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Combination of Standards to Support Flexibility Management in the Smart Grid, Challenges and Opportunities

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Abstract. This paper presents the results of an assessment of a wide range of standards in the smart grid and telecommunications domains that may be jointly used to implement three use cases focusing on the use of the multi-agent systems paradigm in enhancing the smart grid particularly in the area of flexibility management. In addition to supporting a decentralised grid, multi-agent systems can improve other aspects such as reliability, performance and security. The paper identifies relevant standards based on a set of key smart grid use cases from the EU Mas2tering project. The evaluation aims to provide recommendations on combining those standards. This will enable new collaboration opportunities between grid operators, telecom and energy companies, both from technology and business perspectives. The set of telecommunication and energy standards is identified based on existing EU smart grid implementations, models (such as the Smart Grid Architecture Model) and reports published by the European and International standardisation bodies and coordination groups.

1 Introduction

Telecommunication and grid standards are important in addressing specific problems in smart grids. Harmonising those standards can help improve the implementation of smart grids and will allow the energy industry to evolve. In the context of Multi-Agent Systems (MAS), there has been an increased interest in this paradigm together with applications to many systems and domains such as diagnostics, monitoring, simulation, network control and automation [1] which rely on standards to deliver a foundation for market adoption and customer satisfaction. For companies, standards are essential for creating compliant, reliable and safe systems and products, which are compatible with existing systems and products. Regulators use standards to identify efficiency needs, to establish saving targets and to measure compliance. Researchers, on the other hand, are interested in standards to discover new and better techniques for technology development and deployment. Given the significant and growing role of the standardisation in the telecommunications and electricity network, it is critical that the main standardisation bodies and available standards are identified and examined. Substantial amount of research, development, and innovation activities have taken place in the smart grid landscape. A number of authorities have taken a leadership in the process of standards review, development and evolution. Mas2tering project [2] aims to develop a secure multi-agent holonic system for distributed management, control and optimization of the grid while providing an integrated platform for energy and telecom stakeholders [3]. The development of such platform requires understanding of the smart grid and telecommunication standards, their relationships and how they can be implemented.

This paper is structured as follows. Section 2 describes the use cases in Mas2tering project upon which the standards are evaluated and their relevance determined. Section 3 describes the approach taken in the standards' evaluation. Section 4 lists and categorises the standards that are evaluated. The evaluation and the findings are discussed in Section 5. Section 6 concludes the paper.

2 Use Cases

In order to understand the context of the work, this section provides a brief description of the Mas2tering objective and of the three use cases of the project. Mas2tering aims at developing tools and services to be implemented at LV grid level. The scope is to create local communities of end users represented by local aggregators to allow a more effective management of flexibility with respect to traditional centralised one.The home energy box and the MAS platform are the key technologies of the project, since their use enables the local optimization services. To assess the effectiveness of the solution, the project relies on three technical use cases (UCs). Each UC is an enabler to the subsequent one in order and addresses portions of the LV distribution network that is gradually wider:

UC1: Secure and effective connection of commercial home energy boxes with smart meter and consumption profile optimisation

This UC focuses on the Home Area Network (HAN) and the services that involve prosumers. It aims to demonstrate the interoperability between the HAN management system, the smart meter and a technical interface which allows the bi-directional communication between the prosumer and the rest of the LV grid. The communication is a prerequisite to the local optimization proposed in the other UCs and for the prosumer to enter the market of flexibility products.

UC2: Decentralised energy management in a local area with Multi-Agents

This UC focuses on the district, intended as a community of prosumers represented by a local aggregator. It aims to demonstrate that MAS optimisation performed at this local level is effective for energy management and local balancing, as an alternative to traditional centralised optimization. The objective is to maximise revenue for prosumers belonging to the local community when coping with variable external conditions and conflicting requests from the Distribution System Operator (DSO) and other grid actors. This UC will involve the deployment and testing of software-controlled equipment connected to the local grid in testing laboratories supported by large European companies.

UC3: Enhancing grid reliability, performance and resilience
The UC can be considered as an extension of UC2 and tackles the LV grid, intended as the union of more local communities in a given area (represented by a MV/LV substation). The UC targets in particular DSOs and aims at demonstrating that the local optimization enabled in UC2, coupled with proper grid monitoring can be a cost-effective way to deal with local congestions and globally increase grid performances, reliability and resilience.

3 Standards Evaluation Methodology

In order to evaluate the relevance of the standards to Mas2tering project based on the three use cases and to establish the relevance of selected standards and technologies, an evaluation framework has been created as presented in Table 1.

Criterion	Description
Adequacy	Suitability of the standard for the project use cases.
Benefits	Advantages of using the standard and its strength.
Problems	Disadvantages of using the standard and its possible shortcomings.
Interoperability	The possibility of using the standard in conjunction with other telecom and/or energy standards.
Recommendations	Suggestions regarding the approach towards using the standard in the project and relevant comments on the standard.
Scope	Describes issues around the scope of the standard in relation to its applicability to the project and the extent to which it can be used.
License	Access to the standard e.g. free or paid access, and where to find it.
Usability	The level of the standard's ease of use and implementation.
Security	The standard's security aspects.

Table 1. Standards evaluation framework

4 Standards Evaluated

This section lists several telecom and smart grid standards that are provided or recommended by standards bodies including International Electrotechnical Commission (IEC), the European Telecommunications Standards Institute (ETSI), the Institute of Electrical and Electronics Engineers (IEEE), the National Institute of Standards and Technology (NIST), The Union of the Electricity Industry-Eurelectric (EURELECTRIC), CEN-CENELEC-ETSI Smart Grid Coordination Group, and Smart Grid Interoperability Panel (SGIP). All the listed standards are evaluated as part of Mas2tering project and their relevance to the project use cases is detailed in Section 2. The standards are classified into categories for easier understanding of their area of application and usefulness. However, this categorisation does not mean that a standard falls exclusively under a specific category as overlaps exist in the scopes of the standards. The categories names are self descriptive. The categories and the evaluated standards are listed in Table 2. References to the standard sources are not included for brevity.

5 Evaluation of Standards

This section describes the evaluation of the standards and its findings.

Standard category	Evaluated standards
Integration and Interface	Foundation for Intelligent Physical Agents - Agent Communication Language (FIPA-ACL)[4]
	IEC 61968/61970/62325 - Common Information Model (CIM)[5]
	IEEE 1615 - Recommended Practice for Network Communications in Substations
	IEC 62541 - OPC Unified Architecture (UA)
	IEEE 2030 - IEEE Guide for Smart Grid Interoperability
Energy Management	- Open Automated Demand Response Communications Specification
	Universal Smart Energy Framework (USEF)
	ISO/IEC 15067 - Home Electronic System (HES) Application Model
Smart Metering	IEEE 1377 - Utility Industry Metering Communication Protocol Application Layer
	ISO/IEC 15045 - Home Electronic Systems Gateway
	ETSI TS 103 908 - Power Line Telecommunications (PLT) BPSK Narrow Band Power Line Channel for Smart Metering Applications
	ETSI TR 102 691 - Machine to Machine (M2M) Communications
	EN 13757 - Meter-Bus
	ETSI TR 103 240 - PLT for Smart Metering and Home Automation
	IEC 62056 - Electricity metering
	Smart metering equipment technical specifications
Smart Grid Monitoring and Performance	IEC 60870 - Data Transmission Protocols for Supervisory Control and Data Acquisition (SCADA)
	IEEE 1250 - IEEE Guide for Identifying and Improving Voltage Quality in Power Systems
	IEEE 1159 - Recommended Practice for Monitoring Electrical Power Quality
	IEEE 1613 - Environmental and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations
	IEEE P1547 - Conformance Test Procedures for Equipment Interconnecting Distributed Resources
	CLC TS 50549-1 - Requirements for generating plants to be connected in parallel with distribution
	IEEE 1646 - Communication Delivery Time Performance Requirements for Electric Power Substation Automation
	IEEE C37.1 - SCADA and Automation Systems
Networking	IEEE standard for Electric Power Systems Communications Distributed Network Protocol (DNP3)
	IEC 61850 - Communication Networks and Systems in Substations
	ZigBee
	Virtual Private Netowks (VPNs)
	IETF RFC 6272 - Internet Protocols for the Smart Grid
	ISO/IEC 14908 - Control Network Protocol
Physical and Data Link	Synchronous Optical Networking (SONET) and Synchronous Digital Hierarchy (SDH)
	Digital Subscriber Line (DSL)
	Power Line Communication (PLC) standards
	Mobile communication standards: GSM, GPRS, EDGE, LTE, WiMAX
	LANs: Ethernet, IEEE 802.11 (Wireless LANs)
	GS OSG 001 - Open Smart Grid Protocol (OSGP)
Security	IEC 62351 - Power systems management and associated information exchange Data and communications security
	NIST 7628 - Guidelines for Smart Grid Cybersecurity
	IEEE 1686 - Intelligent Electronic Devices Cyber Security Capabilities
	IEEE PC 37.240 - Cybersecurity Requirements for Substation Automation, Protection, and Control Systems
	ISO/IEC 27k series - Information Security Management Systems
	IEC 62443 - Industrial Network and System Security

Table 2. Categories of standards evaluated

5.1 Mapping to the OSI Model

In addition to the categorisation described above, the standards were mapped to the seven layers of the OSI model during the evaluation as shown in Figure 1. The layered model helps analyse each of the standards. It also provides a global picture that assists in investigating how the standards and protocols will integrate together and affect each other's operation.

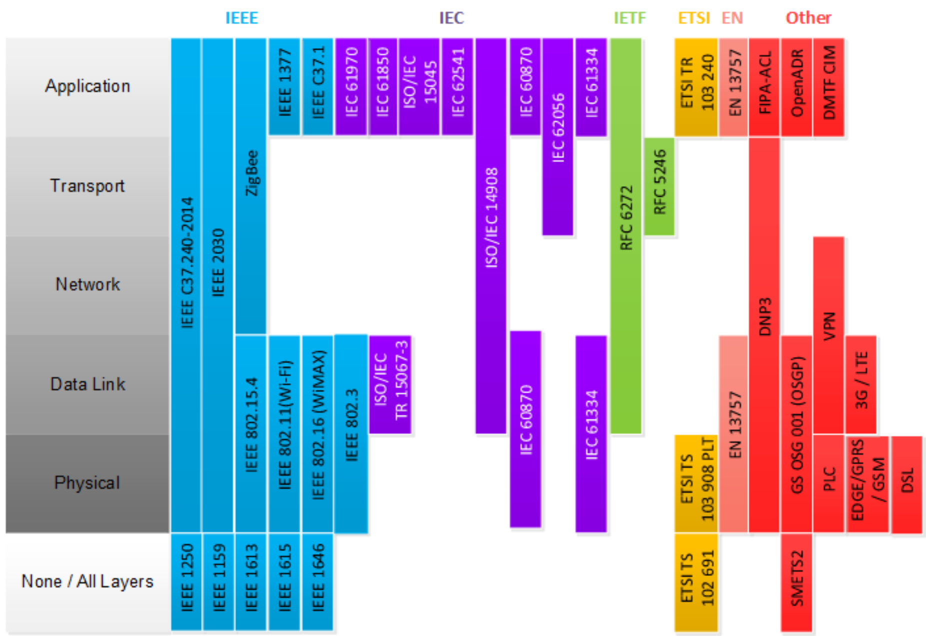

Fig. 1. Mapping of standards, protocols, and technologies to OSI model

5.2 Discussion of Findings

This section discusses a number of standards that were found to be most relevant to the use cases with particular focus to multi-agent systems, integration, energy management and security. In general, some of the standards have wide scopes e.g. applicable to substations, domestic meters, while others have more specific technical features applicable to certain features of the Mas2tering platform.

Messaging and Communication

From the messaging perspective, FIPA-ACL [4] has support libraries covering the full network stack in the chosen MAS platform framework for Mas2tering, namely JADE (Java Agent Development Framework)[6], thus is a low overhead option. Add-ons are available to assist in the encoding and decoding of messages at the application layer and for security. However, no direct support for interfacing to smart grid devices would be achieved without further effort. Hence, a gateway would be needed if FIPA-ACL were to be used. The adoption of DLMS (Device Language Message specification) [7] in ACL content would facilitate mapping between protocols together with exchange transactions compliant to COSEM (COmpanion Specification for Energy Metering) seem pertinent. In the scope of a gateway, the use of the scalable and extensible framework ISO/IEC 15045 would seem desirable.

The Common Information Model (CIM) [5] defined in IEC 61970 and supporting standards such as IEC 61968, is the main model on which FIPA-ACL message content will be based. CIM provides the basis for the design of generic communications for power systems, promoting interoperability. CIM describes elements of the electrical power system to support modelling to facilitate lifecycle stages such as operation of grids. It consists of three layers including the profile layer that allows the specification of sub models of the full specification to support information exchange for specific scenarios and contexts. It is expected that Mas2tering will specify one or more CIM profiles. The use of CIM thus simplifies the interoperability between different software applications delivering syntactic interoperability to support business procedures and objectives. Instead of defining mappings between every participant's internal representations involved in message exchanges and the necessary translations, the platform will map and translate to a common shared model. CIM which is widely reported in the context of the semantic smart grid, describes the smart grid domain but not its logical semantics, instead relying on implied semantics. Lack of semantic definitions may be adequate in some cases in Mas2tering and for that purpose a model with limited expressivity constructs can be used to avoid complicating the model in those contexts. However, where appropriate richer models can be formulated using a consistent representation but with the higher expressivity constructs.

IEC 61850 is an evolving standard with new object models that have been added or under development for electric components such as photovoltaic, batteries and electric vehicles. The use of XML and Ethernet in IEC 61850 contributes to an easier combination with the ICT asset. However IEC 61850 does not define demand response signals such as prices or curtailment signals. Some challenges exist to implementing IEC 61850 such as the extensiveness of the standard, the need for domain knowledge in the area of substation automation, ambiguity due to use of natural language description and inconsistency of different parts of the standard [8]. Although there is some overlap in the role of CIM and IEC 61850, they do not use the same languages. Efforts are underway to improve the interoperability between CIM and IEC 61850 [11].

ZigBee Home Automation (HA 1.2) [12] is a low power wireless sensor network protocol. It is designed for HAN devices, relying on IEEE 802.15.4 protocol specifications for MAC level, and a comprehensive ZigBee Cluster Library (ZCL). ZCL provides a list of functions already modelling and providing a lot of the required interactions between energy boxes and HAN devices such as the exchange of consumption profile and energy cost and the possibility to perform instantaneous demand. ZigBee HA will be used in UC1 to connect home devices with smart meter and the energy box. The main clusters specifying interactions between smart appliances and energy box are the ApplianceControl cluster and the PowerProfile cluster. ApplianceControl cluster enables the scheduling of smart appliances by exposing functions that allow the energy box to set the desired appliance cycle and its start time. The PowerProfile cluster allows the energy gateway to receive information from the appliances about their expected energy consumption in terms of peak power, expected duration and expected energy consumption for each phase of the scheduled cycle. Additionally, both smart meters and smart appliances can use the Metering cluster in order to provide information about the energy and power consumption.

OSGP protocol can be useful for addressing communication between smart meters and aggregators for pricing purposes. The standard includes interesting functionalities such as device discovery. However, there is a lot of room for improvement in this standard as it is missing elements required for the smart grid such as real time interaction with Distributed Energy Resources (DERs).

Flexibility Management

OpenADR aims to automate the demand response to control energy demand and it is among standards that were found to be very relevant to the Mas2tering project. OpenADR supports signals for electricity, energy prices, demand charges, customer bids, load dispatch, and storage. OpenADR "A" is sometimes called the bugged profile as the limited services or devices need the "B" profile to be operated in proper manners. We strongly recommend the developers to go for "B" profile and then narrow down the scale to profile "A" if the scenarios are not using some services. Moreover, profile "B" offers more security options than "A". The cybersecurity tasks will need to take in consideration the validation and the process of certificate provisioning on long periods. OpenADR is based on IP and uses either HTTP or XML. Although OpenADR has been approved as IEC/PAS 62746-10-1 by IEC in 2014, it is not considered as a core standard by the standardization body. There is currently work to adapt OpenADR to CIM that is a core standard [9]. This would make demand response compatible with utility standards.

Although not a standard, the USEF framework [10] is chosen to be used as a reference background to support the definition of the project's business framework and enable the comparison of Mas2tering project with other projects in the smart grid area. In particular, the market mechanisms described in USEF should be used as reference for the definition of the local optimization process. This would give concreteness to the Mas2tering solution from both technical and business perspectives, without imposing any constraint to its development.

Security

Security standards such as IEEE PC37.240, IEEE 2030 are assessed in relation to their usefulness in securing the Mas2tering platform. IEC 62351 can help secure the transactions between agents in the MAS environments. This standard is focused on implementing security for power system control operations. It is useful in securing the implementations for UC2 and UC3. IEEE PC37.240 and IEEE 2030 may be used as guidelines for the design of secure Mas2tering platform. The NIST 7628 guidelines can be used for securing UC1 e.g. HAN data exchange between devices and appliances.

6 Conclusion

This paper evaluates a number of important aspects of standards that are relevant to the smart grid. The aspects include adequacy to the use cases, problems, benefits, usability, interoperability and security. As a result of the evaluation, it has been decided that several standards are useful to the use cases including FIPA-ACL, IEC 61850, CIM, OpenADR, USEF, ZigBee, IEC 62351, IEEE PC37.240, IEEE 2030 and OSGP. This paper provides some of the recommendations regarding the combination and improvement of available telecommunication and energy standards such as IEEE PC37.240, IEC 62351 (for cybersecurity), CIM (for software and data model design), and IEEE 2030 standard (for interoperability). Importantly, gaps still exist in communication standards, protocols, and technologies particularly in relation to interoperability and security of communication systems and in harmonisation between models and standards despite of the significant work being carried out by the standardisation organisations worldwide.

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