SAE International®

SURFACE VEHICLE INFORMATION REPORT

SAE J2931/1 JAN2012

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Digital Communications for Plug-in Electric Vehicles

RATIONALE

This SAE Information Report is intended to provide a common set of requirements, including testing and certification guidance, in order to ensure interoperability and compatibility between PEVs, EVSEs, Home Area Networks (HANs) and Advanced Metering Infrastructure manufactured and deployed by various different parties.

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1. SCOPE

This SAE Information Report SAE J2931 establishes the requirements for digital communication between Plug-In Vehicles (PEV), the Electric Vehicle Supply Equipment (EVSE) and the utility or service provider, Energy Services Interface (ESI), Advanced Metering Infrastructure (AMI) and Home Area Network (HAN).

This is the first version of this document and completes the step 1 effort that captures the initial objectives of the SAE task force. The intent of step 1 was to record as much information on “what we think works” and publish. The effort continues however, to step 2 that allows public review for additional comments and viewpoints, while the task force also continues additional testing and early implementation. Results of the step 2 effort will then be incorporated into updates of this document and lead to a republished version.

The SAE J2931 family of documents has been organized into several “slash” subsections:

This document, SAE J2931/1, defines architecture and general requirements including association, registration, security, and HAN requirements, as well as mapping to other SAE documents.

SAE J2931/2 is under development and is proposed to define a MAC & PHY layer implementation of digital communications using FSK and the SAE J1772™ Pilot wire.

SAE J2931/3 is under development and is proposed to define a MAC & PHY layer implementation of digital communications using NB OFDM and either the SAE J1772™ Pilot wire or mains.

SAE J2931/4 is under development and is proposed to define a MAC & PHY layer implementation of digital communications using BB OFDM and either the SAE J1772™ Pilot wire or mains.

Testing and validation of the aforementioned physical layer specifications is ongoing, and it is possible that the results of said testing may preclude one or more of the proposed solutions as unable to meet the technical requirements. Reduction of the available options to a single, worldwide standard remains the long-term goal.

The document mapping of the PEV communication standards are further defined in section 4.

1.1 Purpose

The purpose of J2931 is to define the digital communications interface between the PEV and an off-board device to which it communicates. Such off-board devices may include one or more of an EVSE, DC charger, Home Area Network (HAN), AMI meter, etc.:

- To provide a safe electric energy transfer
- To interact with energy providers in a secure manner
- To communicate information to the customer on the transaction

In this regard, J2931 serves to complement SAE J1772™, which describes the analog communication between the Electric Vehicle Supply Equipment (EVSE) and the PEV. The Use Cases for communications between a PEV and the utility or service provider are described in SAE J2836™ with the functional message details included in SAE J2847.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

2.2 Related Publications (Optional)

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

J1772™ SAE Electric Vehicle Conductive Charge Coupler (Surface Vehicle Recommended Practice).

J2836/1™ Use Cases for Communication between Plug-in Vehicles and the Utility Grid (Surface Vehicle Information Report).

J2836/2™ Use Cases for Communication between Plug-in Vehicles and the Supply Equipment (EVSE) (Surface Vehicle Information Report).

J2836/3™ Use Cases for Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow (Surface Vehicle Information Report).

J2836/4™ Use Cases for Diagnostic Communication for Plug-in Vehicles (Surface Vehicle Information Report).

J2836/5™ Use Cases for Communication between Plug-in Vehicles and their customers (Surface Vehicle Information Report).

J2847/1 Communication between Plug-in Vehicles and the Utility Grid (Surface Vehicle Recommended Practice).

J2847/2 Communication between Plug-in Vehicles and the Supply Equipment (EVSE) (Surface Vehicle Recommended Practice).

J2847/3 Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow (Surface Vehicle Recommended Practice).

J2847/4™ Diagnostic Communication for Plug-in Vehicles (Surface Vehicle Recommended Practice).

J2847/5™ Communication between Plug-in Vehicles and their customers (Surface Vehicle Recommended Practice).

J2894 Power Quality Requirements for Plug-In Electric Vehicle Chargers (Surface Vehicle Recommended Practice).

2.2.1 SAE PUBLICATIONS

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

2.2.2 OTHER PUBLICATIONS

Other publications may be found at:

OpenHAN Task Force of the UtilityAMI Working Group under the OpenSG Subcommittee of the UCA® International Users Group

http://www.utilityami.org/docs/UtilityAMI%20HAN%20SRS%20-%20v1.04%20-%20080819-1.pdf

ZigBee - Smart Energy

http://zigbee.org/Markets/ZigBeeSmartEnergy/ZigBeeSmartEnergyOverview/tabid/431/Default.aspx

3. DEFINITIONS

3.1 INBAND COMMUNICATIONS

Refers to types of communications using a digital signal modulated over the SAE J1772™ Pilot wire.

3.2 POWER LINE CARRIER (PLC)

Refers broadly to the group of communications technologies in which a modulated carrier is transmitted over AC power circuits. The same communications technologies and designs may sometimes also be applied to circuits that do not carry AC current.

3.3 PEV (PLUG-IN ELECTRIC VEHICLE)

This is the generic term used to describe any vehicle that plugs in to receive electrical energy. This includes many different classifications of vehicles, such as BEVs (Battery Electric), PHEVs (Plug-in Hybrid Electric), E-REV (Extended-Range Electric), and so on.

3.4 EVSE (ELECTRIC VEHICLE SUPPLY EQUIPMENT)

This is the generic term used to describe the device that is physically connected and provides energy to the vehicle. EVSEs may take several physical forms, and their logical function may likewise differ substantially. Physical forms include a mobile cordset used for 120VAC charging, a fixed or wall-mounted 240VAC charger, or an off-board DC charger. In terms of logical function, any EVSE may or may not include one or more of the following: a “gateway” or physical layer bridge function to bridge PEV communications to the HAN/AMI, a device that communicates directly with the HAN/AMI itself, etc.

3.5 ESI (ENERGY SERVICES INTERFACE)

An ESI provides a particular logical function in the HAN. It is an interface which enables secure communications between authorized parties (e.g., Utility or service provider, Consumer, non-Utility or service provider Service Providers, EMS, etc.) and all commissioned HAN Devices that are registered to it. The HAN architecture allows for more than one ESI in a consumer premises. Each ESI creates an independent logical power distribution network within the premises, each with its own security. HAN Devices (e.g., EMS, internet gateway, etc.), which are active on multiple physical networks or transmission media, must have a logical separation between those networks.

3.6 EUMD (END-USE MEASUREMENT DEVICE)

This is the device that is responsible for metering of energy being transferred to a PEV, and is required for Utility or service provider programs such as special EV rates or roaming.Utility or service provider The EUMD may be either a physically discrete unit (for example, a submeter located in a branch circuit for PEV charging), or a logical function integrated into another physical device (for example, the EUMD logical function may be built into an EVSE or the EV). The EUMD is typically (but not necessarily) owned, certified, and implemented at the discretion of the local utility or service provider or energy distributor and may be subject to regulatory control.

3.7 HAN (HOME AREA NETWORK)

Refers to the network inside a residence that is usually owned, controlled and or managed by the home owner. A residence includes houses, apartments and other types of premise. Energy-related devices may use this network in the residence and may share the medium with other devices or networks. Examples of such devices include, but are not limited to appliances, displays, thermostats, etc. A PEV or EVSE may also be considered a HAN device, if it is capable of communicating with other devices in the network.

3.8 EMS (ENERGY MANAGEMENT SYSTEM)

An application used for controlling multiple energy-controllable devices (e.g., pool pump, programmable communicating thermostat, light switches, PEV charging, etc.). This application may reside within a HAN Device (e.g., programmable communicating thermostat, in-home display, computer, cable set-top box, other computing device, etc.). This application may also control other devices or systems in the home providing integrated automated services for the consumer.

It may be owned and operated by the home/premise owner, utility or service provider, or other party.

4. DOCUMENT MAPPING

4.1 Summary

SAE has published multiple documents relating to PEVs and vehicle-to-grid interfaces. The purpose of this section is to describe the content within and relationships between the various documents, and examples of how to apply them to various scenarios. Existing document series are listed below, with a brief explanation of each.

SAE J1772™ - Defines the physical interface and coupler requirements for PEVs.

SAE J2836™ - General Requirements and Use Cases. This document is divided into several sections. SAE J2836/1™ is for Utility/Smart Grid messaging, SAE J2836/2™ is for DC Charge Control, SAE J2836/3™ is for Reverse Energy Flow. SAE J2836/4™ is for Diagnostics. SAE J2836/5™ is for Consumer Requirements and the HAN.

SAE J2847 - Functional Messaging Requirements. This document defines the functional messages required for a given function. This document is divided into several sections that correspond to SAE J2836 above. SAE J2847/1 is for Utility/Smart Grid messaging, SAE J2847/2 is for DC Charge Control, SAE J2847/3 is for Reverse Energy Flow. SAE J2847/4 is for Diagnostics. SAE J2847/5 is for Consumer Requirements.

SAE J2931 - Digital Communications for PEVs. This series of documents defines the requirements to enable digital communications for PEVs. It is divided into several sections. SAE J2931/1 describes overall General requirements, while each subsequent document is proposed to define a different possible MAC/PHY layer spec. SAE J2931/2 is proposed to define an FSK-based MAC/PHY, J2931/3 proposed to define a G3-PLC based MAC/PHY, and SAE J2931/4 proposed to define a HomePlug GreenPHY based MAC/PHY. Testing and validation of the aforementioned physical layer specifications is ongoing, and it is possible that the results of said testing may preclude one or more of the proposed solutions as unable to meet the technical requirements. Reduction of the available options to a single, worldwide standard remains the long-term goal.

The examples in the next section are to provide a clear overview of which specifications are applicable to different architectural and functional scenarios. Note that the scenarios described below are not mutually exclusive, and may be combined. For example, it is possible to implement utility or service provider programs using Smart Energy Protocol 2.0 (SEP 2.0) together with DC Energy Transfer.

4.2 Example - Utility or service provider Programs Using SEP2.0

- SAE J2836/1 defines the Use Cases for utility or service provider programs (U1 through U5) and system architecture.
- SAE J2847/1 defines the functional messaging between the PEV and the Energy Management System (such as an AMI meter, premise-based charge controller, etc) and communication protocol stack information.
- SAE J1772 defines the physical interface and connector requirements.
- Digital Communications interface:
    - SAE J2931/1 defines general communications requirements.
    - The MAC/PHY layer used for communication is defined by a subsequent section of SAE J2931, such as SAE J2931/2, /3 or /4. Harmonization and testing efforts with respect to these sections and technologies is ongoing.

4.3 Example - DC Energy Transfer

- SAE J2836/2 defines the architectural requirements for DC energy transfer.
- SAE J2847/2 defines the functional messaging between the PEV and the off-board DC charger, and communication protocol stack information.
- SAE J1772 defines the physical interface and connector requirements.
- Digital Communications interface:
    - SAE J2931/1 defines general communications requirements.
    - The MAC/PHY layer used for communication is defined by a subsequent section of SAE J2931, such as SAE J2931/2, /3 or /4. Harmonization and testing efforts with respect to these sections and technologies is ongoing.

4.4 Example - Reverse Power Flow

- SAE J2836/3 defines the architectural requirements for reverse power flow.
- SAE J2847/3 defines the functional messaging required for reverse power flow, and communication protocol stack information.
- SAE J1772 defines the physical interface and connector requirements.
- Digital Communications interface:
    - SAE J2931/1 defines general communications requirements.
    - The MAC/PHY layer used for communication is defined by a subsequent section of SAE J2931, such as SAE J2931/2, /3 or /4. Harmonization and testing efforts with respect to these sections and technologies is ongoing.

5. REQUIREMENTS

5.1 High-Level Requirements

The following is a set of high level requirements that shall be met:

- Use the existing charging Infrastructure i.e., SAE J1772™
- Enable both public and residential charging
- Accommodate both AC and DC charging methods
- Interact with Energy Providers to optimize energy transfer at the lowest energy cost
- Provide a single interoperable standard to assure compatible systems. Global Acceptance is desired
- Communicate with customer
- Minimal customer interaction
- Requirements should provide expansion capabilities and headroom
- The selected vehicle communications technology must provide reliable communications in typical residential and commercial environments. These environments may include multiple devices, operating using multiple communications technologies, sharing a medium and therefore drive the need to consider both compatibility of technologies as well as potential interoperability

5.2 Assumptions

The following are assumed:

- Home Area Networks will use a variety of different physical communication interfaces and protocols.
- The communication interface for receiving energy information is known as the ESI. The ESI is defined in the OpenHAN SRS version 2.0. The ESI may host various PEV resources important in managing PEV interactions with energy information. The PEV may "register" with the ESI for a charging session and may request and receive charging session information. In a typical home setting, the ESI may be the premise's Smart Meter as well as other forms (e.g., EVSE, Internet gateway, PEV-hosted).
- An Energy Management System (EMS) if utilized may provide a gateway between the Utility or service provider HAN and the Consumer HAN and the Internet.
- A PEV can implement all of the anticipated functionality.
- If an intelligent PEV is connected to an Intelligent EVSE, the control can be taken over by the PEV.
- EVSE may control the charging of the PEV but may be limited in functionality. E.g., it has no knowledge of PEV’s state of charge.
- A method is required to correctly measure energy consumption of an individual PEV (e.g., for tax credits, special tariffs). This requires that a physical and logical relationship be established between a PEV, the EUMD measuring its consumption, and the premise's electrical meter such that the PEV's consumption be calculated separately from the premise's consumption. This relationship is further defined in this document.

5.3 Existing Charging Infrastructure

The conductive charging Infrastructure is defined in SAE J1772™. The EVSE safely provides power to the PEV. SAE J1772™ covers vehicle charging with both AC and DC current and defines three different power/voltage levels for each.

- AC Level 1 uses of 120V and the EVSE (typically a mobile cordset type) is normally part of the cable between the Electric Vehicle and a 15A outlet.

- AC Levels 2 & 3 and DC Levels 1, 2, & 3 have the EVSE permanently mounted at the charging location.

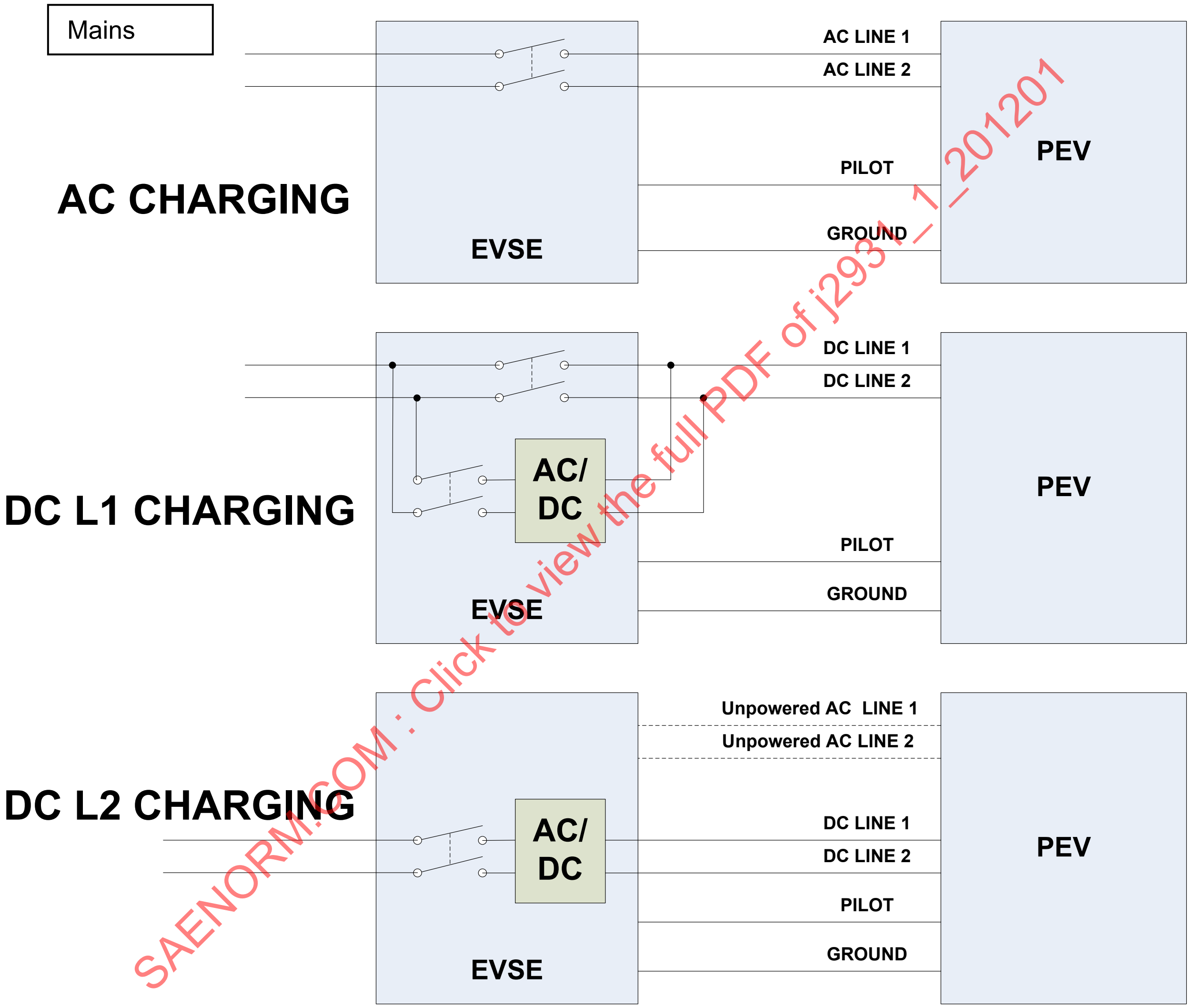

FIGURE 1 - CHARGING INFRASTRUCTURE

Notes for Figure 1:

- The Pilot shares the system ground return circuit.

- If the communications medium between the PEV and the EVSE (or HAN), is not wireless, there are two possible wired connections: the Mains (in case of AC or DC L1/L2) and the Pilot wire, which have a different set of characteristics, such as loads and interfering noise sources. The Pilot wire extends only between the PEV and the EVSE.

- There may exist other media that may play a role in the future but the primary focus of this requirement document is on PLC which is being pursued as a primary option for PEV communication

5.4 General Requirements

The Priority column as defined in HAN SRS 2.0, includes:

- B or Basic – Minimum compliance threshold (required attribute). These are requirements basic to the function or logical device. Logical devices must comply with all basic requirements to be considered Utility or service provider Basic-compliant.

- O or Optional – Suggested requirement; some utilities, service providers, or other users of the standard may require these. These are requirements that are suggested to be included for this logical device. Vendors are encouraged to include optional functionality in a logical device where appropriate or cost effective. It is possible that some Utilities may choose to include these as Basic or Enhanced requirements in their procurements.

- TBD or To Be Determined – The requirement cannot be defined at this time due to a lack of available data, pending development of future standards, requirements, etc.

Requirement ID	Requirement	Reference	Priority
Application Requirements			
RD.App.1	Support basic Utility or service provider use cases	J2836/1	Basic
RD.App.2	Support basic Utility or service provider messages	J2847/1, SEP2.0, ISO15118	Basic
RD.App.3	If DC Charging is provided, then Support off board charger use cases	J2836/2	Basic
RD.App.4	If DC Charging is provided, then Support DC messages	J2847/2, ISO15118	Basic
RD.App.5	Support Reverse Energy Flow use cases	J2836/3	TBD
RD.App.6	Support Reverse Energy Flow messages	J2847/3	TBD
RD.App.7	Support Diagnostics use cases	J2836/4	TBD
RD.App.8	Support Diagnostic messages	J2847/4	TBD
RD.App.9	Support Customer and HAN use cases	J2836/5	Optional
RD.App.10	Support Customer and HAN messages	J2847/5	Optional
RD.App.11	Utility or service provider messages and DC will use as many common components/software layers as possible and still comply with basic requirements to minimize cost		Basic
RD.App.12	Interoperate with all EVSE and EV	J2853/1, J2953/2	Basic
RD.App.13	Communication solution must not interfere with operation of existing legacy devices compliant with the current (2010) release of J1772™.	J1772	Basic
RD.App.14	Support for Multiple EUMDs, EVSEs, and ESIs on the same physical network (transformer)		Basic
RD.App.15	Support public and residential charging		Basic
Common Communication Requirements			
RD.Comm.1	The DC and Utility or service provider messages shall use the same channel or media between the EV and EVSE to minimize cost based on the different requirements		TBD
RD.Comm.2	Meet Industry EMC and Radiated RF Standards		Basic
RD.Comm.3	Full compliance with SAE licensing terms - RANZ preferred (ref is Patent Release Form-2003.pdf)		Basic

RD.Comm.4	Solution shall be automotive-qualified	AEC-Q100 for ICs and AEC-Q101 for discrete semis	Basic
RD.Comm.5	Solution shall demonstrate technological maturity proven in other general contexts.	Specific metrics TBD	TBD
RD.Comm.7	Global acceptance is desired		Optional
RD.Comm.8	Solution shall be available from multiple vendors		Basic
RD.Comm.9	Length of Cordset is defined as in SAE J1772™, with an assumed typical value of 25 feet		Basic
RD.Comm.10	Solution shall be an international standard i.e., IEEE		Basic
RD.Comm.11	Resulting standard shall select one medium and one PLC technology for communication over the cordset		Basic

5.5 Association Requirements

A HAN and neighborhood network may contain several ESIs, EUMDs and EVSEs. A PEV and cordset EVSE are not permanent members of a HAN.

An association process is used to physically and logically associate which ESI, EUMD and/or EVSE is connected to the PEV requesting a charge so that services (e.g., energy usage, billing, special EV tariffs, calculating tax or carbon credits) can be securely offered and managed.

5.6 Authentication Requirements

Once the PEV is authenticated and authorized by the correct servers in the HAN, the PEV can discover the hosts of the Smart Energy Resources (e.g., Metering, Pricing, DRLC) it supports. Depending on the physical communications media used or HAN configuration, the EUMD may make the charging session information available to associated PEVs. The functionality of the system will be determined by the availability of Smart Energy Resource servers in the HAN.

Figure 2 and 3 shows the EUMD is electrically connected between the ESI and EVSE (it may be integrated). Figure 4 shows the EUMD integrated into the EV. Although this could eliminate the need to associate, as in the above, there could be substantial regulatory hurdles to redefine a EUMD in the PEV.

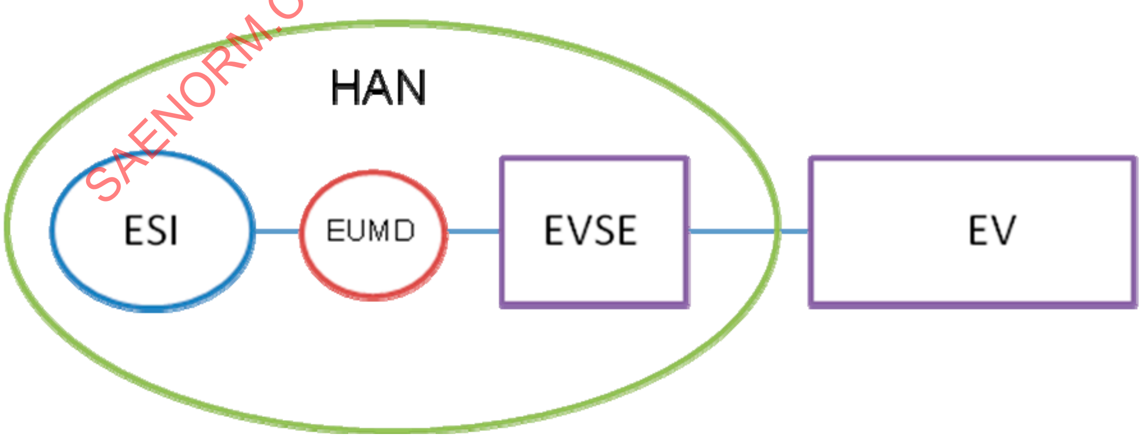

FIGURE 2 - ELECTRICAL NETWORK – HAN EUMD

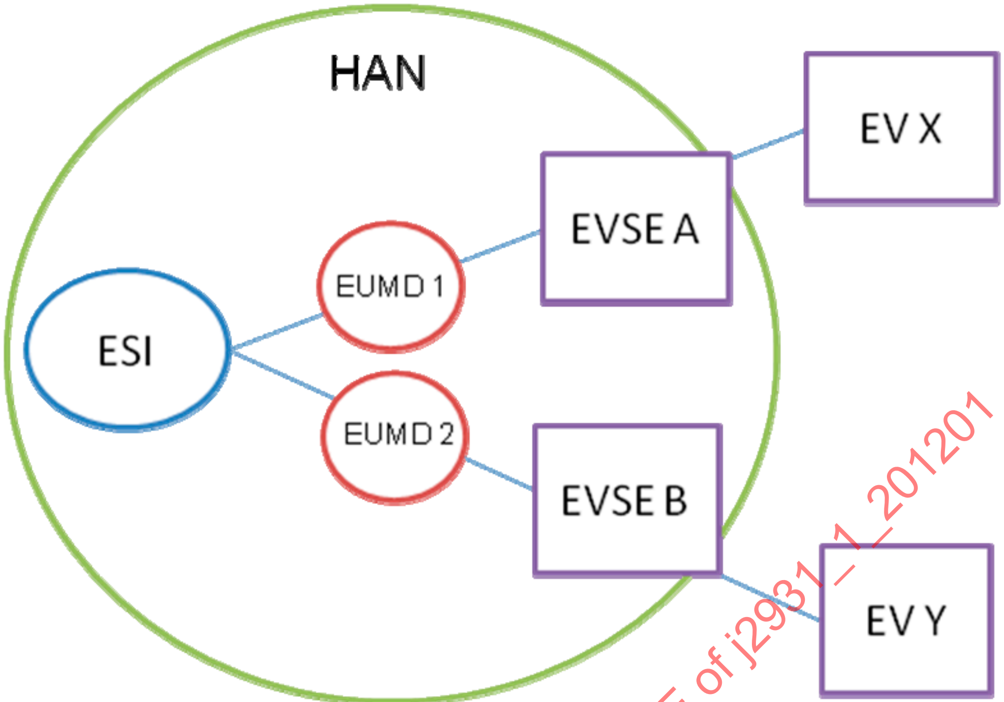

FIGURE 3 - ELECTRICAL NETWORK – MULTIPLE EVSE AND MULTIPLE EUMD

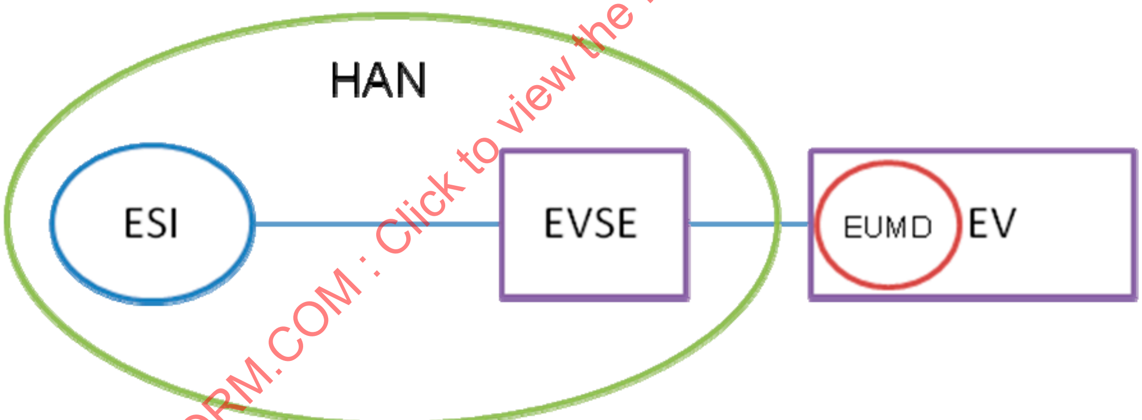

FIGURE 4 - ELECTRICAL NETWORK – PEV EUMD

RD.UtilComm.1	Provide correct association between the PEV and Smart Energy Resource servers (e.g., Metering, Pricing, DRLC) in the same physical electrical circuit		Basic
RD.UtilComm.2	False association shall not occur from two or more twisted EVSE cordsets		Basic

5.7 The HAN and Consumer Networks

In addition to Smart Energy applications, a variety of consumer applications like the Internet, audio, and video may also be served and consumed by a variety of devices. Figure 5 shows the general layout of such a network. In some cases, a dedicated device (e.g., an EMS) may provide network bridging and routing functions to facilitate the co-existence of multiple applications on multiple consumer devices. The different scenarios that were developed by the SE2 MRD working group can be found in the Smart Energy Profile Marketing Requirements Document (MRD) (2). It should be noted that each HAN scenario has to take into account multiple neighbors on the same transformer if (PLC wired technology is used) or nearby neighbors if wireless technology is used. J2931/1 requires Smart Energy resource servers be present in order to enable PEV applications (e.g., Metering, Pricing) but does not specify requirements for other applications (e.g., Internet, audio, visual).

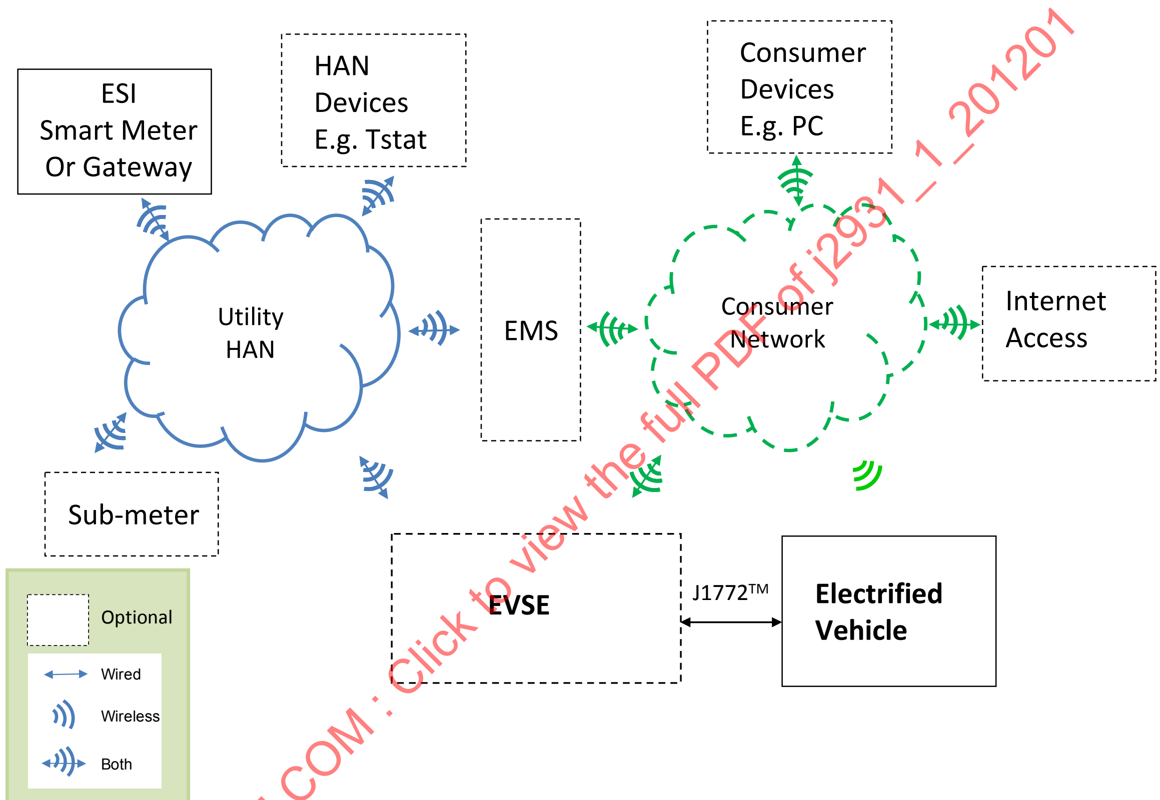

FIGURE 5 - UTILITY OR SERVICE PROVIDER/CONSUMER NETWORK

5.7.1 Communications Performance Requirements

RD.UtilComm.3	MAC/PHY throughput shall be 100kbps or greater		Basic
RD.UtilComm.4	The Utility or service provider message latency is 15 minutes max.		Basic

5.7.2 Protocol Requirements

RD.UtilComm.5	Use IPv6/HTTP1.1 and XML	SE2.0	Basic

5.7.3 Scenarios

RD.UtilComm.6	Minimum distance over which communication capability shall be maintained without intermediary devices independent of the communications medium • minimum distance for utility or service provider communications is 40 meters if using AC mains for communication • minimum distance for utility or service provider communication if using the J1772™ Pilot wire shall be based on the maximum cable length allowed by SAE J1772™	40 meters (AC mains) or As defined by SAE J1772™ (Pilot wire)	Basic
RD.UtilComm.7	Minimum number of devices that share a common communications technology, on a common network, that operate simultaneously and in proximity to the PEV that the PEV communications system must tolerate without causing the vehicle communications to fail to meet minimum bandwidth and latency requirements. Minimum device count, common network, for operation shall be 32 (typically 20)	32 (Typical 20)	TBD
RD.UtilComm.8	Minimum number of devices that share a common communications technology, on separate networks, that operate simultaneously and in proximity to the PEV that the PEV communications system must tolerate without causing the vehicle communications to fail to meet minimum bandwidth and latency requirements - minimum device count, separate network, for operation shall be 200 (typically 120). Maximum has no definable limit	200 (Typical 120)	TBD
RD.UtilComm.9	Minimum number of devices using a different communications technology but share the communications medium and that operate simultaneously and in proximity to the PEV that the PEV communications system must tolerate without causing the vehicle communications to fail to meet minimum bandwidth and latency requirements minimum device count, separate network, for operation shall be 200 (typically 120). Maximum has no limit	200 (Typical 120)	TBD
RD.UtilComm.12	Where a particular scenario has unique attributes for association • association shall correctly identify the correct EV attached to the EVSE in the presence of multiple EVSE and EV within the same premise and neighborhood networks		Basic

5.8 DC Charging / Discharging Communications

When the AC/DC converter is off board in the EVSE, then communications is required between the PEV and the converter.

RD.DCComm.1	Application Data (payload) rate is 6 Kbps or greater concurrently (full-duplex)		Basic
RD.DCComm.2	Round trip message Latency is 25ms max		Basic
RD.DCComm.3	Minimum distance over which communication capability must be maintained without intermediary devices independent of the communications medium is defined by SAE J1772™	25 feet	Basic
RD.DCComm.4	Minimum number of devices that share a common communications technology, on separate networks, that operate simultaneously and in proximity to the PEV that the PEV communications system must tolerate without causing the vehicle communications to fail to meet minimum bandwidth and latency requirements - minimum device count, separate network, for operation is 200 (typically 120) Maximum has no definable limit	200 (Typical 120)	TBD
RD.DCComm.5	Minimum number of devices using a different communications technology but share the communications medium and that operate simultaneously and in proximity to the PEV that the PEV communications system must tolerate without causing the vehicle communications to fail to meet minimum bandwidth and latency requirements minimum device count, separate network, for operation is 200 (typically 120) Maximum has no limit	200 (Typical 120)	TBD
RD.DCComm.6	If utility or service provider messages and DC charge control are combined, then a QoS mechanism must be capable of prioritizing packets and the latency requirements provided in RD.DCComm.2 and RD.UtilComm.2 must be met		Basic

5.9 Security

The PEV communication system must be secured against a number of potential threats. An attacker may attempt to:

- Avoid payment for electricity
- Gain unauthorized access to the utility or service provider's network
- Gain unauthorized access to private customer information, such as time and amount of energy use or vehicle usage logs.
- Cause physical damage to the PEV, EVSE, or electrical distribution system
- Cause denial of service – preventing the customer from being able to charge their PEV

The system must provide a level of security sufficient to prevent these threats, as well as implement a security framework with sufficient flexibility and extensibility to mitigate future threats.

RD.Sec.1	Utility or service provider messages will comply with NIST security requirements	SE2	Basic
RD.Sec.2	DC messages will comply with automotive security requirements		Basic
RD.Sec.3	DC messages will use same security as Utility or service provider Messages		TBD

5.10 Reliability

Communications reliability can be expressed as the probability that a message sent through the system will be delivered correctly to the recipient.

Reliability is the one of the most important requirements for the PEV charging system. Communication reliability can be less than 100% for several reasons. On a shared medium, noise from various sources can cause the message to be lost or unreadable. Noise can come from physical processes, other equipment, or other communications systems that are sharing the medium. Physical limitations of signal propagation, transmitter power, and receiver sensitivity limit the usable communications range. When operating near range limit, reliability will be reduced. Reliability can also be affected by imperfect compatibility between systems. Verification of proper interoperability is essential for reliable operation of communication system, especially standards-based technologies from multiple vendors.

Reliability Requirements			
RD.RelComm.1	There shall be no excessive impairment or degradation to the consumer network e.g., Multimedia distribution. Initial requirement set to 10% reduction in bandwidth maximum between two nodes on the consumer network[1]		Basic
RD.RelComm.2	Communication shall not susceptible to noise and transmissions caused by crosstalk (4-sigma value of 99.4%) from other conductors in the cordset, or from another twisted cordset		Basic
RD.RelComm.3	The technology chosen shall not cause interference to signals that may be on other conductors in the cordset, or another twisted cordset		Basic
RD.RelComm.4	Co-exist with all current physical network interfaces operating on the medium		Basic
RD.RelComm.5	Co-exist with future physical interfaces not present in the market or in development		TBD
RD.RelComm.6	Co-exist with neighbor networks on the same medium without substantial throughput degradation on consumer network or HAN		Basic
RD.RelComm.7	Shall provide connectivity to 99% of the nodes in homes		TBD

[1] The Task Force will collect additional data and refine at a later date

Reliability Requirements - continued			
RD.RelComm.8	The communication technology shall implement mitigation methods to deal with all common interferers found in home networks (Wired or Wireless), including hairdryers, holiday lights, high frequency switching power supplies, and microwave ovens.		Basic
RD.RelComm.10	Interoperability requirements as defined by SAE must interoperate with following technologies: TBD		TBD

5.11 Performance Requirements

RD.Perf.1	The time to indicate to the consumer that communications has successfully established shall be <10s		Basic
RD.Perf.2	Except in the case of DC charging, the PEV shall receive charge if no communications can be established. In the event no communications can be established, the PEV may not qualify for certain PEV rate programs.		Basic

5.12 Communication Stack

The communication stack is planned to address both the utility or service provider requirements for SEP2 messages and the out-of-band path to an off-board charger. The PHY & MAC layers implemented by the PEV and the ESI/HAN may differ, however the remaining layers are common to insure security and other aspects are according to the SEP2 criteria. Figure 6 identifies an example of how this may be accomplished. This example of a stack implementation illustrates just one of the possible architectures, and is thought to be the most common or likely architecture in a typical residential scenario. Other possible architectures may include lack of a SEP2.0-capable HAN, increased functionality in the EVSE, etc.

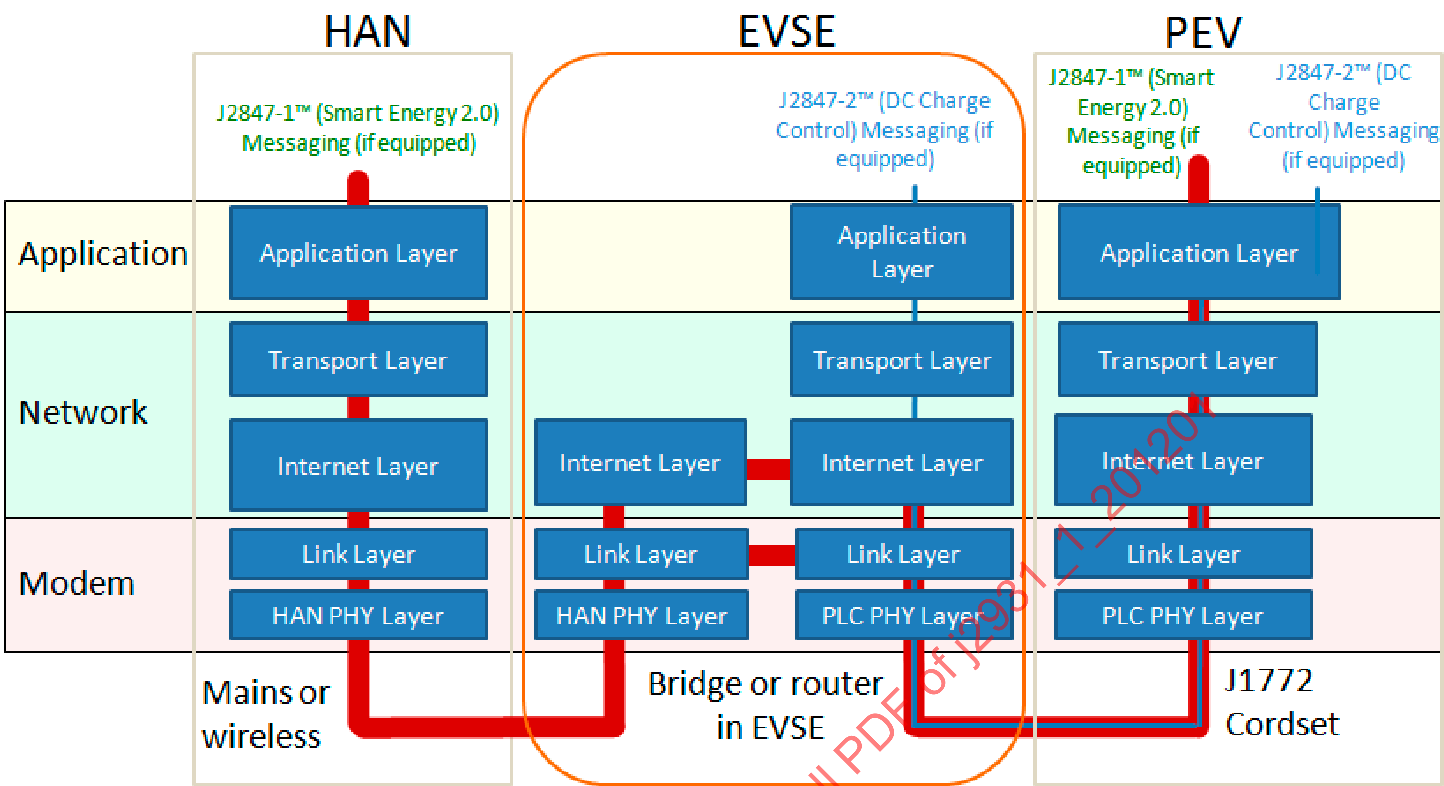

FIGURE 6 – PROPOSED COMMUNICATION STACK

6. SEP 2.0 SYSTEM ARCHITECTURE

6.1 Residential AC Charging System Architecture

Two typical Network configurations of the Residential AC Charging System are shown below. Both consist of at least one PEV, EVSE, EUMD and ESI. Device descriptions can be found in section 3, whereas logical functions are described below. In all scenarios it is assumed that if present, devices are authorized and authenticated to communicate on the network according to their function and role. Note that both the EV and the EVSE could control the Charging and respond to DR and Pricing events. In the event of the conflict, the EV will take control. The EUMD (submeter) could reside in the HAN, the EV or both.

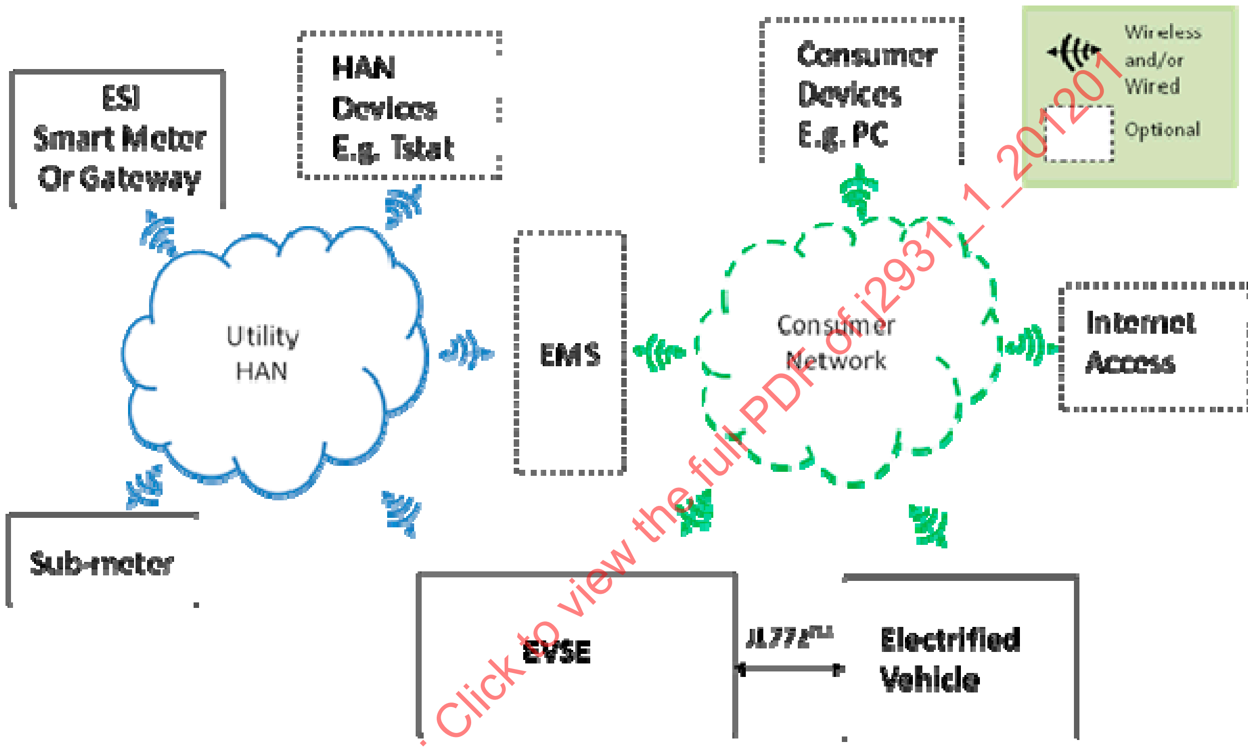

FIGURE 7 - OVERALL NETWORK SYSTEM ARCHITECTURE W/ ONE ESI, EVSE, PEV, EUMD (SUBMETER), CONSUMER NETWORK

Electrically, the Network is connected as shown in Figure 8. Note that this is different than the network configuration.

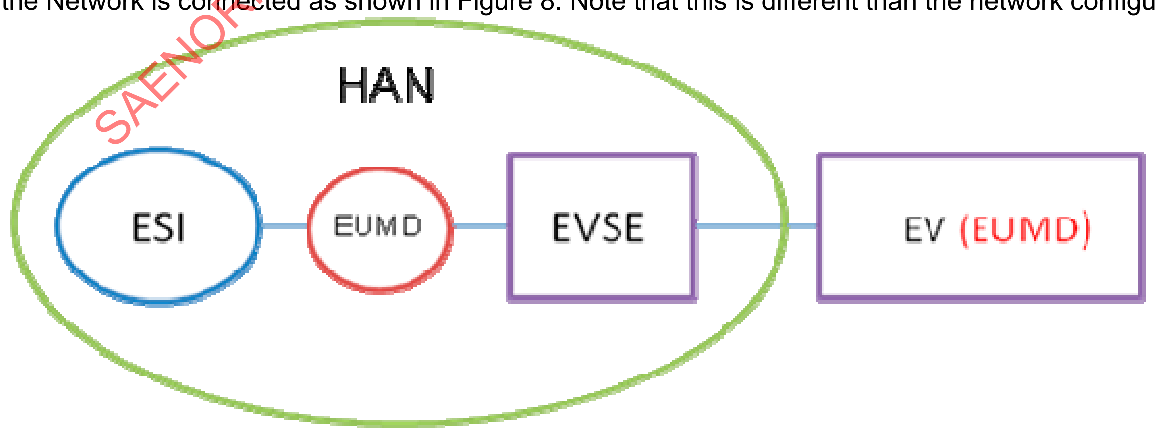

FIGURE 8 - OVERALL ELECTRICAL SYSTEM ARCHITECTURE

6.2 Device Functions and Roles

Within SEP 2.0, devices are described by the function sets and roles that they implement. A function set is a grouping of related data objects that enable a given service or desired capability and represents a network resource which facilitates a given type of transaction. The primary SEP 2.0 function sets of interest to PEVs are Metering, Pricing, Demand Response/Load Control (DRLC), and Distributed Energy Resources (DER) Control.

Roles relate to how a device interacts with other devices. Devices may be clients, servers, or both. Both function sets and roles are determined by device manufacturers, and their configuration in the HAN determines service provider program eligibility. Some devices will necessarily implement a determined function set (e.g., a submeter minimally implements the metering function), while some devices may implement more than one (e.g., a PEV may implement pricing, DRLC, and DER Control).

6.2.1 Metering

The metering function set provides information such as reading type and meter reading between HAN devices. The metering function set is necessary for some service provider programs that require separately metering the PEV energy consumption.

6.2.2 Pricing

The pricing function set provides service provider tariff structures. It is not intended to provide all the information necessary to represent a premises‘ bill but to help determine charging schedules and incentivize off-peak PEV charging. The pricing function set is designed to support a variety of tariff types:

- Flat-rate pricing
- Time-of-Use blocks
- Consumption blocks
- Hourly day-ahead pricing
- Real-time pricing
- Combinations of the above.

6.2.3 DRLC

This function set provides an interface for Demand Response and Load Control. Servers expose load control events called EndDeviceControls (EDC) to client devices. All EDC instances will expose attributes that allow devices to respond to events that are explicitly targeted at their device type. For example, an EDC may contain an Offset object indicating a degree offset to be applied by an EVSE. The EDC will also expose necessary attributes that load control client devices will need in order to process an event. These include Start Time and Duration, as well an indication on the need for randomization at the start and/or end of the event.

6.2.4 DER Control

This function set provides an interface to control Distributed Energy Resources (whereby energy is provided to and managed by the grid). PEVs, as Distributed Energy Resources (DER), are devices which utilize a Reservation for bi-directional energy transfer when load, cost, and timing are such that a simple energy transfer does not suffice.

6.2.5 Roles

The rich variety of interactions on the HAN can make it difficult to define client and server implementations that are true for all deployments. Generically, the server is the device that hosts a resource, and the client is the device that obtains, extends, updates, or deletes representations of that resource. Devices may be both clients and servers.

In keeping with a RESTful paradigm, messages (generally) are not sent to clients. Clients poll servers to obtain representations of the current state of a resource, and take action based on that state. For example, a PEV might poll a meter to obtain a representation of the metering data resource or a DRLC server to obtain the current event list. In order to reduce polling, which can be an inefficient use of resources, devices may also subscribe to a resource. When a change to a resource is made (e.g., an addition to the DRLC event list, or an update to an event's attribute), the server (notifier) will contact each client (subscriber) that is subscribed to notifications for that resource.

6.3 Feature Descriptions

The following general features may be implemented in a PEV HAN. Support for these features is determined by the service provider programs being offered and the client-server implementations available at a particular charge point. Because of the variety of functions and roles able to be implemented on devices, the tables within each section below are informative and not meant to constrain the range of possible implementations

6.3.1 PEV Tariffs

This is the ability for a service provider to provide Pricing information, potentially including special PEV tariffs. Depending on the jurisdiction and policy of the service provider, special PEV pricing information may require authentication of a PEV and presence of an EUMD to separately record the energy consumed or provided by the PEV. EVSEs may be able to proxy for the PEV to the service provide depending on its policy and the jurisdiction.

6.3.2 Demand Response

This is the ability for a PEV or EVSE to respond to service provider requests to reduce electricity demand in response to grid infrastructure constraints. The only way to know with certainty that a PEV has complied with a request is to have authentication/presence of an EUMD. A variety of service provider programs and incentives exist, but compliance with these requests is subject to EVSE and PEV owner preferences.

6.3.3 Charging Management

This is the ability to charge a vehicle based upon parameters determined by the service provider's electricity distribution infrastructure (e.g., dynamic balancing of PEV charging parameters within a circuit or on a neighborhood transformer). Without the knowledge of the PEV state of charge, a service provider may only perform basic demand response. With Distributed Energy Resource Control, the service provider may be able to more intelligently manage PEV charging parameters depending upon the PEV owner's preferences and the PEV state of charge.

6.3.4 Roaming

This is the ability to identify the PEV or its contract at the moment of charging and settle the transaction with the PEV's preferred service provider while crediting the charging spot's owner for the electricity consumed. This requires correlation of a specific PEV to a known actor in the premise able to record the charging energy (e.g., EUMD). An EVSE alone may or not be sufficient to enable this capability without additional input from the PEV owner (e.g., credit card, service provider smart card, mobile phone).

6.4 Feature Enablement and Functionality Requirements

The chart below provides the implementation capabilities and SEP 2.0 function sets required to enable the features described above. This table is not device-centric, as a variety of charging system architecture implementations can satisfy these functional requirements.

Feature/Program	PEV-to-Premise Association	Server and Client Function Set Implementations Required				
		Metering	Pricing	DRLC	DER Control	Billing
PEV Tariffs	Y	Y	Y			
Demand Response	Y	Y		Y		
Charging Management	Y	Y			Y	
Roaming	Y	Y				Y

While some subset of features/programs may be possible with lesser implementations (e.g., without premise association), PEV manufacturers and service providers will want to comply in order to meet the highest common denominator found in their market. For example, a service provider could use demand response features in PEVs if they were not associated to the premise of their charging spot during the event, but the ability to provide incentives based on performance achieved during the event is not possible without correlation to the premise. Premises association is discussed in greater detail above.

6.5 Smart Charging Implementation Design

There are three sets of sequence diagrams of primary importance in understanding basic smart charging:

- EVSE and EUMD initial setup
- PEV registration and service discovery
- Normal and repeating operations

6.5.1 Each diagram describes the steps taken, as well as the device's role for the scenario. EVSE and EUMD Initial Setup[2]

This activity diagram represents the initial setup of the EVSE and EUMD as authenticated and authorized members of the HAN. It assumes the EUMD is located between the ESI and PEV, the PEV owner has provided EVSE and PEV security materials out-of-band to the service provider, and the service provider has populated the ESI with the PEV security materials[3]. The EUMD will follow the same initial setup as the EVSE and so is not shown.

[2] This material is subject to change

[3] Security materials will be a Globally Unique Identifier (GUID). Requirements SHOULD be in place to include a GUID on these devices

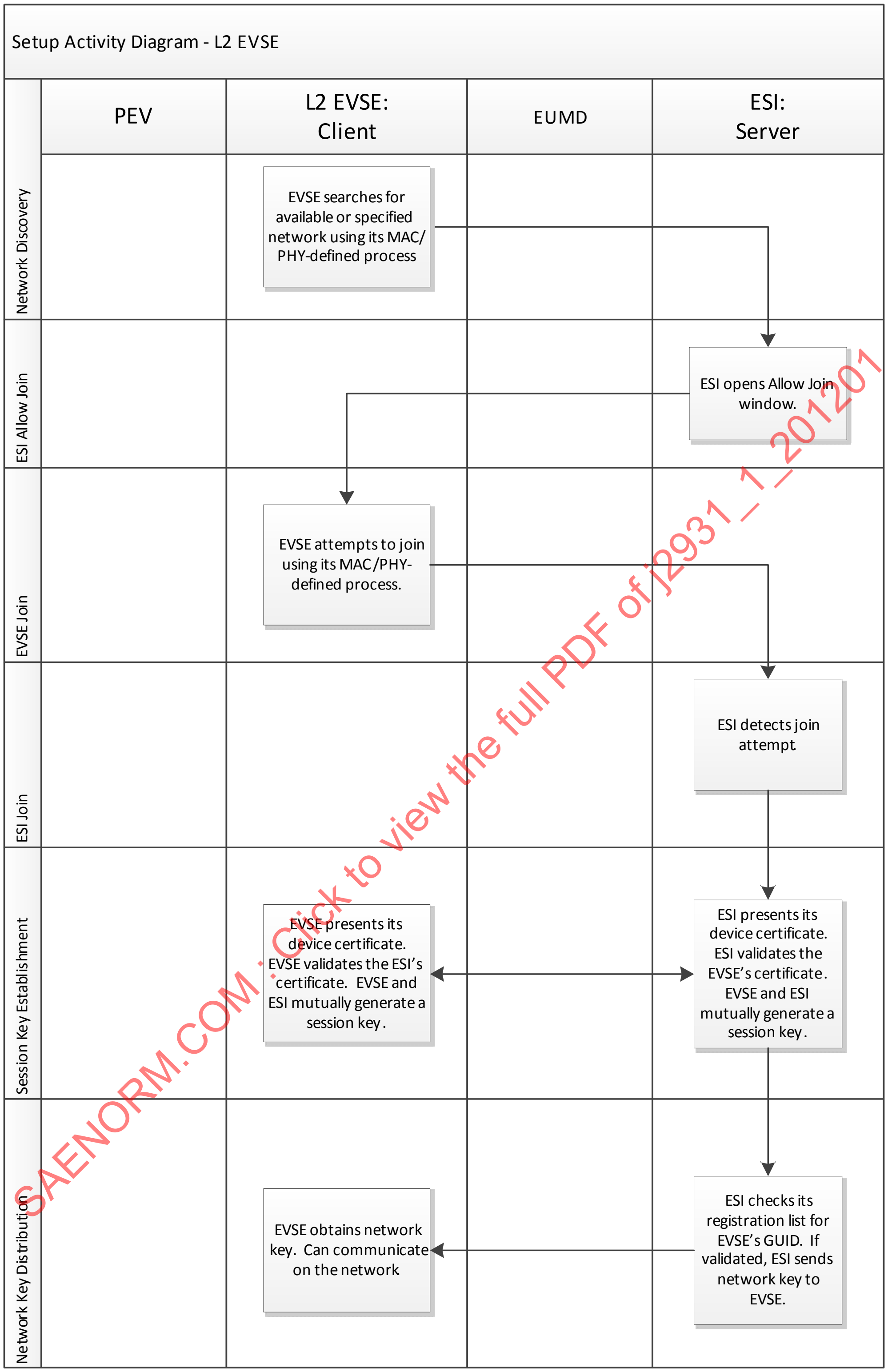

FIGURE 9 - SETUP ACTIVITY DIAGRAM - LEVEL 2 EVSE (W/ASSOCIATION)

6.5.2 Network Discovery

The Installer initiates the EVSE's network discovery functionality. The Network ID could be provided to the user by the service provider, the EVSE could scan for available ESIs allowing joining, or the EVSE could search for all available networks.

6.5.2.1 ESI Allow Join

The ESI operator configures the ESI to Allow Join (if not already done so). The ESI may be permanently configured in the Allow Join state.

6.5.2.2 EVSE Join

The EVSE attempts to proceed to the session key establishment step. There may be multiple ESIs allowing join visible to the EVSE. As such, the EVSE may require a steering mechanism (e.g., button push) or HMI (e.g., PIN input) in order ensure it joins the intended ESI.

6.5.2.3 ESI Join

ESI operator provides the PEV security materials communicated out-of-band by the Installer to the ESI's registration list. This process is out of scope for this document.

6.5.2.4 Session Key Establishment

EVSE initiates the PANA/EAP-TTLSv0 sequence with the ESI. The EVSE and ESI present their certificates to each other and validate them using the PKI to its embedded root CA certificate/public key. The ESI may also do a revocation check on EVSE's certificate (e.g., EVSE is known to the ESI operator as a bad actor and has been black listed by the ESI). The EVSE and ESI mutually negotiate a session key.

6.5.2.5 Network Key Distribution

The ESI checks the EVSE's GUID contained in its device certificate against its registration list. If there is a match, the ESI distributes the network key to the EVSE. The EVSE is now admitted to the network and can securely communicate within the network.

6.5.2.6 PEV Registration and Service Discovery

This activity diagram represents the initial and repeated setup of the PEV as an authenticated and authorized member of the HAN. It assumes the EVSE and EUMD have already joined the network, the EUMD is located anywhere between the ESI and PEV, the PEV owner has provided PEV security materials out-of-band to the service provider, and the service provider has populated the ESI with the security materials[4]. For the initial registration, the PEV will follow the same setup sequence as detailed the EVSE Setup Activity Diagram above.

4 Security materials will be a Globally Unique Identifier (GUID). Requirements SHALL be in place to include a GUID on these devices

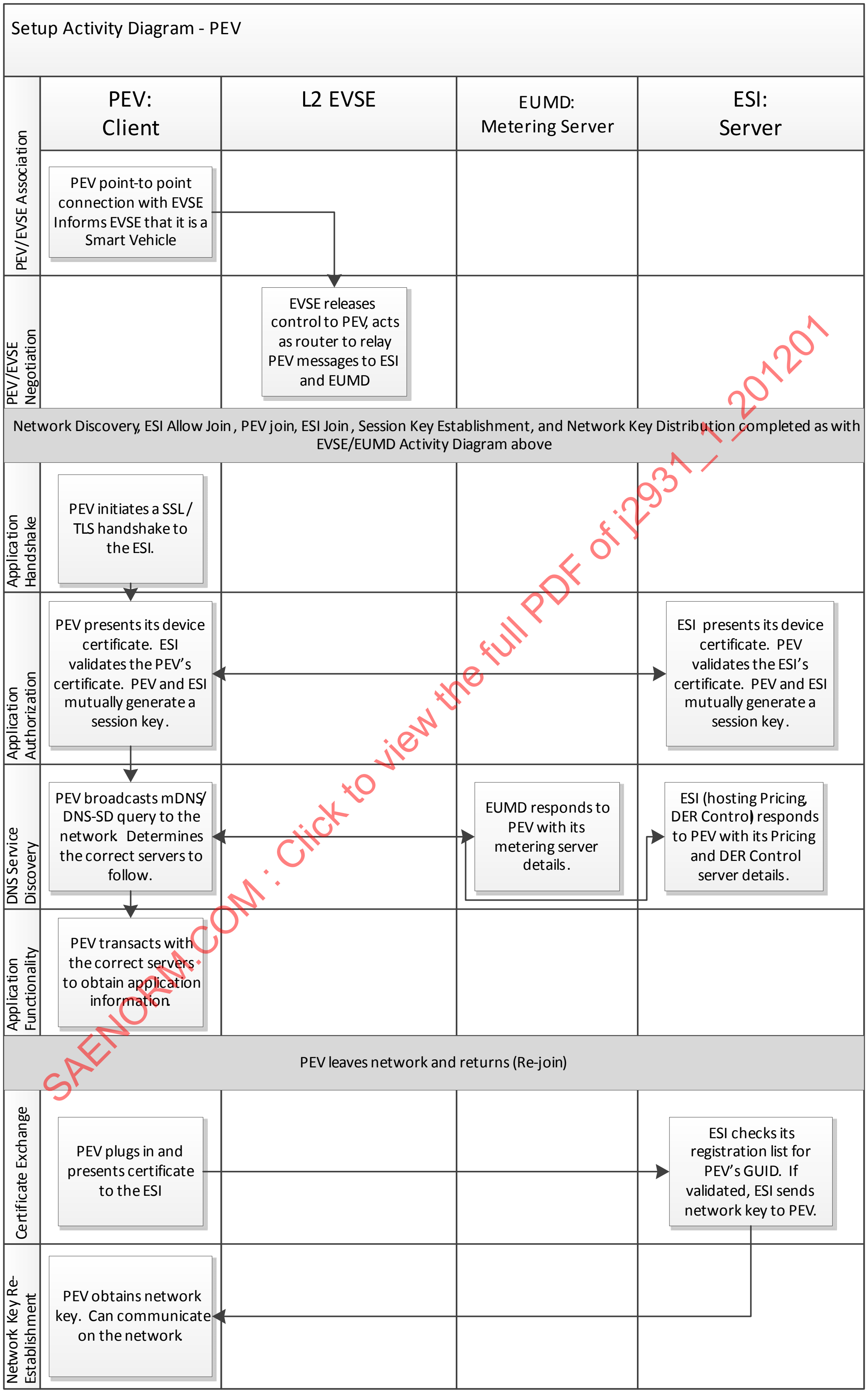

FIGURE 10 - SETUP ACTIVITY DIAGRAM – PEV (W/ASSOCIATION)

6.5.2.7 PEV/EVSE Association

The PEV and EVSE must be associated in order for the EVSE to retain or release control of the charging session to the PEV.

6.5.2.8 EVSE/PEV Negotiation

If the both the PEV and EVSE are capable of SEP2.0 communications, the EVSE shall relinquish control of the session to the PEV.

6.5.2.9 Application Handshake

PEV wishes to access a resource on the ESI. ESI is an http(s) server.

6.5.2.10 Application Authorization

The ESI may populate the resources' Access Control List based on the service provider's security policy rules if it has not already done so. The PEV is now authorized to access application resources on the ESI.

6.5.2.11 DNS Service Discovery

The PEV may broadcast a request to discover all the devices offering SEP 2.0 services or append a service sub-type to locate devices offering specific services of interest (e.g., Metering, Pricing, DRLC, DER Control, etc.). Responses provide the URI of the *DeviceCapability* resource (along with TCP ports used for HTTPS). The PEV can then perform an HTTP GET to retrieve the device capabilities and URI information required to access those services.

6.5.2.12 Application Functionality

The PEV accesses relevant application information from the resources discovered in the previous step. Refer to Section 11 of the SEP 2.0 Application Specification for more information.

6.5.2.13 Certificate Exchange

This scenario assumes the network key has been updated while the PEV was away from the network, and that the PEV and ESI have retained the session key previously created in the Session Key Establishment step. If the network key remains the same, the PEV should be able to communicate immediately. If the network key has been updated and PEV and ESI have not retained the shared network access session key, the PEV will have to redo the full join as above.

6.5.2.14 Network Key Re-Establishment

PEV can now communicate on the network.

6.5.3 Normal and Repeating Operations

This activity diagram represents some of the likely activities a PEV would perform as described by the typical residential scenario. It assumes that the previous two activity diagrams have been completed and there is an associated EUMD, EVSE, and PEV. The PEV is enrolled in utility programs and authorized to communicate on the HAN and has completed service discovery. As a pre-requisite to this diagram, the user has entered his charging preferences into the PEV or other HMI (e.g., smartphone). This could include Time Start, Time End, Price, and Accept DR Events. Detailed messages can be found in SAE J2847/1 and SEP2.0 Application Specification.

In this scenario, as with the others shown here, the ESI is also the function set server for all of the application functionality the PEV would like to access.