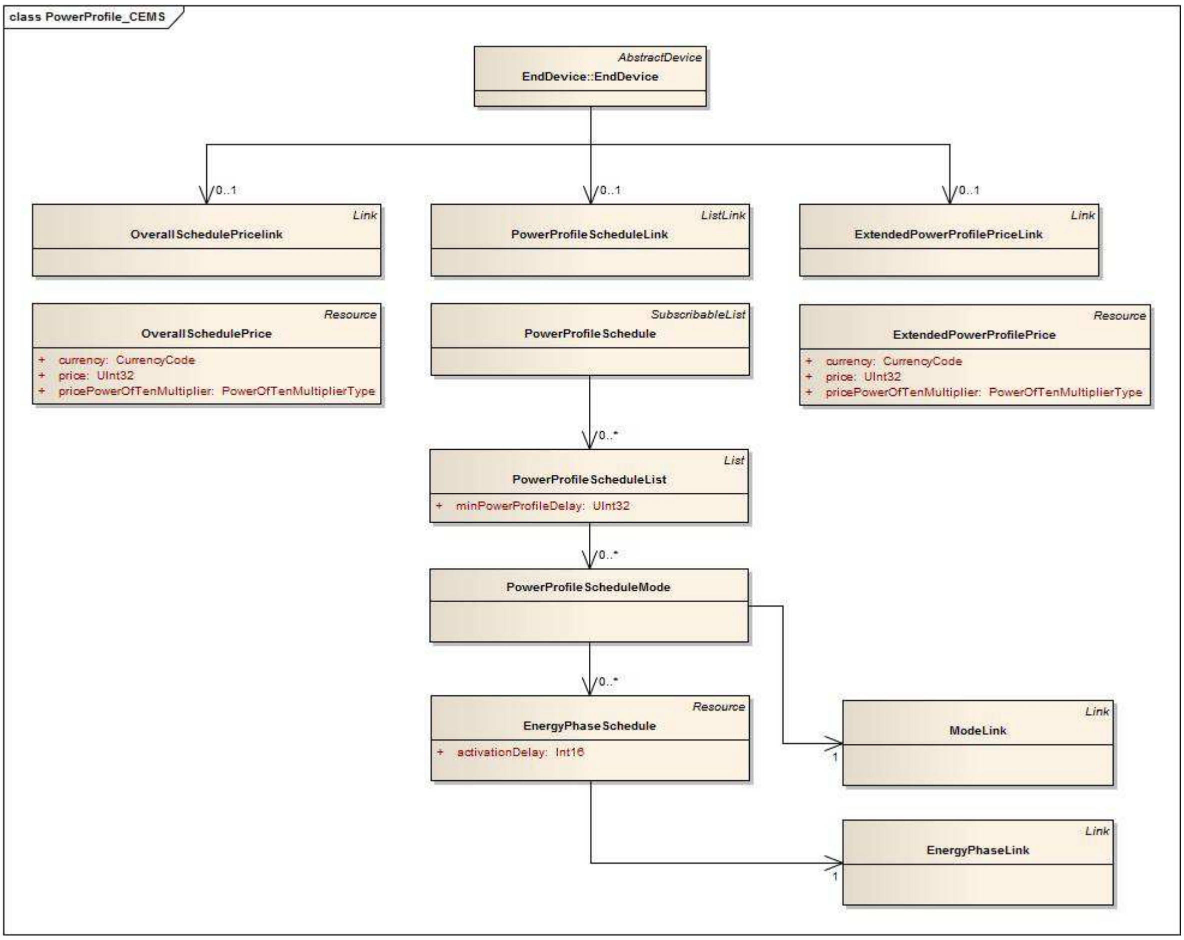
Properties	Type	Optional	Description
Mode Index	Number	No	Mode array index
Mode Energy Phase List	Array	No	Sequence of Energy Phases. Each energy phase duration depends on mode’s phases configuration. All array elements specified in the Power Profile Mode List must be present. If an energy phase have no scheduling data, it will be empty.

Mode Energy Phase Schedule List

Properties	Type	Optional	Description
Energy Phase Index	Number	No	Energy Phase array index
Activation Delay	Number	No	Delay for start the energy phase, the unit is minute.
Advance Time	Number	Yes	Advance time of the energy phase, only if the previous energy phase has the Energy set to 0 Wh, the unit is minute.

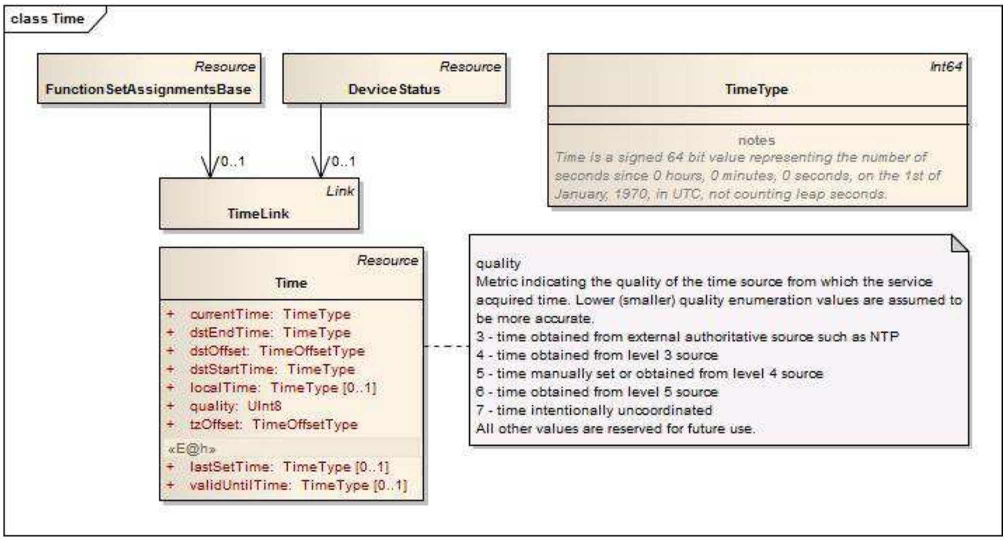
The Activation Delay field represents the relative time scheduled in respect to the end of the previous energy phase. The unit is the minute. The Activation Delay for the first Energy phase represents the scheduled time (relative to the current time) for the start of the Power Profile. The Activation Delay fields for the subsequent Energy phases represent the relative time in minutes in respect to the previous scheduled Energy phase. The Energy phases that are not required to be scheduled will not be included in the Energy Phase Schedule List.
Based on this descriptions, the resulting UML model of the Extended Power Profile is shown in the following figures, where the first represents the objects exposed by a smart device and the second represents the objects exposed by a Customer Energy Manager.




class PowerProfile_CEMS
AbstractDevice
EndDevice::EndDevice
0..1
0..1
0..1
Link
OverallSchedulePricelink
ListLink
PowerProfileScheduleLink
Link
ExtendedPowerProfilePriceLink
Resource
OverallSchedulePrice
+ currency: CurrencyCode
+ price: UInt32
+ pricePowerOfTenMultiplier: PowerOfTenMultiplierType
SubscribableList
PowerProfileSchedule
Resource
ExtendedPowerProfilePrice
+ currency: CurrencyCode
+ price: UInt32
+ pricePowerOfTenMultiplier: PowerOfTenMultiplierType
0..*
List
PowerProfileScheduleList
+ minPowerProfileDelay: UInt32
0..*
PowerProfileScheduleMode
0..*
Resource
EnergyPhaseSchedule
+ activationDelay: Int16
Link
ModeLink
1
Link
EnergyPhaseLink
1

2.7. Time Function Set

The additional attributes required by Energy@home are shown in the following figure.



As can be seen from the above figure, two attributes have been added to Time:

- **lastSetTime:** 64-bit integer representing the most recent time that the currentTime attribute was set, either internally or from the network.
- **validUntilTime**: 64-bit integer defining a time up to which the currentTime attribute may be trusted.

3. SEP2 mapping

As an example of data exchange, consider a client trying to get information about power profiles available on a smart device: first the client GETs the *SelfDevice* resource representation of the smart device, obtaining a response like the one shown in the following figure.

http://localhost:8010/eath/sdev

This XML file does not appear to have any style information associated with it. The document tree is shown below.


```
−<SelfDevice href="/sdev">
    <sFDI>987654321005</sFDI>
    <ExtendedPowerProfileListLink all="1" href="/sdev/epp"/>
  </SelfDevice>
```


From this, the client knows that the device holds one power profile resource, located at address */sdev/pp*. If it makes a GET request to that address it gets a response like the following:

http://localhost:8010/eath/sdev/epp

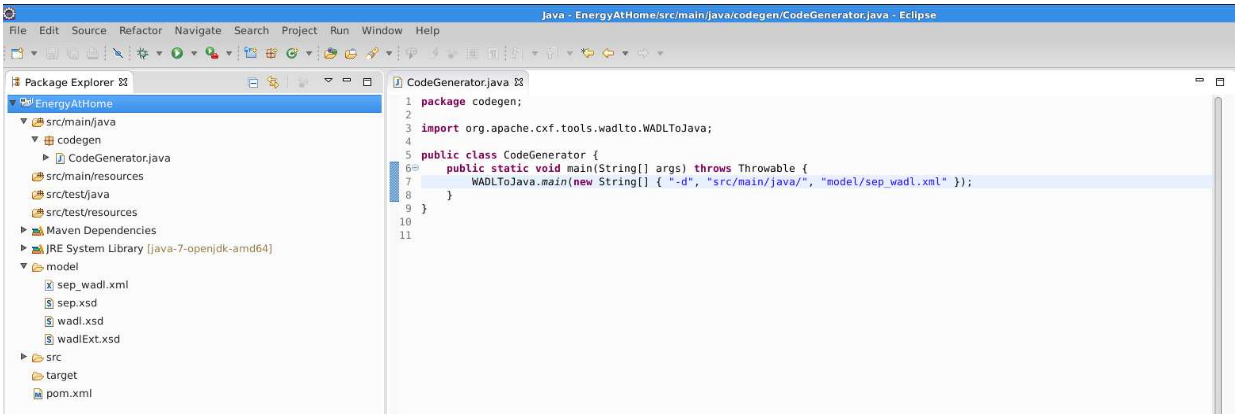
This XML file does not appear to have any style information associated with it. The document tree is shown below.


```
−<ExtendedPowerProfileList all="1" results="1" href="/sdev/epp">
    <energyRemote>false</energyRemote>
  −<ExtendedPowerProfile all="1" results="1" href="/sdev/epp/1">
    −<PowerProfile href="/sdev/epp/1/1">
        <alternativeModesNumber>0</alternativeModesNumber>
        <duration>0</duration>
        <minPowerProfileDelay>0</minPowerProfileDelay>
        <mixEnable>false</mixEnable>
      −<Mode all="1" results="1" href="/sdev/epp/1/1/mod">
        −<EnergyPhase>
          −<energy>
              <multiplier>2</multiplier>
              <value>5</value>
            </energy>
            <expectedDuration>100</expectedDuration>
            <macroPhaseID>1</macroPhaseID>
            <maxActivationDelay>10</maxActivationDelay>
            <maxOverloadPause>0</maxOverloadPause>
          −<peakPower>
              <multiplier>2</multiplier>
              <value>1</value>
            </peakPower>
          </EnergyPhase>
          <repetitionNumber>0</repetitionNumber>
        </Mode>
      </PowerProfile>
    </ExtendedPowerProfile>
    <multipleScheduling>false</multipleScheduling>
    <totalProfileNum>20</totalProfileNum>
  </ExtendedPowerProfileList>
```

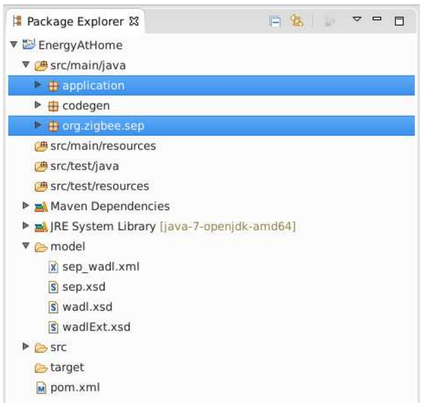

which is the required power profile information.

4. Tutorial: How to use this data model

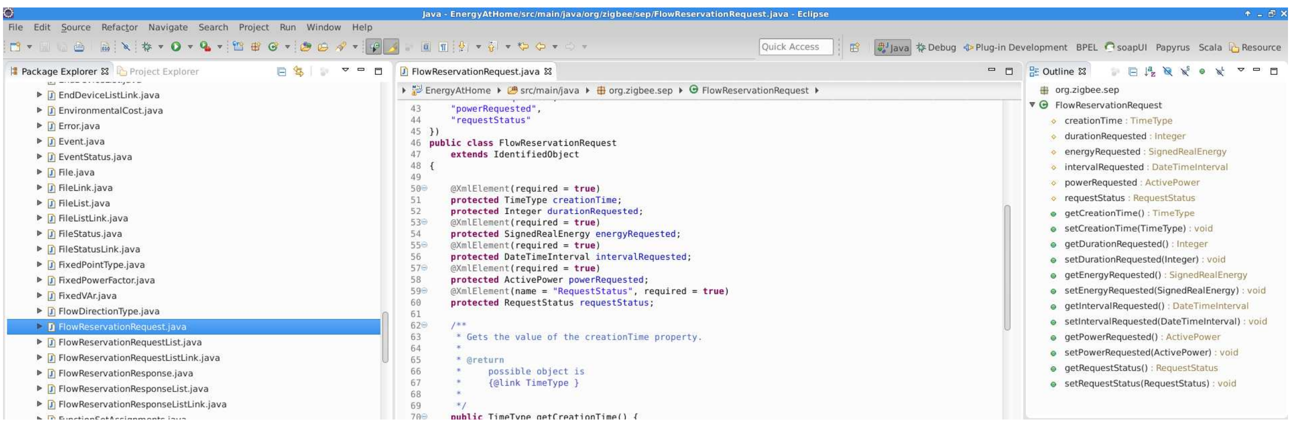
Given the data model artifacts produced by Enterprise Architect and associated tools, it is quite easy to generate Java classes which can be used in concrete implementations of the protocol. In particular, in the following figure an Eclipse Java project containing the SEP 2.0 data model files (both XSD and WADL) is shown. The code used to generate Java classes is also shown in the figure, exploiting the widely used Apache CXF framework. As can be seen, the procedure is extremely simple, involving just one line of code.



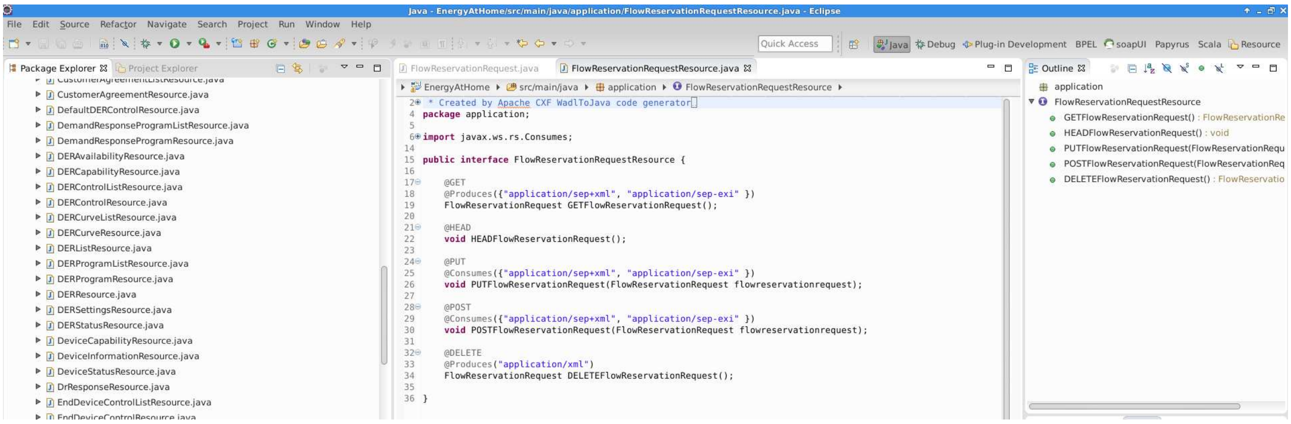
The generated Java packages are shown in the following figure



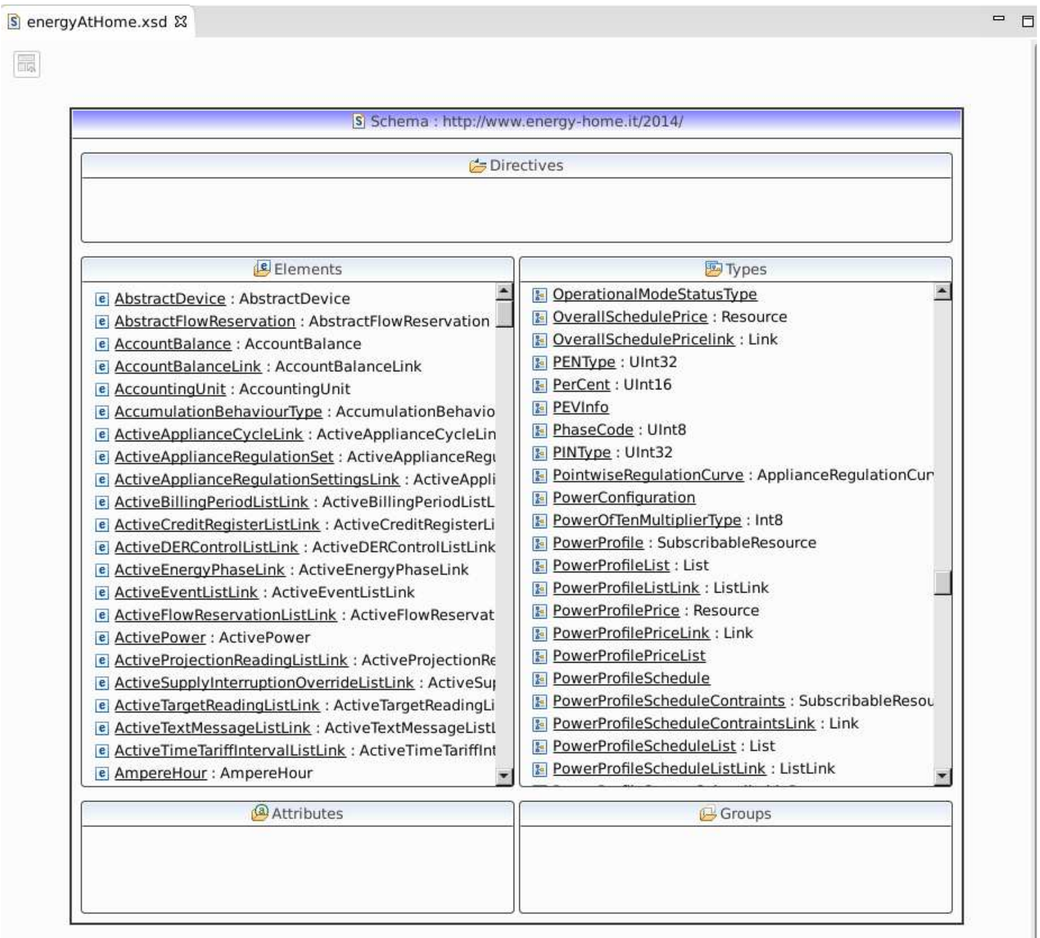
The generated package *org.zigbee.sep* contains all the classes defined inside the SEP 2.0 XSD file, as shown in the following figure.



The *application* package is generated from the WADL file and contains the HTTP resources which can be used by a SEP 2.0 server.



Starting from this generated code, actual implementation of a SEP 2.0 server can be started.
In the same way, the Energy@home data model can be used, since it is an extension of SEP 2.0: a partial view of the Energy@home XSD file is shown in the following figure.



This XSD file, obtained from the Enterprise Architect UML model by means of the CIM EA plugin (http://www.cimea.org/), can be downloaded at the link provided in Chapter 2 or from the Energy@home web site (similar for the WADL file).

Glossary

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 Sub-layer
ASDU	ZigBee Application Service Data Unit
CEMS	Customer Energy Management System (HAN data aggregator)
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 (see [R3])
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	An 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 (see [R5])
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