**IEEE P802.24**

**Vertical Applications Technical Advisory Group**

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| Title | **Proposed Update of Texts and Figures in Clause 3.2 of the AFV White Paper (Doc. 24-23-0007-05-0000)** |
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| Re: | Additional content  |
| Abstract | This contribution proposes update of texts and figures in Clause 3.2 of the AFV White Paper (Doc. 24-23-0007-05-0000). |
| Purpose | To be updated in Clause 3.2 of the AFV draft (Doc. 24-23-0007-05-0000). |
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## Smart Home Energy Management with Advanced Charging Services

### Overview

EV users who frequently commute between their workplace and home rely on an accessible charging infrastructure at both locations. Often employees work in small to medium-sized office buildings, while their residence could be a small multi-family residence or a single-family dwelling, both needing EV charging connections. As these vehicles can remain parked for several hours, L2 AC charging systems are most often used. At the most basic level, L2 AC charging is controlled by analog circuits within the charging device, operating standalone, with limited communications interface necessary apart from the vehicle battery management system negotiation for the charging session.

However, the expansion of EVs can lead to peak loads and bottlenecks in power flows and loads in the grid and at the house connection point. Integrating energy management systems (or energy management agents: EMAs) with EV charging systems is beneficial for small commercial building managers to avoid an overload and the associated emergency shutdown due to power limits. Similarly, homes or small multi-family dwellings with multiple charging stations can benefit from a comprehensive approach to maximize the utilization of charging resources.

There are three basic use cases for utilizing charging resources: home, private, and public charging station management systems. For example, during peak electricity demand periods, the home energy management systems (HEMS) schedules EV charging during off-peak hours or when solar energy production is high to avoid high electricity costs and reduce the load on the grid. In the event of a power outage, the HEMS utilizes the stored energy in the EV batteries to power essential home appliances, acting as an emergency backup power source. The building energy management system (BEMS) oversees the charging of all fleet EVs, ensuring they are ready for use during business hours. The BEMS manages the charging load to prevent any single point from becoming overloaded, distributing the charging sessions throughout the day based on the building’s overall energy consumption and availability of power. The public charging station management system adjusts the charging rates dynamically based on the time of day, demand, and availability of charging spots. These EMSs participates in utility demand response programs, reducing or pausing EV charging during peak demand times in exchange for incentives from the utility company. Storing energy in electric vehicles allows optimal use of power on-demand, augments decentralized electricity generation, or delivers power back to the grid when needed.

To support such Advanced Charging services within home and small building, Smart Home energy management systems interact with charging stations and EVs for exchanging messages. The interaction translates the request message from the energy system into input through the autonomous mechanism, locates collaborators capable of providing the just-in-time energy resources, orchestrates message sending to collaborators to invoke their interactions, and finally returns the results to the energy system. When underlying data change, such as status changes in the utility, the energy orchestration service updates corresponding business services and broadcasts the update to the subscribed energy management systems.

To support the integration of AI services within the car, home, and office environments, electric vehicles must connect seamlessly to both home and office networks. AI services will be used to optimize the interaction between the vehicle, the home energy management systems (HEMS), and the building energy management systems (BEMS). For example, an AI service could dynamically adjust EV charging schedules based on real-time data from the user's calendar, local energy tariffs, and grid demand forecasts. The AI could also manage the vehicle’s energy storage to balance grid loads, provide backup power during outages, and optimize the use of renewable energy.

Additional services, such as charging station contention management, reservations, waitlist queuing, matching user charging requirements with limited charging resources in constrained areas (e.g., small multi-family dwellings or small office commercial complex), improve charging resource allocation.

For small commercial building managers, integrating corporative energy management services such as vehicle to building (V2B), vehicle to grid (V2G) and virtual power plant (VPP) with EV charging requirements is crucial to ensure the sustainable operations as follows:

* Load management (local power management over optimization of operations and tariffs or desired charging plans)
* Avoid peak time of use rates (an overload and the associated emergency shutdown due to specified power limits in the property)
* Optimize energy consumption and generation (optimization of operations and tariff-optimized operation or desired charging plans)

### High level Protocol architecture for Smart Home Energy Management

Smart Home Energy Management Systems provide a coordinated approach to control and optimize the use of smart home devices such as heating, air conditioning, and distributed energy resources (DERs), thereby increasing energy efficiency (e.g., power balance, power-sharing, energy management) [6]. These systems enable high-level communication that allows a bidirectional energy flow among energy systems, including DERs and electric vehicles (EVs) [1]. This control facilitates the management of energy generated from DERs and EVs for consumption or storage within the collective EVs.

ISO/IEC 15067-3-30 standardizes the Energy Management Agent (EMA), which plays a crucial role in optimizing the energy use of home appliances by utilizing standardized two-way communication in smart homes. EMA is a self-contained autonomous software agent for energy management, capable of allocating and scheduling limited energy resources within residential and small buildings [2]. An EMA can be embedded in devices such as thermostats, smart appliances, or other consumer products like DERs and EV charging systems [3]. EMAs efficiently allocate energy among appliances within homes and among homes in a community, accommodating a mix of external and local energy sources linked to DERs or EVs [4]. In this system, EMA automatically react to demand-response (DR) events, charging and discharging EVs in optimal time slots, considering changes in energy consumption, time-of-use rate information, and users’ vehicle usage plans, similar to a virtual power plant (VPP). EMAs help optimize energy use in smart homes by using EVs as emergency backup power during outages and facilitate peak shifting by charging EVs during off-peak periods and discharging them during peak periods through V2G technology.

ISO/IEC 15067-3-31 specifies an interacting EMA protocol, called EMAP, for cooperative energy management in smart home environments [5]. EMAP is an application layer protocol that enables EMAs to exchange energy-related information, including DERs, pricing, and DR commands, to manage customer energy resources such as load, generation, and storage in homes, buildings, and apartment complexes. EMAP relies on standard-based IP communications, such as the Constrained Application Protocol (CoAP) and JavaScript Object Notation (JSON) messaging. CoAP is a specialized Internet Application Protocol for devices with limited processing capability, as defined in RFC 7252 [8].

IEEE standard 2030.5, the successor of Smart Energy Profile 2.0, has been developed to manage energy at the customer premises either directly or through a customer energy management system. It is an industry open standard based on open technologies like REST/HTTP and Extensible Markup Language (XML), operating over any physical layer that supports IP, such as Wi-Fi, ZigBee IP, Thread, Bluetooth, PLC, and Ethernet.

Matter is a unifying, IPv6-based connectivity protocol for smart home and IoT (Internet of Things) devices. It uses transport layer protocols like TCP/UDP for network addressing and reliable data transmission. Matter supports an IPv6-based protocol over Wi-Fi, Ethernet, or Thread as a network communication protocol. Thread is a low-power wireless mesh networking protocol facilitating reliable communication between nodes. Matter 1.3 will expect to include home security cameras, energy management, and EV charging in 2024.

### High level Protocol architecture for Smart Home Energy Management with Charging Services

The smart home energy management framework, i.e., EMA framework, with Charging Services must extend high-level communication that allow a bidirectional energy flow among energy systems including DERs and EVs [1]. In this context, control of the energy systems will allow the management of energy flow generated from DERs and EVs for consumption or for storage in the collective EVs.

IEEE Standard 1609 specifies the architecture and services necessary for automotive communication, known as Wireless Access in Vehicular Environments (WAVE). It follows the open system interconnect model, supporting IP and its transport protocols, and leverages IEEE Std 802.11 as the wireless link technology. This standard facilitates direct vehicle-to-infrastructure (V2I) communication, enabling EVs to securely connect to the Electric Vehicle Supply Equipment (EVSE) to negotiate charging service parameters, similar to standard EV charging scenarios but with the addition of automated valet parking.

SAE J2836/J2847/J2931 and ISO/IEC 15118 are suites of standards of two-way digital communication between EV and EV supply equipment (EVSE) for smart charging and discharging control [7].

The IEC 63380 series defines the secure information exchange between local energy management systems and EV charging stations, separate from the charging interface for EVs as specified in ISO 15118 or IEC 61851-1. Local energy management systems communicate with charging station controllers, where the charging infrastructure is managed by the operator of the private electrical network, and local energy management systems are used for local load management.

IEC 63380-3 specifies the application of relevant transport protocols: SPINE (Smart Premises Interoperable Neutral-Message Exchange) and SHIP (Smart Home IP). SPINE serves as a neutral message framework to model common communication protocols, enabling interactions between SPINE devices and local energy management systems. SHIP describes an IP-based approach for interoperable connectivity of smart home appliances, covering local SHIP nodes in the smart home, web server-based SHIP nodes, and remote SHIP nodes. SHIP nodes may use different physical layer approaches, such as Wi-Fi or powerline technologies. An IP router can connect different physical networks and provide internet access, but this is outside the scope of the SHIP protocol. Both IPv4 and IPv6 are permitted on the IP layer. IP addresses can be preconfigured, assigned via a DNS server, Stateless Address Autoconfiguration (SLAAC), or other appropriate means. A SHIP node must support Multicast Domain Name System/Domain Name System–Service Discovery (mDNS/DNS-SD) for local device/service discovery. The SHIP protocol is based on TCP, TLS, and WebSocket.

These protocols do not cover the communication interface between the energy management system(s) and the charging station, including electric vehicles, such as the management of energy transfer of the charge session, contractual and billing data provided by the energy management systems. These protocols should be extended to transmit information about procurement and tariff-optimized operation from the Smart Home Energy Management System to the charging infrastructure and electric vehicles so that it can coordinate EV charging plans according to local requirements. Therefore, it is crucial to define a standard IEEE 802 communication interface for connecting electric vehicles and/or charging stations to local energy management systems, separate from the physical charging interface for electric vehicles according to ISO 15118 or IEC 61851-1.

 

*Figure N: Examples of High level Protocol architecture that can be deployed over IEEE 802 networks*

### Communications aspects of Smart Home Energy Management with Advanced Charging Services

As Level 2 AC charging is controlled by analog circuits within the charging device and the EV, there has been no need for communications interfaces on either to support the charging function. Nevertheless, some vendors have included wireless communications capabilities in their wallbox products to provide user access to additional Advanced Charging services. Examples include Bluetooth™ for charging station configuration using a vendor-provided app on the user’s smartphone; and Wi-Fi® for communication between the charging station and the vendor’s cloud-based charging network (and device) management system, via the user’s home Wi-Fi AP/router. This external connectivity offers opportunities for consumers and building managers integrate secondary communications for EV charging management such as selecting advantageous utility time-of-day pricing structures, reservation systems, charging payment processing, Vehicle to Grid energy transfer (VTG), etc.

Accordingly, the secondary connectivity should be able to transmit information about procurement and tariff-optimized operation from the Smart Home Energy Management System (HEMS) to the charging infrastructure and electric vehicles. This allows for coordinated EV charging plans according to local requirements. For example, the HEMS knows that one family member leaves for work at 8 AM, while another works from home and uses their EV less frequently. It schedules charging for the first EV overnight to be fully charged by 8 AM and charges the second EV in the early afternoon when rates are low and grid demand is minimal.

The HEMS also integrates personal schedules and preferences to create personalized charging plans. It dynamically balances the load across residential, commercial, and public charging stations by scheduling residential EV charging during off-peak hours, prioritizing commercial EV charging based on work schedules, and adjusting public charging station availability based on real-time charging data and grid demand. If there is an unexpected drop in temperature or a sudden increase in grid demand, the system sends notifications to users and automatically reschedules charging sessions to ensure efficiency and grid stability.

Such EV charging services use IEEE 802 communications (Wi-Fi) in a limited way, and depend on the device vendor (or service provider) and utility to partner on providing service offerings. Developments in Smart Home promise to expand opportunities for EV charging to participate in comprehensive, dynamic cooperative energy management.

1. **References**
2. J. S. Choi, "Energy management agent frameworks: Scalable, flexible, and efficient architectures for 5G vertical industries," IEEE Industrial Electronics Magazine, vol. 15, no. 1, pp. 62-73, March 2021
3. ISO/IEC 15067-3:2012, Information technology – Home Electronic System (HES) application model – Part 3: Model of a demand-response energy management system for HES
4. ISO/IEC 15067-3-3:2019, Information technology – Home Electronic System (HES) application model – Part 3-3: Model of a system of interacting energy management agents (EMAs) for demand response energy management
5. ISO/IEC 15067-30:FIDS, Information technology – Home Electronic System (HES) application model – Part 30: EMA functional requirements and interfaces
6. ISO/IEC 15067-3-31:FDIS, Information technology – Home Electronic System (HES) application model – Part 3-31: Protocol of energy management agents for demand response energy management and interactions among these agents
7. J. S. Choi, "A hierarchical distributed energy management agent framework for smart homes, grids, and cities," IEEE Communications Magazine, Vol. 57, No. 7, pp. 113-119, 2019
8. T. Shimizu, T. Ono, W. Hirohashi, K. Kumita, and Y. Hayashi, “Experimental demonstration of smart charging and vehicle-to-home technologies for plugin electric vehicles coordinated with home energy management systems for automated demand response,” SAE International Journal of Passenger Cars-Electronic and Electrical Systems, vol. 9, no. 2016-01-0160, pp. 286–293, 2016.
9. IETF RFC 7252, The Constrained Application Protocol (CoAP), edited by Z. Shelby et al., June 2014, available at: <https://tools.ietf.org/rfc/rfc7252.txt> [viewed 2023-05-31]
10. IETF RFC 7159, The JavaScript Object Notation (JSON) Data Interchange Format, edited by T. Bray, March 2014, available at: https://tools.ietf.org/rfc/rfc7159.txt [viewed 2023-05-31]
11. A. A. S. Mohamed, A. A. Shaier, H. Metwally, and S. I. Selem, “An Overview of Dynamic Inductive Charging for Electric Vehicles,” *Energies*, vol. 15, no. 15, p. 5613, Aug. 2022, doi: <https://doi.org/10.3390/en15155613>.
12. “ROADMAP OF STANDARDS AND CODES FOR ELECTRIC VEHICLES AT SCALE ANSI Electric Vehicles Standards Panel (EVSP),” 2023. Accessed: Apr. 20, 2024. [Online]. Available: <https://share.ansi.org/evsp/ANSI_EVSP_Roadmap_June_2023.pdf>
13. Han Wang, Youwei Jia, Mengge Shi, Chun Sing Lai, Kang Li, "A Mutually Beneficial Operation Framework for Virtual Power Plants and Electric Vehicle Charging Stations", IEEE Transactions on Smart Grid, vol.14, no.6, pp.4634-4648, 2023.
14. Eltamaly, A.M. Optimal Dispatch Strategy for Electric Vehicles in V2G Applications. Smart Cities 2023, 6, 3161–3191
15. Shin, S., Sohn, K., Park, D., & Choi, J. S. (2022). Special issue on smart cities and its applications. ETRI JOURNAL, 44(2), 179–182.
16. IEC 63380 series (CDV): Local Charging station management systems and Local Energy Management Systems network connectivity and information exchange - Part -1 General Requirements, Use Cases and abstract Messages, Part 2: Specific Data Model Mapping, Part -3 Communication Protocol and Cybersecurity Specific Aspects, Part -4 Test Specifications