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Communication Protocols for Managed EV Charging and V2G Applications

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Summary

The landscape of standard communications protocols for Managed EV Charging (V1G) and Vehicle-to-Grid (V2G) applications is new and evolving. This makes it confusing for utilities to understand and select the right standards for their EV programs. This paper provides background on how standard communication protocols are used today in both EV charge management and EV DER applications. The paper provides an overview of popular V1G and V2G applications, relevant communication and data standards to support these applications, typical control architectures in the EV community, mandates driving different V1G and V2G approaches, and general guidelines for selecting and deploying these protocols.

Keywords: communication, interoperability, smart charging, standardization, V2G (vehicle to grid)

1 Introduction to Standard Communications Protocols, Information Models and EV-Grid Interactions

The communications infrastructure for extracting grid benefits from electric vehicles (EV) and EV infrastructure is a confusing landscape. Grid benefits derive from either managing EV charging behaviour (referred to as V1G or managed charging) or leveraging the EV as a storage system (also referred to as Vehicle-to-Grid or V2G) to better manage grid operations. For grid operators, the choices for application level communications (also referred to as messaging communications) are particularly confusing as no industry-wide agreement exists on the optimum choice of communications protocols [1]. Further complicating this, the standards vary depending on how the EV is being used (e.g., inform and motivate programs like pricing, curtailment of charging, or smart-inverter like behavior).

The need for standardization is clear but the path to achieving it is not clear nor simple.

This paper will summarize the various activities on vehicle-grid integration (known as VGI and includes both V1G and V2G applications) including control architectures for managed EV charging [2] and V2G applications, key regulatory mandates that are driving decisions, and implementations.

The paper also describes the fundamental challenges in managing VGI interactions, provides a review and analysis of the current set of EV messaging protocols, and defines guidelines for selection and use of messaging protocols.

1.1 Definitions

To address the topics in this paper, we start with some background and definitions:

- ***Charge Network Operator (CNO)***: Also called an EVSP or Network Service Provider; this is the entity that manages a network of charging stations (EVSEs).
- ***Control Architecture***: This describes the architecture of the communications system including the different actors, where control is exerted, where decisions are made, scalability, security, etc.
- ***Distributed Energy Resource (DER)***: DERs are physical and virtual assets that are deployed across the distribution grid, typically close to load, and usually behind the meter.
- ***DERMS***: DER Management System is a hardware and software platform to monitor and control DERs in a manner that maintains or improves the reliability, efficiency, and overall performance of the electric distribution system. [3]
- ***EVSE***: EV Supply Equipment. Connects the grid to the EV for charging. The role in using an EVSE as part of DER is not yet clear.
- ***Interoperability Standard***: Usually recognized international standards for communications interfaces between systems and include IEC 61850, IEEE 1815 (DNP3), IEEE 2030.5, etc.
- ***ITCA***: Interoperability Testing and Certification Authority is an industry recognized organization with responsibility for developing and managing test and certification programs for one or more industry standards.
- ***Messaging protocol***: This is the top layer of a communications protocols (sometimes called the application layer) and defines the format of messages (syntax) and the meaning of the information (semantics).
- ***Messaging Requirements***: In order to select or develop a messaging protocol for a given use case, a detailed analysis of the use case identifies the requirements of the messaging communications.
- ***Protocol***: An agreement on how information is communicated.
- ***SAE***: Society of Automotive Engineers has developed a set of standards for V2G applications using IEEE 2030.5 as the primary messaging protocol between grid operators and V2G capable EVs.
- ***SCADA***: Supervisory Control and Data Acquisition system used for real-time control of large generation, substations and other critical distribution system equipment.
- ***SDO***: Standards Development Organization. These include IEEE, UL Standards, IEC, ISO, ANSI, etc.
- ***Telematics***: An EV OEM network that is able to communicate with an EV to monitor and manage charging or DER behavior.
- ***Use Case***: This term is used in the electric utility industry (and others) to describe the actors and desired results of communications. For example, a simple demand response (DR) use case describes the messages to be sent from a utility to a residential thermostat to alter consumption at a specific time. Use cases typically include the actors (usually represented by a machine or information system), the outcomes of the communications and the messages to be exchanged.

1.2 Mandates for EV Communications

While there are numerous mandates for adoption of EVs, only California, to our knowledge, is actually addressing detailed use cases and messaging communications infrastructure. [4]

In California there are existing rules for generation resources like solar and energy storage systems to interconnect to the grid – California Rule 21. [5] The California Public Utilities Commission (CPUC) launched a work group to evaluate whether these requirements were sufficient for V2G applications. The study focused on V2G applications where management is through the EVSE. They determined that current CA Rule 21 requirements are adequate for DC charging where the inverter in is the EVSE. [6]

This is a significant step forward and, although the CPUC has yet to formalize the conclusion in an order, it is expected in late 2020. For grid management of EVs as mobile DERs where the inverter is in the EVSE, it is likely that the same communications rules will apply as apply to distributed solar or battery storage systems.

In parallel, California launched a subgroup to evaluate communications requirements for V2G AC charging. They developed a comprehensive report detailing the current state of interoperability standards for EV communications and evaluated the gaps that must be addressed to enable deployment of V2G AC charging systems with bidirectional mobile inverters on the EVs themselves. The results were focused on the gaps that exist in the current JAE 3072 standard governing EV communications for V2G applications, gaps in the current UL 1741 standard for inverter safety certification, and gaps in the UL 9741 standard for EVSE safety certification. [7]

The encouraging message from the CPUC V2G Subgroup was that the remaining work to update and align existing standards to enable V2G operations in California is not that exhaustive. In fact, both the SAE and UL have begun the work necessary to enhance the standards as needed.

The United Kingdom passed the "Automated and Electric Vehicles Act 2018" which does require "charge points" (EVSEs) to be able to communicate certain information. [8] However, it does not specify a messaging protocol(s) to be used.

2 Use Cases for EV Demand Management and V2G Applications

Much work has been done on defining the use cases for EV to utility grid communications. Three examples include the work from SAE, Argonne National Labs, and the California VGI Working Group efforts.

The Society for Automotive Engineers recently published a series of standards for EV to grid communications use cases. [9] The SAE standards include detailed discussions and diagrams of the use cases and models for deploying the communications architecture. Argonne National Lab is collaborating with industry, government and other research organizations to develop a concept to integrate vehicles into the "Grid of Things". [10] The California VGI Working Group efforts are perhaps the most comprehensive and have defined and evaluated hundreds of V1G and V2G use cases. [11]

For the purpose of this paper, which is intended to illustrate the process of analyzing use cases to select an appropriate communications protocol, we have selected three EV use case examples. These use cases are based on the SEPA and California VGI work and were selected as representative of the most common (and expected to be common) VGI applications.

- **Use Case 1: V1G Residential DC Charge Management** with voluntary participation using rates, rebates, or other incentives, or through active direct control by a utility or aggregator DERMS. Uses price and/or DR event messages and EVSE metrology data.
- **Use Case 2: V1G Workplace DC Managed Charging** using an active direct control model via a network charge operator or aggregator and EVSEs within a single location. Uses price and/or DR event messages and EVSE metrology data.
- **Use Case 3: V2G DC and AC EV as DER** leveraging the CA VGI and CPUC V2G activities where either DC (EVSE bi-directional inverters) or AC (on-board bi-directional inverters) charging can be leveraged to provide active or reactive power to the grid.

DC charging uses an EVSE inverter to convert grid AC current to the DC charge required by the on-board EV battery system. An EVSE inverter may be bi-directional to support V2G applications, but such systems are not yet widely available or deployed. AC charging occurs when the EV has an on-board inverter that may or may not be bi-directional.

It should be noted that at this time, for both V1G managed charging use cases, there is no common EVSE profile which defines the control capabilities of the devices. Therefore, there is no guarantee that any given EVSE is able to execute the types of control presented here.

2.1 Use Case 1: V1G Residential DC Managed Charging

Residential charging is a demand response resource. Charge is adjusted to occur when a utility has abundant, low-cost energy and low demand – e.g., the middle of the night. Fig. 1 shows the load profile and amount of active charging sessions for a set of residential users. It shows a ramp up in the number of sessions and load in the early evening hours. It also shows that vehicles remain connected to their charger much longer than required to fully charge their battery using a standard Level 2 EVSE, implying that utility customers could be flexible when the charging happens.

Utilities are looking for ways to avoid load peaks due to EV charging, and also to take advantage of the vehicle is connected to an EVSE but is not charging. Utilities have multiple choices in how they call on customers to change vehicle charging profiles (e.g., rate changes, rebates, or demand response load control solutions). In this paper, the definition of V1G managed charging includes all of these program types.

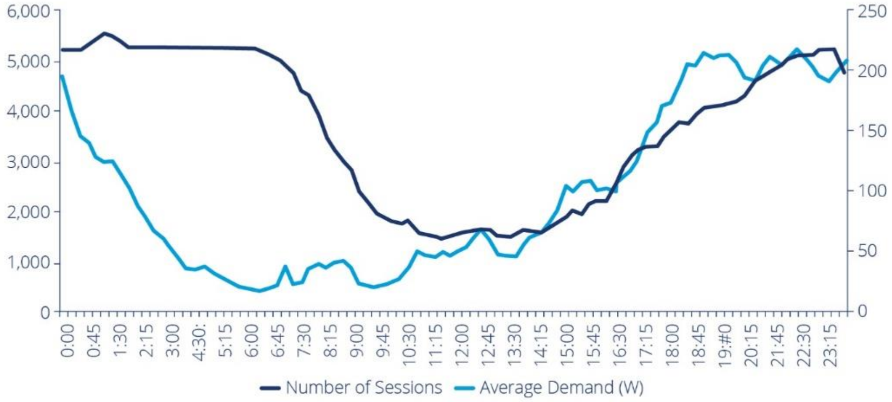

Figure 1. Residential charging profile sample data

Most programs today rely on passive managed charging, attempting to influence the customer's behavior by offering incentives or lower rates for off-peak charging. In such cases, the only data needed is secure collection of consumption from the CNO, metering, or submetering infrastructure. Programs such a time-of-use EV rates or rebates for off-peak charging have generally been very successful at modifying driver behavior. They do not however eliminate the risk of EV charging load peaks because they rely on consumer behavior.

2.2 Use Case 2: V1G Workplace DC Managed Charging

Other than the residence, the location with the longest EV dwell time is the workplace, where most of the charging occurs during day. A benefit of workplace charging to utilities is the concentration of chargers in specific areas of their grid. Many V1G managed charging programs have focused on workplace or commercial deployments with similar networking and communications requirements.

In California in particular, the investor-owned utilities proposed generous incentives for commercial customers with the goal of shifting EV charging from the home to the workplace, eliminating the additional EV load peak during the evening ramp, and absorbing the excess renewable energy produced during the day.

In both residential V1G use cases and workplace charging, a key requirement is data collection to measure and verify the overall impact and EV load generated. Most utilities and/or state regulators who provide incentives require metrology data at the EVSE level as well as aggregated data at the site level, which is what the site owner is ultimately billed for.

A major difference between residential and workplace programs is the shared management of resources: site owners retain control of their chargers and may have conflicting requirements. The CNO typically interfaces with a grid-management system to send the data, receive utility controls, and provides a management portal to the site host for operational controls. Example of operational controls include limiting the access to the chargers to certain drivers/times or limiting the duration of charging sessions/energy delivered per session.

The main applications of V1G managed charging at the workplace are load shaping and load shifting.

Fig. 2 is an example of V1G controls as defined by Southern California Edison in their Charge Ready pilot. In exchange for initial incentives to deploy the chargers, the customers agreed to participate in utility-defined demand response events.

Load Shift and Reduction Details		
	Load Reduction	**Load Shift**
Incentive Period	4 pm to 9 pm M-F, except holidays	11 am to 3 pm M-F, except holidays
Control and Baseline Period	4 pm - 9 pm	6 am - 11 am
Months	June through September	March through May and October through December
Number of Events per Day	Single on-to-five hour control event	Single on-to-five hour control event
Number of events	Up to 10 each year	Up to 10 each year
Shift or Reduction	Up to 50%	Up to 50%
Credits	$0.10 per kWh reduced during Control/Incentive periods	$0.05 per kWh used during the Incentive period
Notification	Day ahead	Day ahead

Figure 2. SCE Charge Ready Demand Response Pilot

2.3 Use Case 3: V2G DC and AC EV as DER

Vehicle to Grid (V2G) services are based on the treatment of an EV as an energy source that can supply power or grid services such as voltage and frequency support through its smart inverter functionality. The use case is similar to fixed battery storage use cases and relies on a combination of pre-programmed behavior of the inverters and messages from the grid operator to schedule, modify, disconnect, connect or otherwise instruct the EV inverter to provide grid services. The applications include peak shifting (storing energy to discharge later), solar smoothing, frequency and voltage support, and multiple other applications that distributed energy storage can be used for.

Our scope for V2G in this paper covers both DC charging paradigms where the inverter controls and functions are in the charging station itself and AC charging where the inverter is in the EV itself. The EVSE is able to communicate with the grid operator directly or through a network operator/DER aggregator and receive DER instructions or report monitoring and status information to the grid operator. The second case covers on-board bi-directional inverters with the same control and electrical functionality. On-board inverters provide additional flexibility but also create additional communications challenges. Our V2G Use Case is based on the work done in California by the VGI and V2G CPUC work groups. [5, 6, 7, 12]

3 Control Architectures for EV Communications Infrastructure

A “control architecture” describes the communications architecture that will be used to get messages from/to the grid operator and the end-devices being managed. For instance, one model assumes that the actual end-devices are managed by a building energy management system (EMS) which does the actual communications with the utility DERMS. In this case, the operator talks with the EMS which talks with the end-devices.

The analysis starts with identifying the control architecture to be used. A useful discussion of control architectures was done between the OpenADR Alliance and EPRI. [12] It was further developed by QualityLogic and presented at several industry forums [13] and is extended by the authors in this paper. The control architectures of relevance to the EV communications challenges are:

- **Direct Management**: A utility directly sends settings or requests to the EV or EVSE. Currently this is only available for V1G use cases.

- ***Pass-thru Aggregation*** (as in CA Rule 21): A utility determines smart inverter settings and emergency dispatch commands for each inverter and these are "passed-through" an aggregator, CNO or other gateway to the inverter without modification.
- ***Smart DR/DER Aggregation***: This is typically used for DR and DER management by a utility when an intelligent gateway (such as a Microgrid controller, a facility DER management system or some other intelligent gateway) interprets the utility commands and requests and determines what settings or commands to send to which end-device. Messages could be advisory in nature (requests, price signals, etc.), specific mandated requirements of aggregated DR/DERs, or both.
- ***Third-Party Charge Network Operator***: This is a specific pathway between a utility and third-party intelligent aggregation system that manages EVSEs and can manage both V1G and V2G EV charging behaviors. The DER resources managed are only EVs.
- ***Vehicle Telematics***: an alternative communications path between a utility DERMS and EVs, by-passing the EVSE. This is typically the auto OEM's network and could be used for managing EVs in a V1G or V2G application.

From a protocol perspective, the selected control architecture impacts the messaging requirements and functional capabilities of messaging protocol to be used. This varies by the messaging requirements, applicability of protocols to each "hop" (e.g. utility to aggregator to EV) in the architecture, and technical/non-technical considerations for protocol selection.

4 EV Communications Messaging Requirements

Messaging requirements capture the actual type and content of messages that must be exchanged to enable an application. These requirements are derived from use cases. For instance, in multiple control architectures an EV and EVSE may communicate with each other to negotiate a charging session. The information exchange requirements would include:

- Security certificates or some form of authentication and trust relationship
- Ownership and billing/credit card information
- Pricing information, perhaps based on schedule, time of day or another variable
- State of charge; state of required charge
- Start/end time of the charging session

Once these are identified, potential messaging protocols can be evaluated to determine which one(s) are able to meet the messaging requirements.

Our method for assessing the messaging requirements is to start with the Use Case and attempt to catalogue the types of messages that will be required. To the extent that the messaging requirements from multiple use cases are similar, then the messaging protocol selected for one use case should cover multiple use cases. In other words, consider the combined requirements for all use cases that may use the messaging protocols.

The use case for a time-of-use (TOU) rate (an instance of Use Case 1) anticipates a set of messaging requirements that need communications messaging support. These requirements include exchanging information to enroll in a utility TOU program, registration of a device or system and the capabilities of that asset. Messages would also include the TOU pricing schedules and changes to such schedules and monitoring/metering for billing and system planning purposes. The information is necessary for the utility DERMS to make decisions about which assets can be deployed when and for what purposes. EVs would be a special type of asset with additional information required about current location, state-of-charge, owner requirements, effective DR/DER services capabilities and the schedule of those capabilities.

Leveraging work done as part of the OpenADR-EPRI 2017 Workshop [13] and further developed by QualityLogic [14] and the authors of this paper, a summary of the EV relevant messaging requirements can be outlined as in Fig. 3.

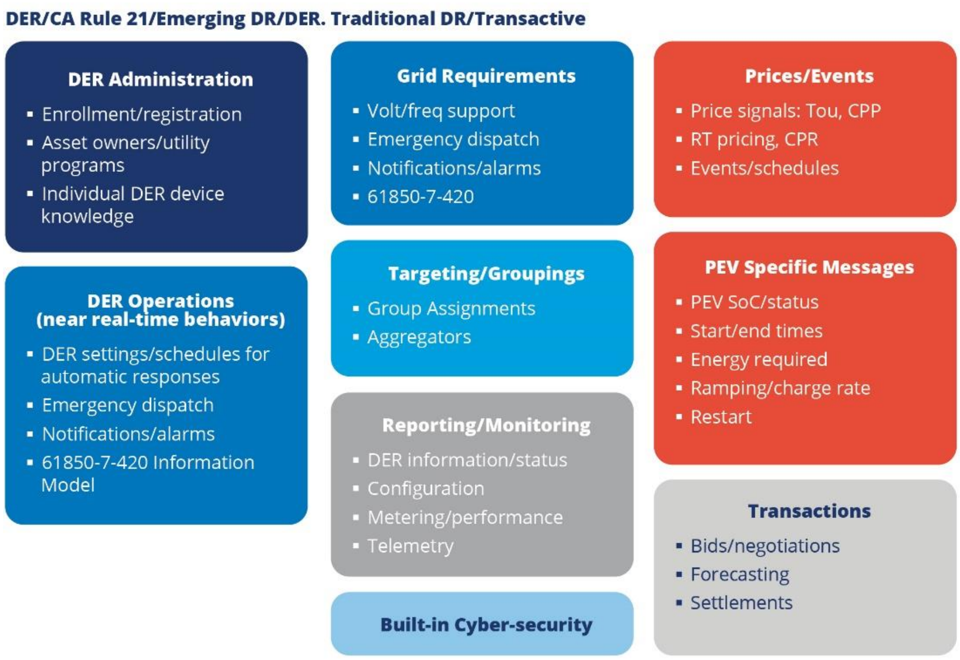

Figure 3: Summary of DR and DER Message Groups for V1G and V2G Applications

More detailed discussions of some of the messaging groups can be found in additional work completed for the OpenADR-EPRI DER Workshop. [13] The EV messaging group has been developed by the authors of this paper. For the example EV Use Cases considered in this paper, Fig. 4 summarizes that applicability of each messaging group to each of the Use Cases.

Messaging Buckets	1. V1G Residential	2. V1G Workplace	3. V2G AC or DC
DER Administration	■	■	■
DER Operations (near RT)			■
Targeting/Groupings	■	■	■
Reporting/Monitoring	■	■	■
PEV Specific Messaging	■	■	■
Price/Event	■	■	
Transactions	□		
Cyber-security	■	■	■

Figure 4: Use Case Messaging Requirements and Use Cases

There is some similarity between the messaging requirements for all three use cases but also some key differences. For the V1G applications (Use Cases 1 and 2), the CA Rule 21 messaging requirements do not apply in our view. This is simply the difference between bi-directional inverter-based technologies versus load only without the potential for energy or power inputs to the grid.

On the other hand, the V2G application probably does not require price signals while the V1G applications may well use them as incentives for participation along with events that signal specific grid critical requirements in addition to the TOU rates. The Rule 21 messaging does not use either prices or events to manage DERs but relies on pre-programmed behaviors in the inverters and emergency dispatch commands as needed.

There are certainly conceptual use cases that would use pricing and event signals for DER management but the selected V2G use case for this paper is constrained by the CA Rule 21 model for DER management.

We've included the Transactions Group in this paper because there are strong arguments for using some form of price negotiations between asset owners to determine which assets will respond to grid needs. California is investing significant research efforts in understanding and validating Transactive methods for managing DR and DER resources. [15] The EV applications are ideal for such methods of determining asset utilization for grid requirements. In Fig. 4, Transactions are an open box because there is no application requirement yet for this function group.

5 Leading EV Messaging Protocols

The protocols considered in this paper are only open standards and include:

1. OpenADR: (Open Automated Demand Response) protocol was developed in California but has been adopted as an IEC standard and is used in Japan, Korea, the U.S., Europe and elsewhere for DR program communications. It has built-in internet security and has become the leading global standard for demand response programs. The OpenADR Alliance has a robust certification program for OpenADR devices and systems. OpenADR is a popular protocol for managed charging programs where a standard utility-CNO or aggregator protocol is used. [16]
2. IEEE 2030.5 has recently been updated to incorporate the CA Rule 21 and IEEE 1547-2018 functionality in the standard. It is an application layer standard based on web services with built-in security (very similar to OpenADR) and is designed to use the modern internet for transport of its messages between devices. It is emerging as the preferred industry standard for DER communications because it is mandated in California. A network of global test labs conducts a SunSpec certification program for products sold into California which is 50% of the U.S. solar market. IEEE 2030.5 is the core messaging protocol for the SAE V2G J3072 series of standards. [17]
3. Open Charge Alliance's Open Charge Point Protocol (OCPP) is an open protocol for communications between charging points (EVSEs) and the EV charging network administrator (CNO). OCPP 1.6 includes smart charging support for load balancing. The most recent version, OCPP 2.0, includes support for ISO/IEC 15118 (among other things). Although not yet formalized as a standard and managed by a recognized standard defining organization (SDO), there is significant adoption of the OCPP protocol and efforts are underway to develop it into a full standard within the IEC. [18]
4. ISO 15118 (also referred to as "OpenV2G"), enables the managed charging functionality in an EV, such as optimized load management. More specifically, it specifies the communication between the EV and the EVSE and supports the EV authentication and authorization (also known as "Plug & Charge"), and metering and pricing messages. Version 2 is currently under review with the final version anticipated by mid-2020 that will include V2G. There is not a formal ITCA or independent certification program for the standard, but there are well defined conformance tests and available interoperability and conformance testing tools. [19]

These protocols were selected for this paper based on the research published by SEPA. [2] Fig. 5 shows the current adoption of the protocols by CNOs. Similarly, a survey of EVSE manufacturers in the same report showed the same set of protocols being adopted.

Number of Managed Charging-capable Network Service Providers by Messaging Protocol Type, U.S., 2019				
OSCP/OCPP	OPENADR 2.0	ISO/IEC 15118	API	IEEE2030.5
14	11	10	6	2

Figure 5: CNO Protocol Adoption for V1G Managed Charging Applications as of 2019 [20]

Fig. 6 illustrates the communications segments for EV management that each protocol addresses.

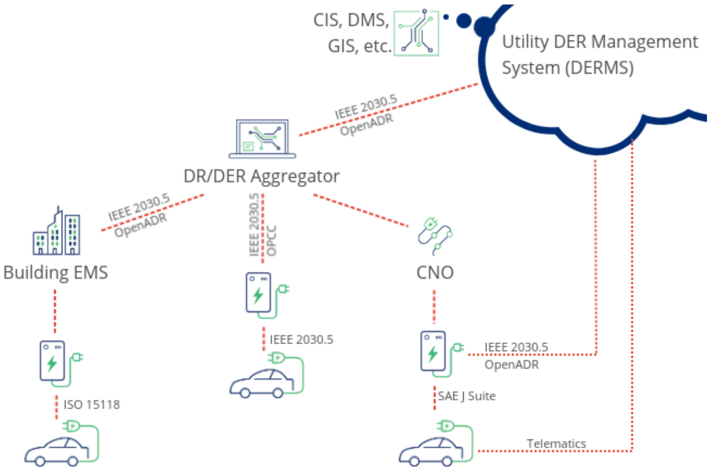

Figure 6: Relationship Between Leading Standard EV Messaging Protocols

The landscape for communications protocols for EV management by grid operators is rapidly evolving. Each of the protocols continues to see increasing adoption and the SDOs/ITCAs continue to evolve the standards and certification programs for the standards. Protocol selection is challenging today and will remain so for several years in our view.

6 Guidelines for Selecting a Messaging Protocol

The selection of the right protocol for an EV application can be informed using two analytical processes:

1. The capabilities of potential messaging protocols compared to the messaging requirements for the application, and
2. Consideration of multiple other factors and implications of a specific protocol selection.

6.1 Selecting the Right EV Messaging Protocols

This paper's methodology for evaluating and selecting the messaging protocol looks first at the technical capabilities of a protocol versus the messaging requirements for the use case under consideration. Fig. 7 summarizes the evaluation of the four selected DER protocols versus the messaging requirements for the three use cases.

	1. OpenADR	2. IEEE 2030.5	3. OCPP	4. ISO 15118
DER Administration	■	■	2 Protocols	2 Protocols
DER Operations (near RT)	⊘	■	⊘	⊘
Targeting/Groupings	■	■	⊘	2 Protocols
Reporting/Monitoring	■	■	2 Protocols	2 Protocols
PEV Specific Messaging	■	■	⊘	2 Protocols
Price/Event	■	■	⊘	2 Protocols
Transactions	⊘	⊘	⊘	⊘
Cyber-security	■	■		

Figure 7: Summary of Use Case Messaging Requirements and Protocol Capabilities

The state of each protocol maturity is constantly evolving so this is just a snapshot. For instance, OpenADR recently published a DER Addendum [15] that profiles the standard to support many of the CA Rule 21 messages. However, to date, there are not actual implementations, testing or certification based on the Addendum.

It is critical to understand the current eco-system in terms of improvements and initiatives underway and the timeframes in which these goes into effect. Consider the impact of regulation in California. In California new requirements were made for smart inverters and IEEE 2030.5 was identified as the default protocol. In response, IEEE 2030.5 (and other protocols) were updated in meet these new requirements. Another example, aggregation of DER (including EVs) and transactive energy are two popular topics. Standards groups are currently evaluating their protocols for gaps against these new paradigms and are updating them accordingly.

6.2 Other Factors in Protocol Selection

While it is necessary for a messaging protocol to technically support the messages for a use case, it is not sufficient. First example, product availability. IEEE 2030.5 technically supports price signals for demand response but only a handful of vendors worldwide have developed DR applications using IEEE 2030.5. It could be deployed for DR but would either require significant industry investment to achieve a robust interoperable eco-system or the use case implementations would probably not be consistent (or interoperable) from one utility to another and one vendor to another. Second example, certification. The new DNP3 AN-2019 provides a technical specification for communicating the required CA Rule 21 inverter curves and settings over IEEE 1815/DNP3. Manufacturers support this in their DER today but there is not a current certification program to ensure interoperability. These systems communicate with each other without certification; however, certification reduces interoperability issues caused by misunderstandings in standard terminology, which materialize as delays or change-orders when they are discovered mid-project.

The factors to be considered in protocol selection include:

- **Maturity of Protocol Ecosystem:** An eco-system is the collection of devices, systems, programs, and stakeholders that touch a protocol. A protocol may be a perfect match for an application; however, mature ecosystems are often synonymous with lower costs and expedited timelines compared to less mature ecosystems. Less mature ecosystems may offer promises of cost, time, and capabilities; however, they may not have been widely proven in the field. Example factors include:
    - **Product Availability:** Implementing a protocol means the protocol must be supported by EVs, EVSEs, and associated management systems. If little to no technologies and vendors support the protocol (including devices or control systems) then additional R&D or costs may be required for products to be available in time for a utility program.
    - **Conformity Assessment Tools:** Even though protocols may be robust, there is always room for misinterpretation or vague language. Tools and processes to validate that EVs, EVSEs, and associated management systems can facilitate this.
    - **Industry Experience:** The more stakeholders have experience with the protocol, the more likely interoperability will occur at interconnection. Maturity in this factor includes individuals with experience across utilities, aggregators, manufacturers, consultants, and other stakeholders.
    - **Use-Cases Understood**: The protocol requirements to implement a specific application (variants of V2G and V1G) vary. Application specific profiles (e.g. CA Rule 21) narrow down the complexity of implementation by providing guidance on how to implement programs consistently so that products can be made to support them.
    - **Certification Program(s)**: These are critical to ensuring that vendors implement the protocol consistently for the applications certified. For instance, the new SunSpec CSIP IEEE 2030.5 program is in full swing for advanced CA Rule 21 communications requirements, but OpenADR, while it has published an Addendum for use in DER management, does not yet have a test and certification program to support it.
- **Mandates/Adoption:** Protocols are adopted based on natural industry adoption but outside motivators like mandates can nudge the industry in a specific direction. A couple examples, include:
    - CA Rule 21 sets IEEE 2030.5 as the default protocol for grid supportive DER. Technology providers are accelerating their implementation of IEEE 2030.5 in response to this.
    - Washington State Legislature - HB 1444 requires all water heaters to have a CTA-2045 port. This will likely lead to an increase in the number of manufacturers who support CTA-2045.
- **Cyber-Security:** Any time connectivity is added to a system or device, the security of the asset and associated data needs to be considered. Different protocols support different cyber-security

capabilities. For instance, IEEE 2030.5 and OpenADR both include cyber-security in the standard while IEC 61850 and DNP3 rely on separate cyber-security standards.

- **Internal Factors:** Adopting new protocols can be an expensive and time-consuming endeavour. It is natural that EV/EVSE manufacturers, utilities, and management system providers will gravitate to protocols they have the most experience in or already have on their roadmaps.
- **Applications Addressed:** While a protocol may be a good technical and business match for a specific use case application, consideration should be given to other DR/DER use cases that are likely to be implemented. The fewer protocols required to address the anticipated DER use cases, the less time and expense will be involved in implementing them.

The analysis of the protocols requires investigation into the details of the protocol ecosystems. The typical starting point is the industry alliance for the protocol, if there is one. But knowledgeable independent sources should be consulted to ensure that vendor or alliance bias are understood and an accurate assessment is made.

7 Summary and Conclusions

The methodology in this paper provides a process for evaluating an EV VGI use case and identifying the appropriate protocol for it. The primary considerations are the technical messaging requirements, but a set of other considerations is discussed.

The VGI industry is in its infancy and the standardization of the messaging protocols between distribution utilities and the EV communications infrastructure will be critical to incorporating the capabilities of EVs into effective grid operations management.

References

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[2] See for instance, "*A Comprehensive Guide to Electric Vehicle Managed Charging*", May 2019, Smart Electric Power Alliance.

[3] See report, "*DERMS Requirements*", February 2019, Smart Electric Power Alliance.

[4] See for instance, *"Motion of the California Energy Storage Alliance to Establish a Sub-Group and Schedule Joint Workshop in Rulemaking 17-07-007 and 18-12-006 to Introduce Sub-Group Proposal on Mobile Inverter Technical Requirements for Rule 21 Interconnection",* California Energy Storage Association, May 29, 2019.

[5] https://www.cpuc.ca.gov/Rule21/

[6] "*Working Group Three Final Report*", CPUC Interconnection Rulemaking R.17-07-007), June 14, 2019, CPUC Working Group 3 Final

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