EVS26
Los Angeles, California, May 6 - 9, 2012

Getting Titans to Talk: Enabling Vehicle-To-Grid Communications

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Abstract

Information Technology (IT) plays an increasing role in everyday life. IT systems have revolutionized the way we work, play and interact with one another. It is no wonder that a significant portion of companies are looking to leverage IT systems to better engage their customers. The electric industry is no exception. Many utilities are currently deploying advanced technologies such as smart meters in an effort to develop what is commonly referred to as the *smart grid*. Ultimately the smart grid will enable consumers to make informed decisions about their energy use including managing important applications such as electric vehicle charging.

Like the electric industry, automakers see value in providing their customers with the tools necessary to properly manage charging sessions. Original equipment manufacturers (OEMs) can leverage the smart grid to provide their customers with customize solutions to yield increased savings, reduced emissions through the increased use of green energy, and shorter charging times. However, these benefits will never be realized if these two titan industries (electric utilities and automotive OEMs) can agree on how to communicate. Technical standards are the key to developing the language between the two massive industries. Each entity will have to establish the systems necessary to send and receive valuable information. In addition, consumers must be protected and insured that their data will be properly managed and secure.

This white paper explores the system architecture and standards required to enable effective vehicle-to-grid communications.

Keywords: smart grid, vehicle-to-grid, standards, communications

1 Introduction

The advantages of integrating electric vehicles (EVs) with the electric grid – to consumers, the environment, and national security – are well documented to the point that even though EV production is in the early stages with only a few models available, both local and national bodies have already implemented or are currently developing incentives and guidelines to advance their wide-spread adoption. These policies are primarily intent on lowering costs for consumers (through rebates and tax incentives) and providers (through investment) while enabling basic services such as public and residential charging. A secondary goal for government entities and electric utilities is to explore shifting energy consumption to off-peak times through time-of-use tariffs and discrete measurement initiatives. The introduction of these EV-related policies and services has many companies, from large enterprises to small start-ups, jumping on the EV movement in the hopes of securing a piece of the expected *gold rush* generated from new services and customers.

The risks introduced by the increasing market penetration of EVs are also well documented. Utilities[1] and policy makers, though not unaware of the advantages provided by EVs, are wary of the negative impacts these potentially large loads could pose on the electric grid. In preparation of and concurrently with the policies meant to advance adoption, a vast amount of work is focused specifically on the monitoring and measurement of EVs, controlling these large loads, and facilitating communications to meet these and other advanced applications. In addition, smart grid applications require end-to-end communications if they are to function as intended, and much thought and debate has ensued about just how the various actors and devices will communicate, and what types of communication and capabilities will be supported. This paper examines the present state of EV adoption and recommends specific deployment options that can be employed by all stakeholders involved in developing an EV infrastructure for communication and control.

[1] For the purposes of this paper, the term *utility* is meant to encompass traditional vertically integrated utilities, deregulated entities for transmission and distribution, and other retail energy providers.

2 EV Communications Architecture

2.1 Overview

Utilities recognize two forms of smart grid communications in regards to EV, EVSE, and distributed device control [Figure 1]. The first is business-to-business (B2B) communications in which utilities communicate to third-party systems that in turn communicates to individual or groups of devices. This method of communication is traditionally used to connect utilities to commercial and industry (C & I) customers, and is expected to be used for the many third-party clouds and aggregation services that are becoming available. From the viewpoint of the utility this type of communications is considered indirect communication.

The second method of available to utilities is direct-to-device. This is the type of communication used with advanced metering infrastructure (AMI) technologies and for some demand response (DR) communications. Utility-direct communications could also be used to support the Home Area Network (HAN) and the HAN device deployments expected in the next few years. Direct communication facilitates the enrollment of specific devices in utility programs, while indirect communication is used for C&I and future third-party programs.

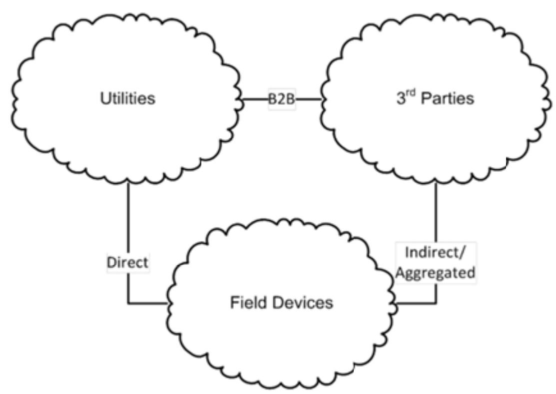

Figure 1: Smart Grid Communications Path

2.2 Indirect Utility Communication

The existing fleet of deployed EVs and EVSEs could be considered first- generation in that they have little functionality beyond SAE J1772™[2]-based charging [1], local charging management, and customer energy information display. The interfaces available to access these functionalities are also limited. For the most part, consumers must use existing or new telematics services between the original equipment manufacturers' (OEMs) back-end systems and the device. Because these telematics services are the first to hit the marketplace, OEMs are working on increasing their functionality, and it is possible that some OEMs will decide to solely implement the telematics interface on the vehicle. If that is the case, the OEMs will act as aggregators from the viewpoint of utilities, and utilities would not be able to interface directly with the EV. Instead they would have no choice but to utilize B2B communications. Telematics-based communications may make it possible for utilities to transmit EV loads wherever they are (often referred to as a component of *roaming* along with metering) and for use by third-party EV metering programs in situations where utilities are unable to access the meter directly. This type of B2B communication is currently being done to DR aggregators for automated DR purposes.

Utilities have an alternative to communicating with EVs through their back-office systems, a type of B2B service referred to as communications-to-deployed systems. This type of communications is used to send demand response (DR) signals to energy management systems (EMS) or similar systems used to control loads. Though neither of these communications approaches allows for utilities to monitor and access EVs, it is believed that both could be used for aggregation based programs.

2.3 Direct Utility Communication

A great deal of work has been done to leverage HANs so that utilities are able to access EVs, EVSEs, and other devices directly. In the HAN, these devices are typically users of the of the utility's energy services interface (ESI), which is usually the smart meter. Many ongoing AMI rollouts include HAN capabilities, and within California many of the smart grid roadmaps and pilots are precipitated by the implementation of AMI- and HAN-based communications. AMI communications typically utilize mesh and cellular networks for two-way communication between utility head end systems and the ESI. In addition to back hauling metering data, AMI infrastructure is also meant to enable communications between the deployed utility interface and customer domains. Although a premises' smart meter is most likely used as the utility interface for communications into the home, it is possible that utilities, customers, or third parties could install a secondary device in the HAN to translate lower layers of communication (e.g., ZigBee to Wi-Fi). As AMI-based communication is usually a utility secured communications channel, the utility interface could also be viewed as a firewall between the utility AMI network and the customer's energy network. Utilities in the future could also deploy a field area network (FAN) to communicate with a customer's premises. This could be similar to AMI communication in that it is a protected utility channel with higher capacity, however it would use HTTP to send HAN messages to an alternate utility interface. This FAN could be implemented as an alternative to or to compliment AMI because of the early deployment of many AMI systems and the subsequent emergence of new latency and throughput requirements related to advanced grid/EV use cases. It would probably use Wi-Fi as the means of communication.

From a utility viewpoint it is not necessary for both the EV and EVSE to employ HAN communications. The communications systems being implemented by many utilities to support HANs, EVs and EVSEs are also capable of leveraging additional utility programs and services where direct control is required. None of these HAN/device interfaces is presently enabled; therefore, it is unclear how much EV and EVSE OEMs can be expected to support these direct interfaces as opposed to indirect communication methods (in fact, it is probably more likely that the EVSE is the HAN device, and the EV does not support the HAN communications at all).

Due to the various architectures deployed and expected to be deployed, it is also envisioned that a hybrid of direct and indirect communication paths could be used to facilitate participation in utility

[2] SAE J1772 is an SAE Recommended Practice that covers the general physical, electrical, functional, and performance requirements to facilitate conductive charging of EV/PHEV vehicles.

programs. For example, if an EV or EVSE has no HAN communication, it is feasible that an OEM or other third party could provide a HAN gateway device for utilities to connect to, which could then be used to connect to a third party's back-end for indirect (e.g., telematics) communications to the end device. This third party gateway would then be a proxy for the EV or EVSE, still allowing the device to be enrolled in direct communications-based utility programs. Alternatively, third parties could provide customers with HAN devices and use indirect utility communications networks to provide EV related services (e.g. submetering).

3 Standards

3.1 The Current Status

The goal of smart grid communications is to enable consumers and utilities to monitor and control, while allowing third parties to provide value added services, all while ensuring the stability of the grid. This was originally expected to be accomplished by the standardization of the various necessary communications. However, looking at the present state of smart grid communications, it is safe to say that standardization efforts of standards bodies and regulators have not been entirely successful. Ongoing debates, whether centered on the standards' design or their presumed need, have hindered their completion and implementation to the point that it is entirely possible, if not guaranteed, that ultimately there will be multiple standards accomplishing the same purpose, as well as a mixture of standards and proprietary communication protocols used from one end of the smart grid to the other. Additionally, even though the advantages of standards for cost, implementation, and interoperability are well documented, the use of proprietary communications are based on business cases and their use and development does not necessarily mean ill intent. They will be a part of the future EV communication ecosystem.

3.2 EV/EVSE Grid Functionality

From the utility's viewpoint, EVs and EVSEs are the smart devices with the greatest potential for having a tremendous effect on the grid; therefore, developing the communications and capabilities for EVs and EVSEs is a top priority. Because many of the communication paths mentioned earlier are already planned or in place, utility-based applications for EVs and EVSEs are not meant to be implemented solely for these devices and systems. Instead, the ongoing standardization processes attempt to incorporate EV specific requirements through SAE Standards. Not all of these are applicable to utility monitoring and control, hence Table 1 provides a list of applications[3] utilities might consider necessary for the integration of EVs onto the grid, as well as information about how (and if) they could be accomplished directly or indirectly.

[3] Based on SAE J2836/1 use cases

Table 1: EV/EVSE Grid Functionality

Functionality	Description and Purpose	Direct	Indirect
Registration and enrollment	Enables security and privacy of customers, devices, and 3rd parties. Might involve enrolling in programs, registering devices, communication access, security procedures, customer privacy, etc.	Devices are registered by the utility and commissioned to communicate to the utility interface (ESI).	3rd parties are enrolled in programs (and possibly permitted by customers or utilities depending on the type of application) to offer EV-related services, access customer data, and communicate to and/or control devices.
Load Control[4]	The curtailment or throttling of EV charging could be done with the EVSE or EV. Will necessitate utility program enrollment. Probably involves prior notification and discounts for number of enrolled devices	Utilities are able to control enrolled devices or groups of devices directly. Customers would be able opt out of load control instances, but may incur a penalty.	Instead of communicating directly to devices, utilities communicate to 3rd party systems (e.g., shed this amount of load) that then communicate to devices. Programs and penalties for non-compliance would be attributed to 3rd parties.
Pricing	Involves the publication of prices (time-of-use, real time, critical peak, etc.) in order to move charging to a more favorable time. Could be done annually, seasonally, daily, etc.	Devices would use pricing information supplied by utilities to make decisions about charging. For certain programs (e.g., Critical Peak), penalties might apply to customers for noncompliance.	3rd parties would supply utility pricing information to devices. Programs and penalties for non-compliance would be attributed to the 3rd parties
Discrete Measurement	Used for utility billing and to enable EV time-of-use tariffs or program compliance.	EV meters would be read using utility communication systems	3rd parties would supply utilities with EV metrology.
Charging Management[5]	Utility enabled charging negotiation based on many factors that could include grid status (e.g., frequency regulation), rate requested, pricing information, source of energy (green or not), timing, amount, etc.	Similar to pricing, but would probably be solely for use by devices based on customer preferences	3rd parties could use utility provided information to control charging

[4] Though subjective, the author has used the term *Load Control* instead of *Demand Response,* which often includes pricing
[5] Considered to be an *advanced* use case. It is still unclear what utility functionality this may end up including

3.3 Utility Applications

The standards[6] suggested in Figure 2 were selected for many reasons. First, they either are or will be available shortly. Second, they are able to fulfill the application requirements detailed in Table 1. Third, they are consensus-based standards with the backing and support of a large part of the industry including utilities and OEMs. Lastly, they meet the unique requirements of both direct and indirect communications.

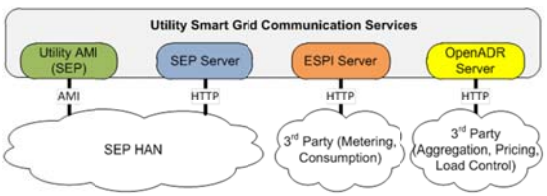

Figure 2: Utility Smart Grid Communications

For direct communication utilities would most likely utilize the Smart Energy Protocol (SEP) over the AMI and/or the alternate FAN (using HTTP). SEP has its critics, but it is the only complete HAN protocol around, and is based off of HAN requirements originally supplied by utilities [2]. There are two versions of SEP (1.X and 2.0) that are not interoperable with each other. The decision on which to deploy, if not already made, would depend on many factors. It is important to note that SEP 2.0 has used SAE requirements to develop many of its EV-related capabilities. SEP2 was developed using open IP based Internet standards, includes specific EV information as well as distributed energy functions (DER), has open standards-based security, and can run on multiple PHY/MAC layer protocols (1.X is only for ZigBee). SEP 2.0 is expected to be completed in Q4 of 2012.

Two standards are suggested for indirect communication in order to meet all of the EV/grid functional requirements. Like SEP, the Energy Service Provider Interface (ESPI) and OpenADR are based on utility requirements [3]. ESPI 1.0 is limited for EV applications in that it only provides customers and third parties (with the customer's permission) consumption information. In California though, it is being proposed for use with third party/customer owned submeters to communicate EV metrology back to the utilities (as opposed to using utility secured direct communication channels). Requirements for a second version of ESPI are presently being determined. Many utilities use OpenADR 1.0 for automated demand response services to third parties (e.g., commercial industries, aggregators, etc.). It includes both pricing and load control. OpenADR 2.0 is in development; it differs from 1.0 by being based off of multiple standards, and by including testing, certification, and expanded capabilities [4]. Though not shown in the diagram above, it is possible to use SEP for indirect communication and OpenADR for direct communication. For the purposes of this paper, and to better allow for the integration of 3rd party services, it is suggested that alignment on the use of these standards (at least for EV-related services) be consensus based to the maximum extent possible.

4 Conclusion: Harmonization, Translation, and the Future

Unfortunately, implementing the utility communications methods described in this paper is difficult and more costly due to the fact that application translation could be necessary in both direct and indirect communication scenarios. Because SEP 1.0 and 2.0 are not interoperable and because both may be present in the HAN or the utility is speaking a different version of SEP than the device acquired by the consumer, employing direct communication might require a translation gateway to accommodate all SEP devices. Due to the fact that utilities will do their best to ensure consumers are aware of which devices are interoperable with their HAN, direct communication is not as susceptible to this problem as indirect communication.

Though SEP would be recommended for third party communication and control of installed devices in the HAN, it's possible that many will use their own proprietary protocols. With the proliferation of third party clouds and proprietary communication, it would be impossible for utilities to support all of them; therefore, 3rd parties will need to translate the utility communications into their own formats. With OpenADR and commercial applications, successful translation has been possible for quite some time, with the commercial and industry EMSs being able to translate the OpenADR signal into the building

[6] The descriptions provided are solely intended to give an overview of the functionality provided by the standards.

protocol. New applications and actors such as EV aggregators must have the same capability, but will probably not replace application gateways such as EMSs at the premises being used by commercial entities; therefore, it is expected that this type of indirect translation will have to be done in 3rd party back-office systems [Figure 3].

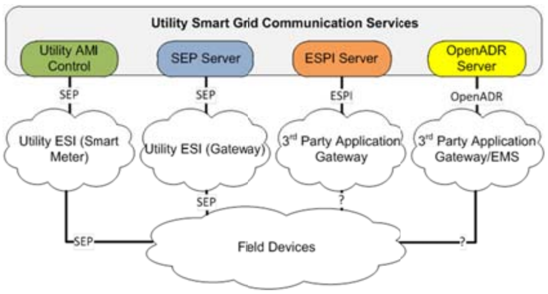

Figure 3: Grid/EV Communication with 3rd Party Integration

An example of this would be an aggregator scenario (such as an EV telematics provider), whereby a utility delivers a demand response signal to enrolled third parties. The third parties would then translate the signal into the format used by their device (e.g., SEP 2.0, proprietary, etc.), which they would then communicate on to the EV or EVSE. This sort of utility signaling, translation, and third-party signaling is expected to be very common in future smart grid applications.

Of course, third parties will have to bear the cost of translation, some of which will probably get passed down to consumers. There are two practical recommendations for making translation simpler and more cost effective. First, if they meet third-party business needs, use the three standards suggested [Figure 4]. Efforts to harmonize SEP 2.0 and OpenADR 2.0[7] are already underway. It is also possible that future versions of ESPI and OpenADR will have overlapping functionalities with only one being necessary to meet indirect communication needs. This model could possibly allow for third-party business practices, while also mitigating the risks of stranded assets. Should they not meet the business needs of a third party, participation in the standardization process is recommended to ensure they will in the future.

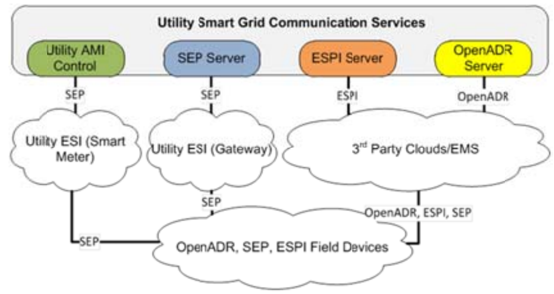

Figure 4: The Standardized Approach

The second suggestion is to harmonize proprietary communications with the three standards. Though this may not be nearly as desirable as the first recommendation, achieving closer one-to-one mapping will result in easier, quicker, and less costly translations, especially if these functions exist in consumer devices. It has been suggested that using standards is one of the safest approaches to protecting investments in a rapidly changing technology environment [5].

[7] Both SEP and ESPI are profiles of the IEC Common Information Model (CIM), while the OpenADR Task Force is actively working with the SEP 2.0 working group on harmonization

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