AI-Based Enhancements for Vehicle-to-Home Integration

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1. Introduction

Vehicles and infrastructure involved in different domains are converging, such as from transportation infrastructures evolving along the lines of the Internet of Things to smart cities, which are expected to benefit from plug-in electric vehicles that provide V2H interfaces enabling smart home systems. This seems very suitable for today's smart marketplace. However, with smart functionalities and distributed resources rarely ever occupying center stage, energy management seems more worth considering than being overlooked. In this context, what is especially brought home is the V2H solution that connects a smart household to not only the transportation system but also an autonomous system in which vehicles can provide energy and other services without human intervention. Then, the logical follow-up seems to be the lofty realms of AI that can transform the idea of V2H and its building blocks, such as VPPs, which are the focus of a great deal of research, into a bold sort of autonomous units. AI can do both on the levels of automating vehicle-to-home integration and improving vehicle performance while providing energy for smart homes.

In this essay, the relation between AI and V2H systems is discussed. First, this indicates that AI not only enables a vehicle with more autonomy to guarantee comfort, cost, and other metrics but also allows it to provide power voltage and frequency control and can anticipate V2H bids in a vehicle-to-everything scenario. Furthermore, these systems have not been paid much attention because the V2G issue at hand is seldom treated as a multi-agent affair. It can also be expected from these systems that they may exploit the V2H structure, for instance, by homeowners tearing off parts of their energy management system control system. In this context, future research may try to control VPPs not merely with the V2H inputs, as has so far become the convention, but also with certain selected V2H outputs.

1.1. Overview of Vehicle-to-Home Integration

Vehicle-to-Home (V2H) refers to the connection of electric vehicles (EVs) to a home property management system (HPMS) for the integration of electric vehicle charging management and home intermediate energy management. The available functionalities differ based on the specific hardware devices operating as the interface of the V2H system, but they often include energy transfer functionalities on the go, offered in correspondence with the specifications of the different EV model interfaces. Alternatively, for scenarios where the EV is already parked and the vehicle does not require a predefined power capability, there is the option to act as an electric energy distribution point between the local battery and the EVs.

Operationally, V2H systems can offer multi-service functionality including vehicle charging with direct solar power, which in turn is beneficial in terms of home consumption costs and sustainability; vehicle-to-home energy transfer during constraints, further improving the HPMS performance during day-ahead energy scheduling and trading; and electric vehicle integrated battery sources serving as backup power, not only increasing the homes' self-sustainability when coupled with a photovoltaic unit, but also providing a separate potential revenue stream commemorating their extra-system functionality as energy storage units. The relationship between electric vehicles (EVs) and home property management systems (HPMSs) is a current topic of study both in academic research and in the industrial field. The main driver of this interest is the recent push for zero-emission, battery electric-powered vehicles and the expected significant increase in vehicle-to-home (V2H) systems with HPMSs on the market. When focusing on HPMS design, ensuring a consistent and reliable HPMS operation over prolonged periods is of paramount importance when dealing with the interoperability of EV models and autonomous functionalities that rely on them, such as backup desiccation in the presence of outages. In fact, while with hybrid vehicles on the market only one power interface was available, nowadays, all-electric vehicles are available on the market and different brands offer a wide range of possibilities. This scenario has direct implications for the socio-technical reliability of the systems. For this reason, investigating the technical and social implications of a V2H integration in new housing solutions is becoming more and more relevant.

1.2. Significance of AI in Enhancing Integration

Artificial intelligence (AI) technologies provide more effective communication pathways between the vehicle and the home systems. These technologies have increasingly been demanded for a variety of applications including autonomous vehicles, smart home automation, and augmented sensory communication enhancement applications. The AI-based services in the V2H integration can be optimum, assist user convenience, and provide user-friendly applications for energy management systems. Such planning for energy management can only be done by checking the real-time data from the energy management systems. Regarding the necessity of AI in the V2H concept, the analysis of real-time data is crucial for efficient energy management in the V2H systems, which is significant for energy conservation.

Many V2H systems rely on heuristics to make decisions. The application of AI in V2H is an emerging field. A lot of potential dimensions of research are not being surfaced in V2H. AI-enabled V2H technologies have the capability to communicate efficiently with the total household appliances in a diversified environment. Innovations in energy management technologies can be brought to light through optimizing decision systems in V2H applications. This can increase energy efficiency, reduce peak demand, and provide system flexibility through advanced demand-side management programs. Integration of energy consumption data and prediction of energy consumption through AI in V2H systems results in reduced energy consumption.

2. Autonomous Vehicles and Smart Home Systems

Autonomous vehicles are a culmination of some of the most sought-after features and capabilities that new cars have acquired over the past few years. These include external and internal communication systems, advanced sensors like cameras, LIDAR, and ultrasonic sensors to assist drivers, lane assistance, adaptive cruise control, automatic parking, blind spot information systems, voice control, and, of course, detailed maps and navigation systems. These have been integrated into multi-modal systems to be able to act without human intervention and could travel anywhere a typical human-driven vehicle goes. Most of these individual components have also been features used in smart homes for automatic doors and windows, controlling smart appliances, and connected healthcare purposes to help the elderly age safely in place. Furthermore, there are also developments in machine learning, and most of these vehicle systems, such as driver assist systems, can predict human reactions more accurately now. This opens up better and personalized user interface designs to work on these vehicle capabilities for any user when the car is part of your "home." But can the integration of an autonomous vehicle and smart home technologies, now or in the future, act as an effective architectural and social system, allowing citizens to live more efficiently and with a higher quality of life? It presents an opportunity to look at how artificial intelligence-based enhancements using data from machine learning vehicular technology now and in the future can merge with smart home systems architecture for its benefits. This sets the stage for quite an interesting transformation, which is the conversion of vehicles from an asset of use mainly by humans for transporting people and cargo. Changing its architecture can now expand our vision for vehicular design or architecture to include it as part of our ecosystem with greater derivative transactions emanating from such arrivals. What has so far been the architecture of smart cities and smart homes can be transformed when we allow a conversion of vehicles to home domains and an urban platform. In such an environment, autonomous vehicles can make faster adoption of smart home advanced technologies as they are now moving out of 'being smart enterprises' and turning into an 'intelligent system platform' for the community, like a hub, bridge, and coordinator of interactions on various interoperable systems with end users as passengers. That is, the vehicles become our means towards a vertically integrated autonomous ecosystem capable of delivering vertical platforms. Furthermore, this integration is now equipped with an architecture that can ease and provide a myriad of home activities they are possibly engaged with. In pursuing this possibility, we first need to understand the details of their integration by pointing out the advantages of it, besides the technological challenges involved in incorporating existing urban socio-technological systems.

2.1. Key Features and Capabilities

Autonomous vehicles present a more advanced level in driving policies that enable vehicles to monitor their environment and navigate without direct driver control. Self-governing driving policies make use of numerous technologies such as radar, lidar, odometry sensors, and epicameras to sense the environment and provide an ADAS with the ability to navigate through city streets and highways. Moreover, autonomous driving capability through a collection of advanced technologies like machine learning and computer vision allows autonomous vehicles to gain situational awareness both inside and outside of a vehicle and to share data with the vehicle’s micro-navigation fleet operations.

Predictive functions and big data analytics are increasingly being embedded in vehicle systems; ADASs with a degree of machine learning capability are already common and are expected to become ubiquitous in the future. Autonomous vehicles introduce themselves to residential energy systems and equipment, and the ability for vehicles to collect and share data from residential systems can inform vehicle functionality, increase interaction between vehicles and represented residential energy management systems. For example, autonomous vehicles might offer occupants the option of specifying heated or cooled seats based on their own temperature preferences in order to subsequently find an agreeable temperature setpoint. Home automation demonstrates outside temperature, indoor home office temperature, thermostat decisions, and so on using other devices. All these feature offerings are additional functionalities to an end user that are related to maximizing the user’s comfort, increasing energy efficiency, and control of the home.

The common factor and common advantage of home comfort are enabled by the synthesis of vehicles, vehicle data, trips, user profiles, etc., with a home. Particularly, AI algorithms and smart home devices will not have to infer users’ schedules or usage patterns – home and vehicle products will become assistants utilizing mobility and home user profiles to enhance ease, comfort, and peace of mind. One potential home comfort use case that is strongly related to therapeutic management is the thermal comfort variance while at home. In other words, vehicles can communicate with homes, cars, and motorcycles, and offer features and options or factor controls that can impact a home or a given personal lifestyle. Vehicle-to-home intelligence and user control can potentially enable a specific vehicle to record driver choices, like immediately turning off the vehicle’s air conditioning system when a driver switches off the car or opening a home garage upon the autonomous vehicle's home arrival. Overall, these trends show the growing interest and capabilities in integrating vehicles with technology and devices into the smart home and demonstrate the potential breadth of effect that autonomous vehicles can have on home energy management.

2.2. Current Challenges in Integration

Although several solutions have already been proposed to integrate autonomous vehicles with smart home systems, significant progress still needs to be made to address diverse technical, infrastructure, and regulatory issues. Seamless interconnections between applied devices, data, software, and human users are one of the most challenging obstacles, especially involving vehicles and in-home technologies. When trying to develop their specific technologies, each manufacturer often has a different understanding of various aspects. As a result, the achievement of full interoperability between home automation, vehicle-to-home, and in-vehicle solutions from various manufacturers still presents a significant obstacle. In addition, the potential lack of accuracy of some smart home devices, lack of safety features, non-widespread use of reliable protocols in commercial developments, and user interfaces on in-home device-friendly platforms arise as researchers are still struggling to investigate these challenges. Mismatches between human behavior and smart home solutions are also present; they challenge researchers when trying to develop integration services. Even if an autonomous vehicle or one using the infrastructure can serve as a powerful communication platform and storage and computing location, the potential and challenges are presented, as well as several best practice applications that are already in place.

3. Machine Learning Applications in Vehicle-to-Home Integration

Machine learning and its applications are currently one of the most popular research segments. For vehicle-to-home (V2H) integration, the amount of data exchanged between electric vehicles (EVs) and home systems could be significantly large, and processing this data provides a profound understanding of EV use and user behavior. Appropriate algorithms for data processing can be used to fine-tune the models to reveal insights that would, for example, connect intervals of time where the EV is recharged with probable user behavior in the house. Through regression with an appropriate model, predictions for energy consumption can be made. By analyzing the data, it is possible from the V2H perspective to view the entire ecosystem and gain insight into how the user behaves and how the house uses energy. Predictive models are designed to find when is the right time to take energy from the EV and vice versa to increase the use of your own energy, using the energy stored in the EV, to reduce the user’s dependence on the electricity market.

Machine learning has found applications in V2H for real-time control of EV charging and discharging. For instance, different machine learning techniques have been applied using various datasets with different applications. Clustering techniques are used to cluster EV driving data into morning working, morning nonworking, afternoon working, and afternoon nonworking clusters. Regression is then applied to create a predictive charging demand model for clusters and vehicle-to-grid operation. The House Model is used for decision-making based on machine learning for EV energy storage control. Wind speed is used to create a prognostic model for battery charge, while EV power predictions for the coming hour are being forecasted. Artificial neural networks are used to create models and make decisions in the case study presented for predicting domestic energy consumption and PV production. Artificial neural networks are used to shed light on the energy rate of price and control EV charging. Linear programming combined with reinforcement learning predicts household consumption and power consumer location. Hybrid forecasting models are used for predicting PV generation and the energy on the site from the house. It uses various machine learning and soft computing techniques that include neural networks, regression-based techniques, and ensembles. Some of the main applications for using machine learning in V2H integration include clustering, data-driven predictive models, anomaly detection, situation awareness, decision support systems, and real-time applications. Machine learning used in the right way could potentially reduce electricity bills, increase the use of renewable energy in the community, and there are many other applications. Some case studies are presented in which machine learning and data are used to solve problems and make decisions in the community.

3.1. Data Processing and Analysis

Data processing and analysis are the most salient aspects of any V2H integration. Vehicular telemetry data is used to understand the parameters. However, merely the actual vehicular usage is not enough. Hence, data from home energy systems is used to compensate. The data related to different parameters are essential for any kind of insight analysis. A huge amount of data produced must be interpreted and processed to form actionable items. In this manner, data handling with artificial intelligence can be beneficial in the decision-making system.

Most of the time, no data are perfect. Most data require cleansing and extraction to derive the correct patterns and genuine truth. Proper handling related to data mining techniques must be undertaken. Feature members, which are most important in decision-making, must be extracted from the data. Features or items can be raw input through sequential data. AI algorithms can be beneficial in this task. Supervised learning is constructive for learning to gain mapping from the features. The unsupervised algorithm is used when an anomaly occurs. Both algorithms can be applicable for drawing features from the raw input to outline.

Once the pertinent data are achieved, numerous forms of analysis will be needed. Depending on the design, the algorithm will tell whether it has a similarity or dissimilarity approach. Pattern recognition studies are applied. Streak or trend is carried out to show the trail motion. Anomaly detection is undertaken for the outsider. The solution is: these are used for adaptation. Collaborative filtering is one of the solutions, which clusters people by using similarity, clustering, and sequence mining. Data processing requires a robust infrastructure and technology that manages data flow and the processing of data. Taking into consideration the nature of handling large data volumes, a cloud-based solution is recommended. Due to its on-demand resources, scalability, and service flexibility, one can easily use its infrastructure and expanded access to the entire resources and services.

Data cleansing and learning patterns from huge data are to control energy, dispensing and controlling the sensed data by the home electric device under various situations. The data have numerical imbalance, and both the consumption of the vehicles and the house needs to be optimally adjusted. The V2H is to control the power systems.

3.2. Predictive Maintenance and Energy Optimization

In a vehicle-to-home application, it may be possible to schedule preventive maintenance of the electric vehicle through predictive analytics. The vehicle data and charging data can be analyzed to forecast when the vehicle's condition calls for maintenance. Enriched with event logs and incidents, a machine learning model can extract relevant information based on large amounts of operational data accumulated over time, providing managers with insights for informed decision-making. In a large corporation with a large number of vehicles, predictive maintenance processes have been documented to result in substantial savings. Conversely, merely reacting to faults as they arise often incurs extensive downtime. Furthermore, predictive maintenance enhances system reliability and reduces customer dissatisfaction. Preventive maintenance scheduling is crucial to performance in a vehicle-to-home environment. Proactive scheduling gives operations the chance to modify the energy flows of electric vehicles to deliver assistance to the home while at the same time minimizing V2H usage. The flexibility in the scheduling of maintenance interventions provides the algorithm with the ability to shift the energy used for maintenance to the most advantageous time window. An adaptive energy management setup can benefit from predictive information that is used to adjust the energy strategies during the vehicle battery charge. The hybrid method uses a real-time optimization framework to adjust the electric loads during the charging process. The pioneer instance is represented by artificial intelligence and machine learning techniques that provide computational methods supporting the predictions with accurate results. Predictive techniques determine when the electric loads shall be raised and lowered. This can save up to 8% of the charging cost in a vehicle-to-grid scenario. Additionally, the AI technology could forecast equipment-related consumption, which improves the performance of the approval vote heuristic strategy in energy scheduling. Dedicated monitoring and assessment of the V2H battery status are reported in optimized public schedules for drivers of electric vehicles that participate in V2H services. They provide real-time control software with a short-term load forecasting module based on the drivers' habits and a look-ahead battery state of charge prediction module based on weather data. When synchronizing the V2H facilities with the users' projected energy demand, an adaptive center-of-gravity algorithm based on real-time data is developed. Each of these system-wide optimizations and decision-making scenarios is supported by predictive intelligence proactively scheduling battery maintenance and repairs. In summary, the flexibility of scheduling maintenance and repairs should be considered when V2H scenarios are put to use in the energy platforms. This way, highly efficient maintenance scheduling saves everybody involved—home occupants, utility providers, and maintenance professionals—time, effort, and money. Predictive maintenance in the vehicle-to-home environment powered by AI platforms can help with energy cost savings in infrastructure. Predictive platforms can draw on techniques including dynamic energy audits and weather adaptation models for both urban infrastructure and private homes.

4. Security and Privacy Considerations

The communication channel between vehicles and the smart home system is one field that might have potential security vulnerabilities. The data communication from the vehicles to the smart home system shall be secured so as not to compromise the user's privacy-sensitive data, such as user location, user driving activities, user electricity utilization, etc. The secure transmission of data is very essential when the V2H systems are considered. This naturally requires a secure channel of communication for the information being transmitted. The secure channel is to be built within the V2H process life cycle. The regulations to provide the requirements for privacy continue to be developed. The security regulations are the most demanding factor. Since valuable data is being dealt with, as well as the smart infrastructure, there is a need not only to improve the security of V2H systems but also to increase awareness and build confidence with the users.

It must also be considered that throughout the transmission, the transferred data has not been altered during the amnesic process, and in the V2H system as a whole, or the client schemes in the V2H system that utilize unidirectional data transmission. An entity that transmits and subscribes to data in the V2H integrations should follow this guideline in order to create signed and encrypted files for communication between the vehicle and the smart home. It also discusses different policies to secure the information of the end user and gain the trust of the end user in order to apply these systems in society.

4.1. Data Protection Measures

The first part of this section concentrates on the data protection measures relevant to Vehicle-to-Home (V2H) and the associated data transfer between them. First, encryption methods continue to be of central importance; employing end-to-end encryption ensures secure data traffic between the V2H and V2X subsystems. Due to the high computational complexity of the microcontroller in authenticating the public and private keys of the two parties involved, while the microcontroller ensures resource efficiency, employing RSA-based hybrid data encryption techniques provides a robust solution to increase data transmission security. Furthermore, only data encrypted using the public key of the vehicle user is securely sent by the V2X to the V2G controller for decryption and forwarding to the V2H.

This approach is recommended in that it is adequate, application-independent, and represents a fundamental requirement within the development of the V2H integration. The secure integration of this principle is of key importance to both improve user experience and conserve confidence in the system, ensuring that other V2X systems can be rapidly and securely integrated as they continue to develop. One key method of ensuring that data breaches or data leaks do not cripple the V2H network is to conduct frequent security audits. Whether normally scheduled or conducted in the wake of a known threat, a regular audit ensures that the organization continues to be on the offensive. Periodic audits make it easier to adapt organizational policies to security solutions and databases. Given that there are competing priorities within V2H, security functions must be implemented such that they do not detrimentally affect or hinder comfort and usability. There is a clear security kiss principle ("keep it simple and secure") to be observed in the design of such systems; unused hardware, software, and functions represent different easy attack targets, and therefore, the attack surface should be minimized as much as possible.

4.2. Preventing Unauthorized Access

To prevent unauthorized access, advanced access controls can be designed and implemented. Multiple monitoring and restriction subsystems can be developed for every aspect of the V2H system. The whole system can offer anomaly detection capabilities that can be enhanced by employing AI. Advanced security features, such as multi-factor user authentication, can be deployed in order to strengthen access management. Implementing advanced antispam and anti-phishing systems can be used for securing user data. User education is also highly significant. Educators and service providers can educate end users about cyber threats. Organizational security policies, such as the restriction of downloading software from the Internet, use of licensed software, employee formal vetting process, clear desk and clear screen policy, and regular backups of critical data, can be developed and implemented in order to prevent users, both in private and professional contexts, from becoming victims of cyberattacks. The software can be regularly updated and patched to minimize cyber vulnerabilities.

The service provider can work with customs to devise and implement a V2H incident response plan. Preparation can speed up the recovery process and reduce the costs associated with the cyber event. An incident response plan can describe the requirements for responding to a data breach or cybersecurity incident, including the likelihood of unauthorized data access. Training exercises, such as penetration testing and vulnerability scanning, can be developed. Training can be organized to help relevant staff learn what constitutes suspicious activity and how to recognize it. In light of the numerous threats and vulnerabilities associated with IoTs and artificial intelligence, and the increasing threat landscape, addressing unauthorized access is likely to facilitate building users' trust and making society excited about proposed V2H solutions.

5. Future Prospects and Implications

5.1 Emerging Technologies for Improvement of V2H Landscape In the not-so-distant future, blockchain and the Internet of Things (IoT) might be two of the most functional systems that would orient energy systems to be free from trouble or lessen the operational time of managers. When fully integrated into a standard V2H system, these two technologies can make V2H operations more efficient, effective, and simultaneously improve other aspects of human life, such as the security of data, quality of living, and enhancement of transport and energy independence.

5.2 Societal Changes The development of technology with clear and obvious functionality for the community is driven by societal needs and deep-rooted, universal guides, such as addressing climate change, reducing the carbon footprint, and promoting sustainable energy for all. For example, during operation, a V2H system or EV can generate power and operate smart household appliances, thus ensuring an independent, comfortable, and trouble-free life, while eliminating the likelihood of failing to supply power in the event of a natural disaster. All the aforementioned advantages are mainly led by the instantaneous, dual application of AI, showing how a big data model can find, recognize, and disseminate real situations of driving-specific load usage across the V2H community, while defining control over optimal energy usage within all EVs, in exchange for preventing a roadblock for other V2H users making the same journey. As a result, citizens can decide whether it is the best time to start their journey by considering the latest V2H updates, forecasts, and traffic. Moreover, it will play a vital role in enhancing the overall awareness of road safety, as V2H systems will help to reduce CO_2 output by preventing congestion. Nevertheless, a critical assessment is needed of both the benefits and ethical implications of V2G technology. Despite its potential societal value, the implementation of autonomous systems, including V2H, also encompasses harmful aspects. Several considerations to be highlighted here concern the risks of transferring data, such as GDPR violations, vulnerability of data to cybercrime, and data leakage. Additionally, the scalability of these two revolutionary technologies can be hindered by an ethically justifiable narrative. For example, blockchain technology has been at the crossroads of technically solvable and ethically challenging alignment. The growing dependence on AI, data, and advanced technologies entails a substantial risk. A socioeconomic slowdown might be one of the adverse measures impacting the automobile industry and the future of this technology because if these technologies are deemed non-compliant, governed, or overvalued, the industry will undoubtedly suffer material ineffectiveness. Currently, V2H technology does not violate any existing EQ standards and regulations. Nevertheless, it is important to remember that various elements of V2H can enhance public health and well-being. Given the shortcomings and risks related to V2H technology, when the time comes to create V2H-compatible units, important ethical considerations must also be taken into account. These issues should be foreseen and handled in good time, providing guidance to generate affordable, secure, and transferable power.

5.1. Emerging Technologies and Trends

The future trend of V2G requires improving V2H functionalities, and in this direction, emerging advances in smart grid and electricity sectors contribute to energy optimization concerning efficiency and reliability. Smart renewable energy acquisition, distributed generation of renewable energy sources, improved energy storage systems, demand response programs, dynamic electricity pricing, and load balancing could perform better in the wake of such enhancement. Smart grids are dynamic and interactive, which can use advanced communication technology to make decisions and optimize the supply, transmission, and use of electricity. Deployment of advanced metering infrastructure, real-time demand-side management, wireless communications, and smart home appliances are a few technological advancements that are revolutionizing electricity sectors.

Trends in such areas point to deeper integration of various systems for utilizing electrical energy effectively and efficiently. A trend toward sustainable electricity management has recently emerged due to increasing environmental concerns and consumer preferences regarding green technology and a secure way of life. Consumers are increasingly interested in solutions that are appealing from the carbon footprint and cost-effective point of view and give them control over their environmental influence and expenditure. During this year, the share of renewable energy sources has risen significantly. In terms of newly installed capacity, it accounts for a growing and attractive global energy market. There is an increased demand for smart homes, where energy-efficient systems, energy management, and a preference for smart grid systems can be installed. This can be done through industry collaboration partners in the areas of ICT and sensors and actuators, wireless communication, and home automation.

In the trend report, it has been forecasted that the integration of AI, especially machine learning, will be on the rise. Looking at current trends in AI development, it is high time for automotive companies to start collaborating with voice home automation companies and developing reliable and energy-efficient models of smart home to car/home integration. The home module is interacting with the home hub for information and control of the devices without any internet. It also has a wide application in home automation where it can help in monitoring and controlling home appliances. So operating the smartphone for controlling home appliances now turns into the operation of the home hub. It is also integrated with very famous online radio and music. Additionally, it has an important feature of broadcasting. The user can broadcast from any corner of the house with the home hub. A message can be sent to the home device situated at any corner where it will be broadcast.

A study conducted on the "Domestic Smart Home" found that atmosphere comfort controllers are highly desired by more than 77% of the people, and half of the potential users are willing to pay for more automation systems in their homes. Such a controller is a prerequisite for a successful integration of home and car automation. More than 50% of domestic people are in favor of a decentralized system that will be able to forecast electric prices. This, together with the flexible charging pattern, can result in huge benefits for domestic consumers, as the trend shows that electricity will be cheaper in the near future.

5.2. Potential Benefits and Risks

5.2.1. Benefits

In comparison to less intelligent energy management strategies, V2H integration yields great potential for higher energy and consequently cost savings. Well-designed energy management can further result in cost savings. Even the ad hoc use of PEVs can reduce the fuel energy demand significantly, thereby rendering off-peak charging superfluous for lowering marginal costs and augmenting systemic benefits. Furthermore, the reduced consumption of fossil fuels in the transportation sector will aid in reaching the key sustainability goals. From the consumer perspective, the high convenience and flexibility of V2H integration further raise user satisfaction, a factor that is somewhat crucial for a successful rollout of new energy services in the market. Risks of V2H integration include data privacy issues and risks associated with remote vehicular access and V2H critical home loads. They will have to be addressed by regulations, compensatory liabilities, and cybersecurity mechanisms—not necessarily dominated by the economic interests of the investor. The centralized control and automated car use can, on the supply side, lead to price and load fluctuations or increases from the perspective of the management of large PV car-sharing systems compared to only decentralized street charger operation.

5.2.2. Risks

Risks of V2H integration can be generally ascribed to remote system access and data privacy. On the supply side, the processes of sharing and managing recharged batteries and maintaining batteries, such as through less energy-intensive heating batteries, are legally challenging. Yet, with smart, distributed storage capacity, intermittent renewables can be tapped. V2H standards have progressed to the latest version. The established protocol has also included V2H technology; likewise, the standardized digital signature, end-to-end communication, and market transactions support the operation. These communication stacks play a crucial role in V2H operation. However, the software stack for the V2H embodiment of the smart electric car developed is generally the security layer to maintain the secure control of the V2H process. The car should also be compatible with the chargers, and it should recognize the relationship between the charging station and the handed-over electromotor with the motor vehicle’s energy storage system. Eventually, the smart, distributed storage capacity would supply the pilot electric vehicles, where energy would be fed into the grid. These trials will address the challenges in a world of diminished energy demand and renewable power. For the trials, we will consider using multiple electric vehicles as electrodes to examine layers of intelligent networking. Together, the trials in the northern region will use the electric vehicle for V2H. In this case, surveys, badge collection, and workshops will explore and empower participatory consumers to minimize energy costs by promoting V2H and electric vehicle use. The evaluations post-trials will generate recommendations. The results obtained through the trial will provide indications on the advantages and potential of V2H from the necessary control techniques to permit the productive and secure use of electric vehicle batteries for multiple applications supporting electric vehicle and DER management.

6. Conclusion

In this paper, we have reviewed various opportunities, challenges, possible solutions, and future potential for Vehicle-to-Home (V2H) integration. With an ever-increasing amount of complexity both in stakeholder and solution, AI/ML solutions can be seen as a related factor in order to increase performance and functionalities of current and future V2H systems. This short essay describes two of the major considerations for vehicle-to-home systems: AI/ML related functionality enhancements and the possible challenges and opportunities stemming from V2H developments. We cover functional, physical, and financial integration challenges. AI/ML system advantages of autonomous learning models, hedging against functionality risks, the ability to abstract vulnerabilities, and the ability for autonomous real-time anomaly detection were discussed. Furthermore, the potential for V2H systems to help meet regulation changes, reduce barriers to entry, phase out introduction of changes that are unfeasible with established infrastructure, and the potential commercial and governmental interest in low carbon fabrication were outlined. We are also facing difficulties within house security, and these have to be very carefully evaluated. Also, the user's privacy, preferences, and security can be affected quite openly due to appliance/product link parameters usage/public availability that can give behavioral characteristics and habits of a user. To solve these, we need the appliance owners to work with us on the system development, or we need to innovate to go around all these uncertainties. On a larger scale, security issues and data privacy management being of utmost concern, and by addressing these challenges, we could really lead that market to another way of thinking. In conclusion, with such technologies available, it is exciting to be in the extreme forefront to think about these IoT and V2H in-vehicle technologies development. And while the future might be bright, the fact that the e-merchant and e-equipped vehicle are not really there yet, it takes this vision to a whole new perspective. I guess that we need the whole environment that is supporting it to really make it work.

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