Analysis and comparison of common device profiles for intelligent in-house energy management

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Introduction

Communication technology is playing an increasing role in the evolving electricity grid as more and smaller distributed energy resources and loads (herein after referred to as Distributed Energy Systems) are connected and intelligently managed. Therefore it is crucial that communication technology is robust but low cost and devices from different manufacturers can be easily connected. Standardized access to devices is the key to reach this goal. Existing protocol standards often define so called “device profiles” that represent certain classes of devices. These profiles will be investigated and compared in this paper with regard to their usefulness for energy management applications. Thereby, the paper will focus on profiles of CHPs, heat pumps and PV systems.

“Device profile” definition

In this paper a device profile is defined as a data model that represents a certain class of devices. The data model includes parameters that constitute the important features of that device. Parameters can be read for monitoring purposes and device type information or written to enable control of the device. The device profiles shall be perceived as network-visible representations of the corresponding real technical device. In the following, the terms device profile, object profile, and function profile are regarded as synonyms.

Comprehension of interoperability and conformance and the main criteria of investigation

According to the definitions of European Telecommunications Standards Institute interoperability shall be deemed to be as “application interoperability” [1]. In these terms nodes of different vendors connected to an in-house or a smart grid communication network need to pursue a consistent implementation of syntax and semantic of exchanged parameters (conformance). Additionally, interoperability

requires the definition of exact (mandatory) sets of properties, above called device profiles. It is crucial to point out the difference between interoperability and conformance. Conformance is not the equivalent of interoperability but rather the basic prerequisite. In the following, interoperability will be analysed by looking at the protocol's definition of profiles, provided existing profiles and the level of standardisation (LOS). The LOS indicates the level at which protocols require the use of standardized parameters. Interoperability simultaneously increases with the level of standard-disation (cf. figure 1).

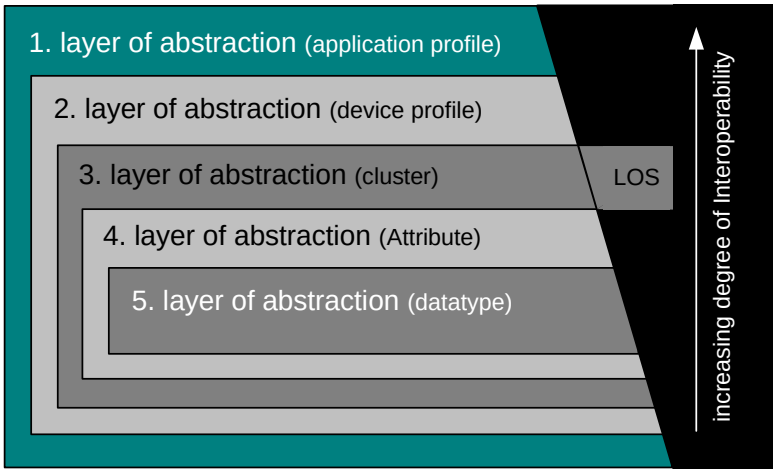

Figure 1 *Explanation of LOS (as example: ZigBee structure)*

Local Operating Network (LON)

In the Local Operating Network specification (for application layer) two forms of "function profiles" are defined. Profiles released and approved by LonMark International are so called "standard function profiles". Profiles developed by manufacturers are specified as "user function profiles". In contrast to user function profiles, standard function profiles only contain "standard network variables types" and "standard configuration property types" as well as the "network configuration variables". Producers are obliged to implement the common device variables (mandatory variables) and have the possibility to make use of implementing further optional variables. The relations are depicted in figure 2. As an independent institution the "Interoperability Association" was founded to certify LON nodes of different vendors based on released rules to ensure the interoperability. One essential requirement is the use of at least one standard function profile on a certified device. [2]

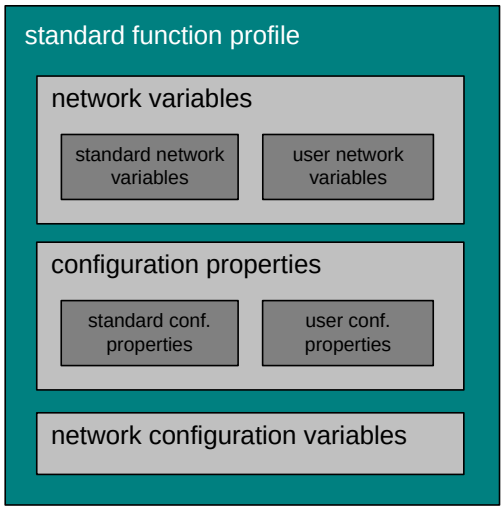

Figure 2 *LON's definition of function profil*

Level of Standardisation

The fundamental requirement to get certification from the “Interoperability Association” is the inevitable use of the standard network variables defined by LonMark [3][4]. The network variables permit the data exchange between LON devices. According to that, network variables are standardized as basis of specification’s conformance and can be declared as level of standardisation. Since the specification still allows for defining new profiles, interoperability cannot be seen as assured.

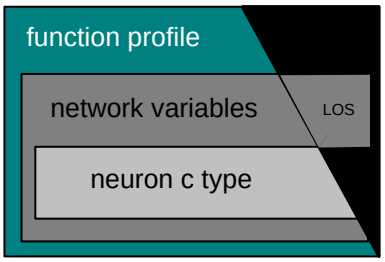

Figure 3 *LOS of LON*

Existing device profiles

The published function profiles listed at LonMark International homepage concentrate on home and building automation (e.g. LonMark Lighting Functional Profiles or LonMark Fire & Smoke Device Functional Profiles). In addition, several function profiles for heating, ventilation and air conditioning (HVAC) are published. Regarding profiles for distributed energy systems LON only defines a heat pump profile while descriptions of CHP and PV-System are missing. Nevertheless, LonMark International released functional profiles for electricity metering and schedules (defining device operation time periods). [3]

Conclusion

Summing up, LonMark International is strongly following the concept of defining exact device profiles for several devices focusing on the field of home and building automation. Beyond that, LON seems to achieve the important profiles for future smart home connected to a smart grid. LonMark networking community is aware of the importance to make LON ready for future Smart Grid considering the focus on “Smart Grid Roadmap” released by NIST [5]. However, important device description for CHP and PV-systems are still missing.

As an open standard LON ensures interoperability by offering an independent certification of manufacture’s nodes that have to be conform to the level of standardisation. Unfortunately, LON also allows the implementation of manufacture specific functional profiles that meet conformance of standard but endanger interoperability.

ZigBee

ZigBee defines three interwoven types of profiles which are depicted in figure 4. Public Application profiles characterise a special range of applications. The application profile includes the specification of the stack profile, the device profile as well as the definition of valid formats of a network message and communication. Unlike other protocols e.g. LON, the application profiles can be seen as a thematic frame within behaviour of supported devices is described and detailed information about these devices, given in the “device profiles”, is listed. So far, ZigBee Alliance released five so called “public application profiles”. This paper will cover an analysis of the “ZigBee Smart Energy public application profile” and its containing device profiles and clusters.

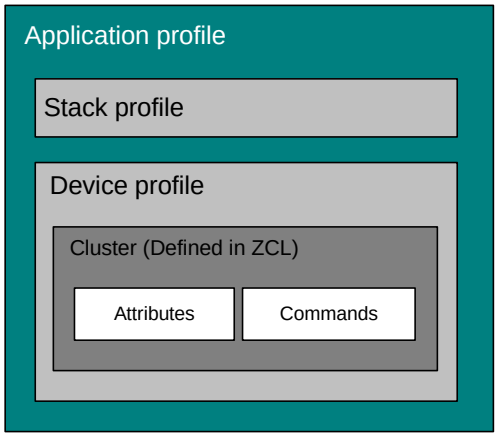

Figure 4 *Structure of ZigBee’s profiles*

Level of Standardisation

To ensure conformance of ZigBee nodes developed by different vendors and manufacturers, the ZigBee Alliance released the ZigBee Cluster Library (ZCL). This library contains a set of approved clusters for use in all application profiles and device profiles, respectively. It is crucial that developers of new ZigBee nodes implement profiles referring to the ZigBee Cluster Library. According to that requirement, public application profiles are based on ZCL and the within listed standardized clusters. Hence the ZigBee clusters shall be deemed as level of standardisation.

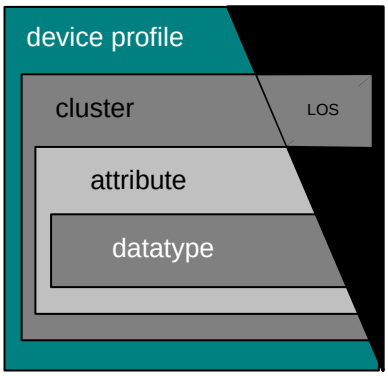

Figure 5 *LOS of ZigBee*

Existing device profiles

The Analysis of clusters and device profiles reveals a conspicuous focus on metering and price information. With regard to the previous label “Advanced Metering Initiative” (AMI) of “Smart Energy application profile”, the reason for this focus becomes obvious. Beside a “Simple Metering” cluster (that includes common metering commands and responses) and a “Complex Metering” (that enables vendor-specific metering commands), a price cluster to communicate tariff information for electricity (in terms of full flexible tariffs) exists.

Unfortunately, the present specification of the “Smart Energy application profile” does not cover (precise) descriptions of device profiles for DES. Instead, the ZigBee Alliance defines a “Load Control Device Profile” and the containing cluster “Demand Response and Load Control”. The “Demand Response and Load Control” clusters emphasize on the common consumer loads, e.g. Water Heater, Exterior and Interior Lighting just as well as HVAC compressor or furnace. Nontheless, the essential description for DES is currently missing in this cluster. The problem of missing device profiles can be solved more or less using two different ways:
Both are based on developing a “manufacture-specific profile”. The first option is to create a new manufacture-specific application profile containing new device profiles by using the clusters covered by ZCL (which ensures conformance to other ZigBee nodes in the respective ZigBee network). The second (indirectly) option, admits pooling devices defined in the “Home Automation application profile” at the condition that HA devices support the use of the Smart Energy “security models” and “Link Keys” (security requirements by the Smart Energy application profile). [6]

Conclusion

Currently, the ZigBee public smart energy profile is not ready for standardized integration of heat pumps, CHPs as well as PV-Systems into a smart inHouse communication structure. The two possible ways described above are workarounds which endanger the interoperability whereas conformance is complied with the use of ZCL. Furthermore, the option given by ZigBee to create and develop new manufacture specific application profiles is critically in terms of interoperability.
A multitude of vendors implement their own proprietary ZigBee extensions nowadays. This stands in clear contradiction to the assumptions made in this paper. However, regarding the released “Smart Energy Profile Marketing Requirements Document (MRD)”, it seems that the ZigBee Alliance realised the need of device profiles for DES [7].

BACnet

The definition of a device profile in this paper and the definition published in the specification of BACnet are vastly different. Instead of defining an abstract image of a real device, BACnet device profiles define several functions or rather services that have to be implemented on a BACnet node. All standardized functions are structured as “BACnet Interoperation Building Blocks” (BIBB). Depending on the five Inter-operability Areas (IA), BACnet device profiles contain special BIBBs. An overview of the described structure is given in figure 6. A certain BACnet node does not need to describe one of these device profiles. Instead, the nodes are assigned to the device profiles when they implement the required functions. The Specification does not define special profiles that describe a special set of (mandatory) objects or properties. Quite contrary, BACnet allows vendors to define their own (proprietary) objects and properties, respectively. The proprietary objects have to be defined in “object profiles”, an expression only used for non-standard objects. Against the definition in the BACnet standard, in the following, descriptions of standard object types are also declared as “object profiles”.

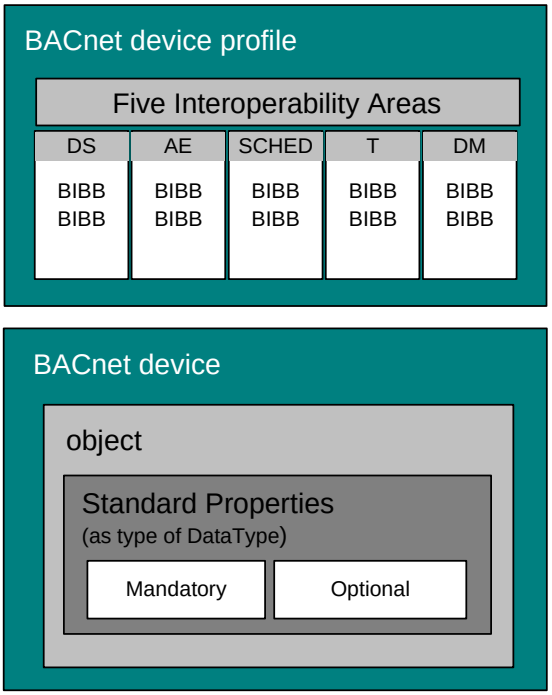

Figure 6 *BACnet device profiles*

Level of Standardisation

Defining a level of standardisation in BACnet turns out to be fairly difficult. Unlike the protocols described above, BACnet does neither explicitly require certain objects for a device nor standard properties for (proprietary) objects (except the object_identifier, object_name property and object_type). Beyond this, vendors are also allowed to define proprietary datatypes. In the context of paper’s definition, datatypes shall be declared as the level of standardisation.

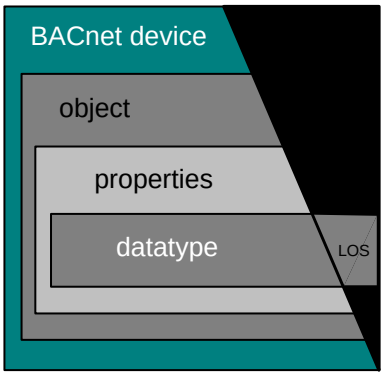

Figure 7 *LOS of BACnet*

Existing device profiles

At this time, BACnet specification provides 30 “object profiles”. In comparison with the plenitude of defined profiles in ZigBee, LON and IEC 61850, BACnet strongly has to focus on creation of new objects or rather “network-visible representations” as named in the specification. Standard objects that represent certain technical devices are - with some exceptions (e.g. Accumulator object for metering) - still missing. Beside that, standard “object profiles” for CHP, HP and PV-Systems are not provided, yet. The published aim to specify “macro-objects” for monitoring and controlling “larger-scale” devices like heat pumps shall be deemed to be the first step in the direction of renewable distributed energy systems [8]. Unfortunately, since the release in October 1998 the crucial definition of these “macro objects” has not been put into practice [cf. 9]. BACnet defines a schedule object, which at least ensures meeting a small part of requirements for future communication in smart grid and smart home.

Conclusion

BACnet cannot assure a standardized interoperable communication of DES regarding the specification’s standard “network-visible” representation (objects). The wide range of possibilities for vendors combining own properties with standard properties as well as the high percentage of optional properties contained in the standard objects endangers the interoperability. Missing “object profiles” of distributed energy systems are not conducive, as well. Additionally, defining only standard functions or services to establish interoperability is insufficient. [9]

Summary

Containing intelligent loads and energy resources, smart homes will play a major role in the future era of renewable energies. Connecting larger loads (e.g. heat pump) and energy recourses (CHP) neither to an in-house management system nor directly to a control centre of a virtual power plant, intelligent and robust communication is required. This paper investigated today’s possibilities given by common protocols on application level to meet the needs of a future interoperable and low cost in-house communication network. Unfortunately, the above-named protocols are not well prepared for these future requirements. While almost every protocol provides scheduling and metering, standardized profiles for distributed energy systems like heat pump, PV-system or CHP are not implemented in most instances, yet. To

ensure “application interoperability” [1] protocols need to provide less opportunities to extend profiles by optional properties. The feasibility to create new proprietary profiles is judged as endangerment for interoperability, too. Furthermore, enhance-ements of protocols and their profiles should support highest possible level of standardisation. This is necessary, to cover interoperability and also to meet a minimum of conformance. Defining LOS on datatype-level is unrewarding, regarding the interoperability. Finally, this paper showed up the need of further research in terms of intelligent energy management and communication systems in smart homes. In doing so, Fraunhofer ISE is facing further investigation not only on application layer but also on all other OSI-layers.

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