Addressing the Key Challenges of Residential Electric Vehicle Charging

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Innovating through Standardization

1 Introduction

Consumer mindsets are shifting towards more sustainable mobility, resulting in the proliferation of Electric Vehicles (EV). As this market continues to grow, so too does the installation of residential charging stations with an expectant penetration rate of above 50% or one residential charging station for the sale of every two EV's. However, the deployment of residential charging stations is still in the very early stages of smart grid integration, and the Electric Vehicle landscape continues to change at a very fast rate in particular due to a lack of standardization.

This leaves home owners with a dilemma on whether to install an EV charging station now or to wait until more mature solutions become available. This is not only true for home owners that already use an Electric Vehicle but equally applies to those who are contemplating acquiring an EV in the future.

So how do homeowners evaluate a situation when the future is unclear? And what questions need to be considered?

- What is the total cost of operating an EV and is it more cost effective than an internal combustion vehicle?
- Is using a separate energy supplier for the EV the right path and will it be possible to change or upgrade the system in the future if more cost-effective solutions become available?
- Is the capital investment of installing solar panels and energy storage profitable and how will this work in the future?
- Will installed EV Charging Stations be compatible with future services that may become available?
- With regulations and standards for residential EV Charging Stations still under discussion at government levels, should homeowners wait until these are defined before investing or will current installations be compliant?
- How will the EV Charging Station integrate with other home appliances?
- Will it be possible to monitor and control the residential EV Charging Stations via a mobile application or web portal?

A parallel can be drawn between the evolution of Advanced Metering Infrastructure (AMI) where energy and water usage has been automated and controlled. There is no doubt that the same will eventually be achieved for residential EV charging. However, some significant distinctions exist between the two markets notably because the Residential EV Charging will possibly require:

- Large ecosystem of cross-industry players:
  - Separate energy supplier for EV charging,
  - Government bodies offering potential bonuses, reductions, or tax advantages,
  - Micro-grid operators.

- Additional cross-device and cross-network data exchange:
  - Homeowner electricity meter and EV charging meter,
  - Energy consumption meter paired with the EV charging station,
  - EV Charger and cloud-based application servers,
  - EV Charger and EV charger energy supplier backhaul systems,
  - EV Charger and homeowner remote display metrologically-relevant devices and applications (smartphone, computer, or tablet).

The large ecosystem of players and the additional data exchange possibly occurring depending on the EV Charging station configuration will significantly add to the complexity and challenges to be faced in the residential EV charging space particularly relating to:

- Connectivity and availability of communication transport links
- Authentication and security of data exchanges
- Standardization and interoperability
- Innovation and expansion for future functions and services

2 Challenges

With the exponential growth of EV's, the transport sector is set to drastically evolve in the coming years. Residential EV installations will need to become more common, and this will present a unique set of challenges. We will unpack the main barriers facing the market in the following section.

2.1 Ecosystem of Cross-Industry Players

The residential EV charging ecosystem consists of a large number of market players. The challenge is to understand the required dataflow architecture. The availability and sharing of data need to be guaranteed, therefore, it is essential to know who is responsible for the data, what can be shared and with whom while ensuring that the two major non-negotiable pillars of data privacy and data security are not compromised.

The allocation of responsibility and data provision may not always be the same. Depending on the use case or scenario, different actors may assume these roles.

Business and service processes need to be developed to address this challenge. These processes need to be flexible as not all parties will be present in all installations. For example, in some cases, a homeowner may have solar generation and energy storage and in other cases, this will not be available. Alternatively, Mobility Operators may offer a "Charge-as-a-Service" subscription.

The DLMS UA provides standardized processes for many use cases and scenarios that are readily available and can be built upon for residential EV charging.

2.2 Governmental Legislation

Legislation to regulate technical aspects of EV charging is important and needs to be vigorously managed. This will enable standardization and ensure the availability of harmonized and interoperable applications and solutions globally.

However, legislation is a lengthy and slow process that sometimes slows down the deployment and availability of technologies. This is no exception for residential EV charging systems. The challenge is therefore to find a path that enables early adoption and participation in the legislative process but that also provides a growth path for future conformance.

The DLMS UA is ideally positioned to address this dilemma. The DLMS UA protocol is communication technology agnostic therefore allowing data exchange between applications and devices to evolve according to legislation independently of the evolution of communication technology. This ensures that the hardware and communication technologies are protected from the evolution of the legislation.

Thanks to its international recognition as a key standard, the DLMS UA is already a key advocate in building proposals for legislative changes to overcome these barriers that currently prevent the emergence of new innovative services that bring digital convenience to the consumer. As an example, we can mention the current energy metrology legislation that does not authorize consumers with remote displays or applications to execute energy related transactions.

2.3 Security

Security plays a pivotal role in a home-owned EV charging station system. Consumer privacy is a key factor for all end-users and in some countries, it can be regulated by legislation. It is mandatory that solutions provide strong control on the security and privacy of data exchange between devices, and that all transactions occur in an identified and authenticated manner.

The example of a mobility operator controlling the charging rate at the EV charging station is a prime example. In this case, proper authentication is an absolute necessity.

The DLMS UA provides a proven, standardized approach to application layer security which addresses all security aspects for identification and authentication even with the expansion to multiple parties and peer to peer communications including device commissioning and decommissioning, which become particularly relevant in complex wireless communication environments where the highest security during device commissioning and decommissioning is not always guaranteed.

2.4 Evolution and Futureproofing

Evolution and future compliance were briefly addressed in the legislation section. However, it is not only on the legislative front that the market needs to address futureproofing. As mobility operators, micro grids, co-generation, and energy storage evolve to provide better and new services, it is essential to develop both forward and backward interoperable and compatible solutions. If this is not properly addressed, the homeowner's solution may become quickly outdated or left behind.

Many future services will be provided by different companies and the homeowner needs to have the ability to change service providers and easily choose new services more aligned to needs in the future.

The DLMS UA is already well placed with its standardized data models and objects based on specific data exchange profiles. The DLMS UA standard can be easily implemented with the addition of new data objects and use cases to address future needs. The hundreds of millions of installed devices using the DLMS UA data exchange protocol attest to the effectiveness of the supported DFU (Device Filed Upgrade) offered by DLMS since many years. This has proven viable in many situations, with the recent expansion to Prepayment in the AMI domain being a prime example.

2.5 Interoperability and Diversity

To enable services to evolve and be readily available to the homeowner, interoperability is an essential requirement. Without the ability to be interoperable with existing equipment and services, new services cannot be deployed and will be limited to green markets. This will seriously limit the development of this promising field of services to the detriment of all players.

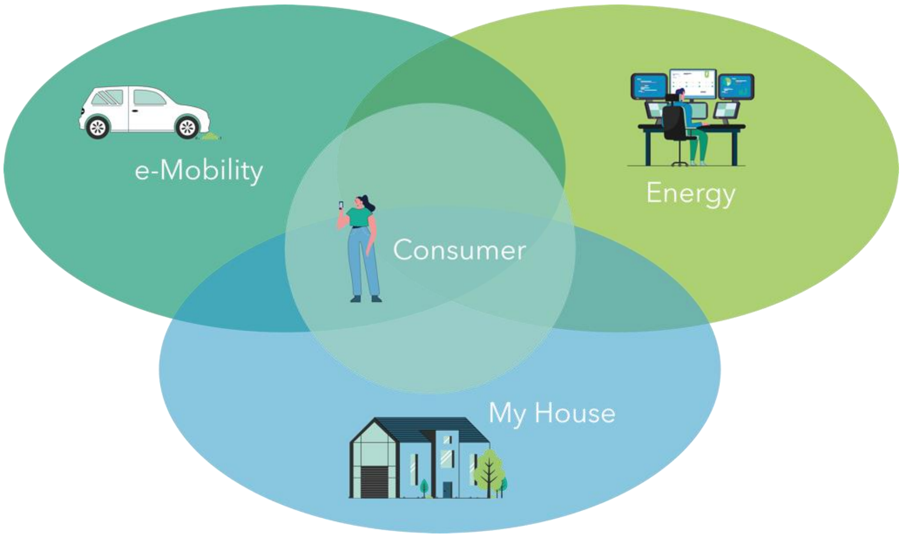


Figure 1 – Market Convergence

Services and components will be available from a large number of component suppliers and service providers. Homeowners must be able to draw from this diversity to tailor systems to specific needs without facing obsolescence and market lock in. Looking at this ecosystem from a high level, three different worlds are now converging as shown in the figure 1: the e-Mobility sector that is facing major disruption; the Energy sector, that is highly regulated and that while becoming more liberalized, will continue to remain highly regulated; and finally, the consumers' residence, the sector that is evolving at the fastest pace thanks to disruptive consumer electronic devices resulting in increased consumer digital convenience expectations.

While open and interoperable standards for data exchange are required to enable new business models, it is impossible to have a one-for-all solution. These sectors are dramatically different, sometimes with opposing interests, and while some are already established with heavy infrastructure investments made over the years, others are in their infancy and still need to find growth paths. Therefore, the most pragmatic solution is to leverage existing solutions to enable data exchange at the device level, while ensuring consumer privacy and security control, independently of the communication technology used by these devices to communicate.

The DLMS UA is a recognized industry standard, adopted by both the IEC and ANSI, that could be the central pillar to guarantee interoperability in the EV charging market. The DLMS UA device compliance and certification programs guarantee compatibility and interoperability with all certified DLMS devices and other standardization bodies that have implemented this standard. The DLMS UA standard has demonstrated its scalability and is deployed into hundreds of millions of installed devices and is therefore the most logical place to start for sharing relevant data with EV Changing Stations. It can bridge the consumer sector with the Energy and e-Mobility sectors in a fully compatible manner and it is foreseen to play a major energy management role in the "MyHouse" ecosystem in the years to come.

The DLMA UA standard is also the best way to guarantee consumer privacy and security for sharing data amongst devices in the "last mile". The shared data will remain under the control of the consumer, thus guaranteeing full privacy, while enabling innovative services and operations without excluding data aggregation once anonymized to permit the emergence of innovative services bringing the expected digital convenience to the consumer.

2.6 Connectivity Paths

For optimal use and diversity of services for EV charging, many parties will need to communicate with each other. Certain connectivity paths are well established and have already been forged in the advent of AMI systems. For example, the connectivity between the retailer and the electricity meter is already available for most homeowners. The use of mesh radio and Power Line Carrier (PLC) in conjunction with cellular backhaul, is currently dominating the market, with the adoption of direct cellular with LTE and NB-IOT making inroads.

Connectivity within the home, and especially with the electricity meter, has been advocated by many AMI programs over the years but adoption has fallen short of expectations because of the limited added value offered by the proposed solutions.

Home automation or domotics has been more successful, and adoption is picking up significantly. Connectivity is primarily via Wi-Fi combined with cloud services from the Internet Service Provider.

Home-owned EV charging stations are trending mostly towards cellular technologies and cloud services. However, given the location of the charging station (garage or parking places), connectivity may sometimes be problematic.

For the homeowner, the use of applications on mobile telephones or tablets in conjunction with cloud services is prevalent with the occasional use of computer access. Connectivity is mostly achieved via cellular data or Wi-Fi.

However, the bridging between the various network technologies may pose a challenge for certain required communication paths.

As a standardized data exchange protocol, the DLMA UA is an ideal candidate to bring a solution that is communication technology agnostic. The DLMS UA protocol allows data to be exchanged between devices while embedding different types of communication technologies or connecting to different types of device networks or communication networks.

3 Use Cases

By analyzing the interaction between the ecosystem of cross-industry players and the data flows for the main use cases for EV charging, the value of the DLMS application layer protocol may be demonstrated. To highlight the importance of the DLMS protocol for EV charging, two use cases will be presented – one use case to demonstrate a current solution and another use case to demonstrate a potential future solution.

3.1 Use Case 1: Dynamic Load Balancing

Home owners receive their electricity energy supply from a DSO with a maximum instantaneous supply, that is based on a specific energy subscription and managed with a circuit breaker or other protective device. It is therefore imperative that the combination of the consumption of the home and the demand for the EV charging station is regulated below this level. Failing to correctly manage consumption within this threshold will require the installation of an EV charging station outside of the current home electricity architecture causing substantial installation costs to the consumer.

In its simplest form, the mobility operator will manually set a charging rate for the EV charge assuming a specific household load when installing the EV charging station. However, given the uncertainty and variability of the household load, this charging rate needs to be set at a low level, regardless of the EV charging power rate, which can result in long charge cycles and a reduced value when purchasing a higher power rate EV charging station which will never be capable of operating at its optimized charging capabilities.

The installation of an additional energy meter measuring the instantaneous household power consumption can address the dynamic load balancing of the home in function of the EV charger demand. However, the home owner would need to cover the additional installation costs, which sometimes can be double the overall EV charging station costs.

Thanks to DLMS, the instantaneous household load can be identified using real time communication with the smart meter, and the EV charger energy demand can be adapted dynamically, thus ensuring that the maximum charge rate can be used and that the total instantaneous load does not exceed the energy supply contract limit.

Multiple market players, as shown in Figure 2, will need to co-exist and collaborate:

1. DSO
    - The DSO interfaces with the smart meter via a DLMS/COSEM link for consumption and load limit information;
    - Load and consumption information is shared between the EV charging station and the smart meter via another DLMS/COSEM link;
    - Information exchanges between the EV and the EV charging station is managed via a IEC15118 interface.
2. e-Mobility Operator
    - The e-Mobility Operator interfaces with the EV charging station via a IEC63110 interface for managing charging parameters;
    - Information exchanges between the EV and the EV charge station is managed via a IEC15118 interface.
3. Home Owner Z
    - e-Mobility Cloud Services can link to the home owner's remote display metrologically-relevant information through a DLMS/COSEM link, permitting energy transactions for setting charge parameters and account information.
    - The home owner's remote display interfaces with the EV charger and the smart meter to obtain charge status and consumption information via a DLMS/COSEM link.

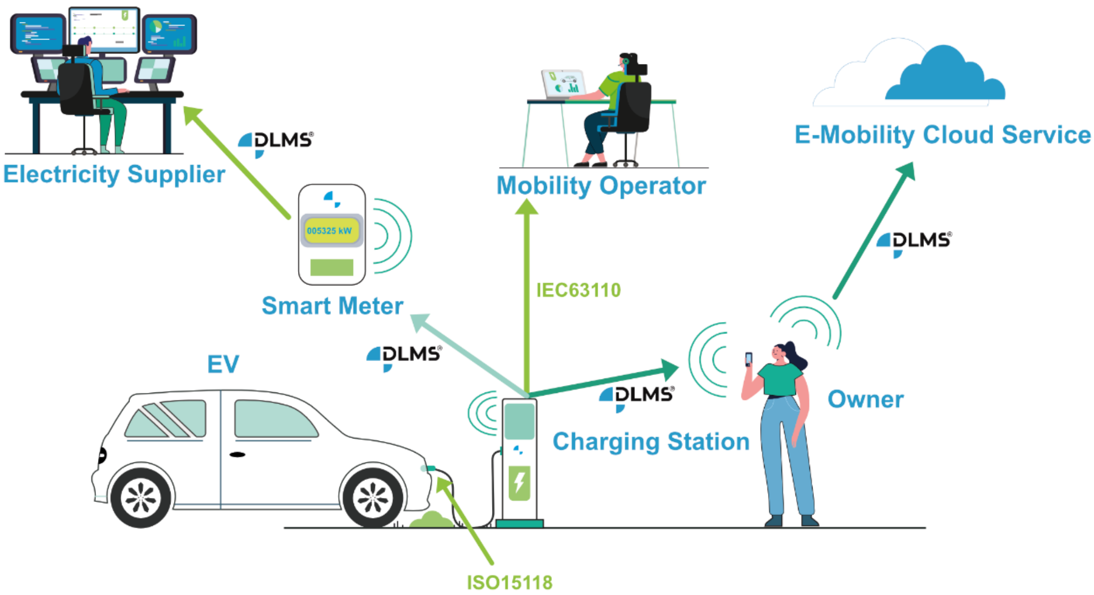
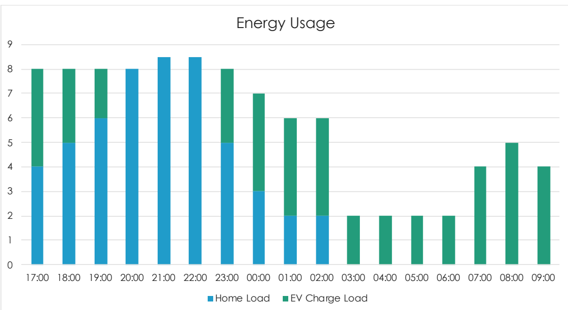


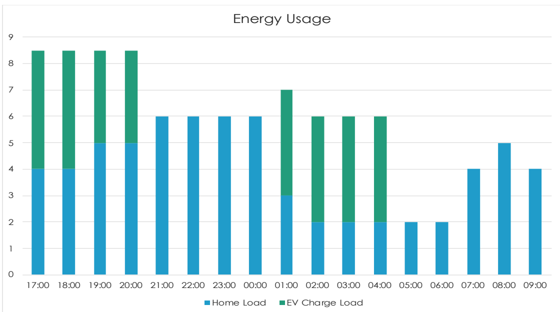
Figure 2 - EV Charging provided by an EV Mobility Operator

Two scenarios can be considered for energy usage with dynamic load balancing as illustrated in Figure 3:

- A normal evening when the EV is parked and will only be required the following morning.
- A "fast charge" evening when the EV will be reused the same evening and requires a certain charge level, with additional charging necessary once returned to be ready for use the next morning.



Normal evening



Fast charging evening

Figure 3 – Energy Usage using Dynamic Load Balancing

The following behaviors can be observed with dynamic load balancing:

- The total energy consumption of the EV charging station is regulated to ensure the maximum contracted demand for the home is not exceeded in any case.
- The charging of the EV is maximized benefiting in real time from the maximum permissible energy.
- In the case of a normal evening, EV charging occurs based on the maximum available residual energy within the energy subscription limit, resulting in EV charging being pushed to later in the evening or night, but in an optimized manner (the fewer appliances are using energy withing the home, the faster the car will be charged).
- In the case of a "fast charge" evening, the subscribed home energy supply can be over-ruled or forfeited for a specific duration by the home owner, in agreement with the energy supplier, to enable dynamic load balancing at a higher charge rate for the EV. The EV charging is resumed later in the evening upon return.

3.2 Use Case 2: Demand Response

In the case where a forward-looking, time-based demand constraint defined by the DSO, coincides with an upcoming charge cycle, the home owner will be notified if this constraint impacts their default charge parameters. Depending on the terms and conditions of the e-Mobility or DSO supply agreement (based on who supplies the energy for the EV), one of the following scenarios will occur:

- The EV charging load will be set to zero during the specific time-based demand constraint period;
- The EV charging load will be set to a reduced value during the specific time-based demand constraint period;
- The EV charging load will not be restricted during the specific time-based demand constraint period but the pricing may be increased;
- The home owner may receive a bonus or credit if no EV charging is used during the specific time-based demand constraint period;
- The homeowner will finalize the charge parameters before launching the charge cycle.

It is important to note that currently no energy-metrology-relevant transactions can be legally executed in Europe by remote displays. This means that transactions for demand response need to be performed by the smart meter, and this is guaranteed by the regulated communication with the electricity supplier.

Currently, the DLMS/COSEM based data exchange between the smart meter and the EV charging station serves as a backup solution to overcome this barrier, while waiting for EU legislation to be adapted.

Current efforts deployed by the DLMS UA to broaden the adoption of the IEC62056 Suites by other standards, and ongoing contributions to legislative activities within the European Commission, will be fundamental steps towards creating the legislative framework to simplify these transactions and offer flexibility for architectural implementation.

Once this is completed the homeowner will be fully enabled to execute demand response transactions directly from a remote display for example to accept a higher charge price per kwh despite demand constraints in place directly with energy-as-a-service services.

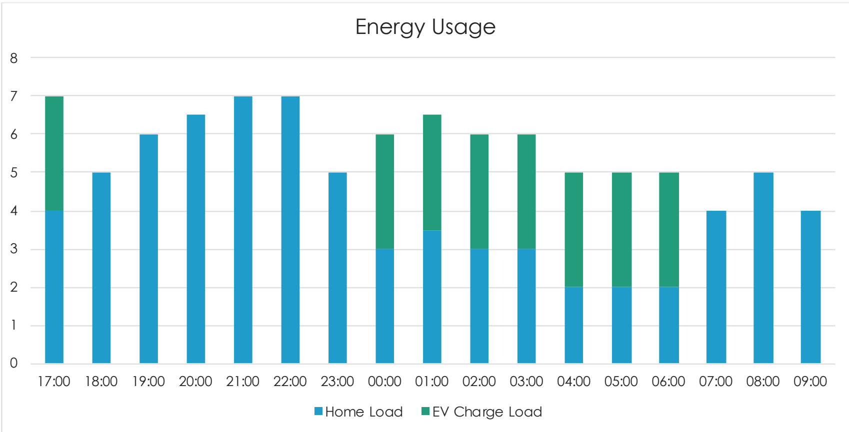


Figure 4 – Energy Usage during Demand Response

The above graph shows consumption behavior when the above-mentioned scenario is implemented:

- The homeowner accepts the demand response regime;
- The energy balancing application does not use the maximum allowed load, but modulates this according to the demand response period;
- As a result, energy consumption is reduced during the demand response period.

4 Opportunities

Multiple opportunities exist for the residential EV charging market to evolve in the future.

It is evident that the push towards co-generation will play an important role. Not only will more homeowners embrace these opportunities, especially with the emergence of solar panels, but the evolution of energy storage will also play a significant role. Services around these opportunities will emerge and solutions must be open and adaptable to enable them.

Figure 5 below shows the additional players that could come into play in future EV charging systems.

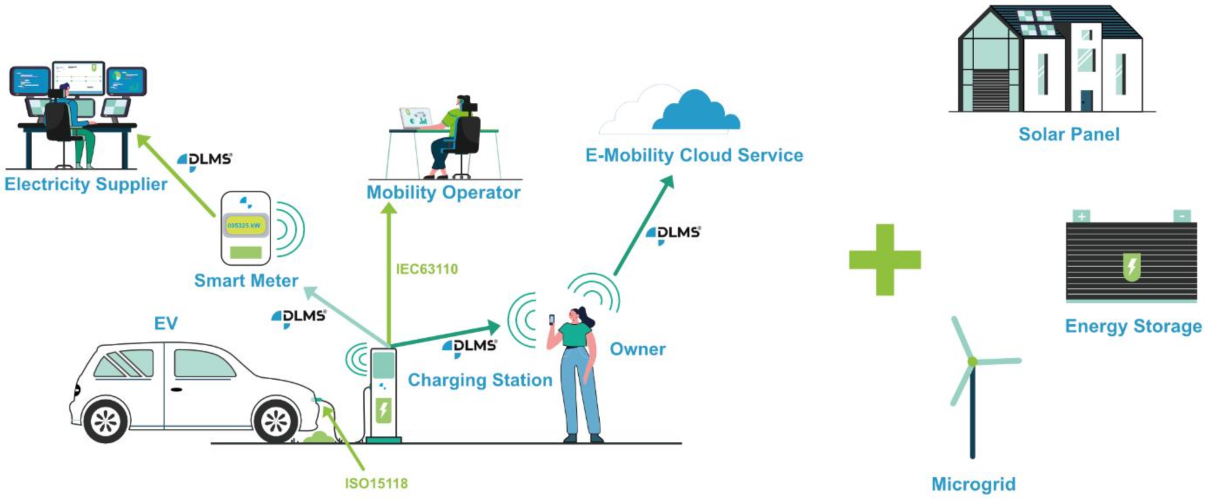


Figure 5 – Additional Future Players

This will naturally lead to additional opportunities of real time pricing as the availability and the demand for energy will become more volatile. Charging an EV at the most economical price and taking consumer-specific requirements for a specific instance into account, will become a complex business model. This presents an opportunity for the expansion of the Demand Response use case described earlier.

Communication technologies to enable interaction between the different market players will be determined in the future. However, the DLMS UA standard data models and application layer exchanges are ideally placed to enable this.

The following elements need to be considered:

- Energy price forecast at the Mobility Operator;
- Energy price from home grid co-generators;
- Energy available from co-generation or energy storage;
- Price forecast for the potential charging period;
- Desired charging time (when the EV will be used and how much additional charge is needed);
- Home energy usage for the potential charging period.

With these considerations, the following evaluations are required to decide on a charge profile:

- The maximum available energy for charging and the associated price for each specific pricing interval for the potential charge period.
- For each specific pricing interval for the next 24 h period, the potential revenue if stored energy is sold and how much stored energy is available.
- For each specific pricing interval for the next 24 h period, the potential co generated energy sold.

- How much reserve stored energy is desired for the next 24h period.
- How much home load can be scheduled at which pricing timeslots?

Using the above evaluations, various schedule scenarios can be determined to obtain the most economical charging profile. This evaluation needs to be executed by the homeowner application since microgrid information needs to be taken into consideration. These scenarios pave the way to the decentralized management of energy resources within an "Energy-as-a-Service" model. This will result in the decentralization and the digitalization of energy distribution and management that will allow the exploitation of the full potential of the smart meter as the first node of this intelligent energy management decentralization. These are the future challenges that the DLMS UA is standardizing.

5 Adopting the DLMS UA Standard

The DLMS UA is well positioned to provide readily available solutions to address the immediate issues described in this paper and also to provide a path towards the future needs and challenges of the EV Charging market.

- Many of the data objects required for data transport are already standardized by DLMS.
- New data objects that may be required in the future can be made available as new standard objects in a short timeframe after being identified as required by the DLMS UA.
- Multiple communication technologies are already supported, and additional ones can be added on short notice if required.
- Application interactions for specific use cases are already standardized enabling interoperability via an agnostic approach to both underlying communications transport technology and hardware platforms.

Based on this proven experience and given the fact that EV charging is so closely linked to AMI as far as data objects and application-level transport are concerned, it is evident that a large portion of the current DLMS UA offering can be reused as is.

Additional data models are constantly evolving and the DLMS UA is committed to offering a standardized and structured process for implementation and deployment. To address new market needs, the DLMS UA recently defined the data objects required for dynamic load balancing and has released new standards for DC measurement which will support DC charging.

Using the latest recommendations from NIST for algorithms, key generation, and distribution, the DLMS UA embeds security suites into its standard to ensure that end-to-end security requirements are met. Thanks to its demonstrated scalability with several hundreds of millions of deployed devices across the five continents and its Certification and Qualification Program, the DLMS UA guarantees the highest level of compliance and compatibility and guarantees interoperability at the lowest cost of ownership.

The communication technology agnostic DLMS UA protocol enables data exchange between applications and devices across multiple communication technologies. The DLMS UA has established agreements with numerous communication technology standardization associations and the most popular transport protocols have already been certified within DLMS UA.

The broader adoption of the standardized application-layer protocols and data exchange models of the DLMS UA will provide the most appropriate solution to address the existing and emerging challenges of EV charging.

6 Conclusion

The DLMS UA has a unique and proven offering to address the challenges of residential EV charging. The DLMS UA approach embraces innovation and evolution and can provide additional data objects and business processes as required and in a short timeframe. The open standard and certification process provided by the DLMS UA will ensure interoperability and futureproofing for the EV Charging market.

7 Key Takeaways

- The residential EV charging station market is facing numerous challenges that will impact the future energy supply and demand significantly.
- The landscape of devices and future services is very dynamic and will change significantly in the next decade.
- The DLMS UA provides a readily available solution to address the challenges of residential EV charging leveraging its current position in the AMI industry and its evolution capabilities, by sharing relevant data in the respect of the data privacy and security, whenever it makes sense.
- Both regulated and unregulated communications will benefit from DLMS UA Data Exchange Protocol.
- The DLMS UA provides solutions not only from the home owners perspective but also addresses the needs of other cross-industry players including Energy Retailers, DSOs, Mobility Operator's, Micro Grid participants and Legislation bodies.
- The DLMS UA offers "plug and play" capabilities to all market players, irrespective of underlying communication technology or hardware by providing device manufacturers with application specific, off-the-shelf Generic Companion Specifications, reducing device development costs, accelerating the device time-to-market, and permitting full compatibility or in other words device exchangeability in the field, to the benefit of the consumer.

8 About DLMS UA

The DLMS User Association is a non-profit organization and a leading voice internationally in interoperable and secure data exchange to support strategic energy and water management.

Our mission is to foster member collaboration, drive innovation through standardization and deliver world leading specifications and certification programs that support interchangeable devices and secure data exchange.

Recognized by major international standardization bodies, over 300 members currently use the DLMS specifications in the IoT, e-Mobility, Smart Grid and Smart Metering segments.

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