An Optimal Cloud Based Electric Vehicle Charging System

Research Article

i-Proclaim .my

Asia Pac. j. energy environ.

Venkata Naga Satya Surendra Chimakurthi

Solutions Architect, CDBDX-Platforms-DAM (Digital Asset Management), Cognizant Technology Solutions, Dallas, **USA**

*Email for Correspondence: chvnssurendra@gmail.com

Manuscript Received: 07 June 2021 - Revised: 11 July 2021 - Accepted: 20 July 2021

Abstract

With the evolution of the internet-of-things and the emergence of cloud computing, the charging dynamics of vehicles have changed. This work discusses cloud-based monitoring and management used in charging electric vehicles and their impact on the smart charging system. Charging management plays a key role in assessing the charging infrastructure because of the automakers and charging service providers. As the market evolves, this system looks at the present public and private sectors that provide charging stations and contrasts them with modern cloud-based charging in electric vehicles. The cloud module developed contains layers, with the top layer of the robust calculating ability, which is globally optimized using machine learning technology. The bottom layer counters the real-time issues with the controller. The system also analyzes the current demands in the market and forms strategies to maximize profits through smart charging systems.

Key words

Electric vehicles, Cloud Computing, Cloud Charging, Load Management

Terminology

ICEV - Internal Combustion Engine Vehicle
EV - Electric Vehicle
IOV - Internet of vehicles
CIO - Client Infrastructure Operator
REST - Representational State Transfer
P(t)-curve - Point of Tangent curve
ITS - Intelligent transportation system
BIL/EIL/VIL - Battery/engine/vehicle-in-the-loop

Introduction

The rapid growth of industrialization and urbanization has doubled the demand for transportation, and conventional vehicles adding to the pollution has become a massive concern. It is appealing that cities concentrate economic activity and demand for energy services, and so tend to experience heavy concentrations of harmful air pollutants (Saqib et al., 2017). On the other hand, the energy resources such as coal and natural gas with the ever-changing economy are becoming scarce and difficult to retrieve. According to Yan (2016), setting off a global new round of upsurge development of new energy vehicles is to promote all over the world, to accelerate the strategic transformation of transportation energy. This brings to the realization of the growing tech industry, and IOV and the idea of their incorporation in the transportation sector have proven to be a game-changer for the industry. As Yan (2016) says, "The use of electrical energy as original power of the energy power system, EVs are an alternative to ICEVs with the potential to reduce transportation emissions" (Choma et al., 2020). The emergence of electric vehicles seems to address the concern of pollution, proposing a solution to a sustainable, eco-friendly environment where transportation is no longer seen as a threat to endangering the air. The requirement of charging stations to deploy smart charging solutions for electric vehicles has been in great demand from automakers and charging service providers looking for efficient charging models. A cloud-based charging system for EVs is the optimal charging solution to handle different charging stations. Thus, it is the call of the hour to develop a centralized EV/PHEV charging management system that controls demand and supply problems within the dedicated time frames (Saqib et al., 2017).

LITERATURE REVIEW

The charging methodologies of electric vehicles have been evolved with the influence of new technologies. A grid integration EV charging strategy was established by Litzlbauer (2012), discussing the load management of electric vehicles. The concept of grid integration was further amalgamated with a more technological approach, introducing cloud-based EV charging management (Chimakurthi, 2017). The results show that the proposed intelligent battery energy management scheduling service substantially reduces the required number of interactions of PEV with parking lots and grid as well as predicting the load demand calculated in advance with regards to their limitations (Khayyam et al., 2013). As the infrastructure developed, an algorithmic approach was introduced by (Efthymiou et al., 2017), which provided a solution to the EV charging optimization issue, hailing in previous researches. The later studies focused on polishing the cloud charging infrastructure to propose efficient EV charging management system, beneficial for the market (Azam et al., 2021). Chen and Chang (2018) assessed the demand response on the electric vehicle market and proposed a remote xEV solution for cloud charging. Saqib et al. (2017) highlighted cloud monitoring and management a “smart way of charging.” Across these studies, there are consistent improvements on the charging system for electric vehicles; the proposed infrastructures help in establishing an ideal system that can be used on commercial basis to benefit the EV market. Nonetheless, there still needs to be robust research on how cloud-based EV charging systems can be implemented globally (Manavalan & Chisty, 2019).

CLOUD-BASED CHARGING INFRASTRUCTURE AND COMMERCIAL SERVICE IN ELECTRIC VEHICLES

The electric vehicle market needs to evolve with the new proposed solutions to establish better and profitable systems that are beneficial for all. Electric vehicles mainly depend on the charge and exchange to maintain the operation, and the business will directly affect the development of the electric vehicle industry (Yan, 2016). The infrastructure and charging mode operations at current are divided into the following categories:

Conventional Charging

The conventional charging mode of electric vehicles is considered the first method devised for charging. It comprises rechargeable batteries that are provided power supply through the energy supply system. This solution is slow and inefficient when time and power consumption. These vehicle batteries take a few hours to charge up fully and hence, do not make a good charging solution as consumers might find it tedious. Looking at this first method of EV charging, it has some positives too. The model has little effect on the battery life; the battery life is long, the investment cost of the infrastructure is relatively low, and it is easy to realize (Yan, 2016).

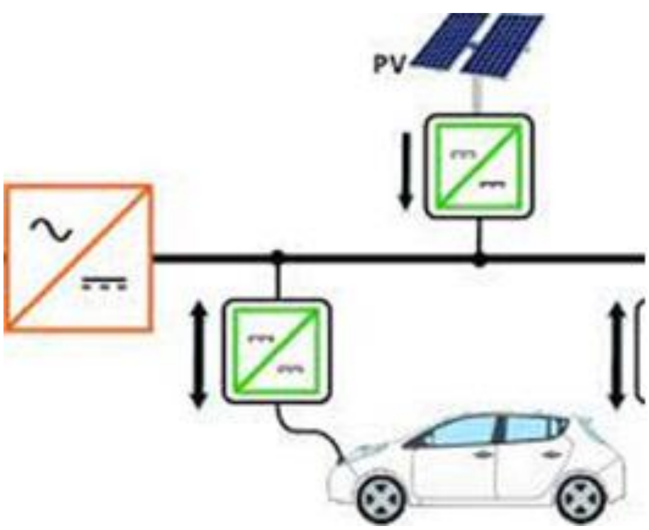

Figure 1: Conventional EV charging model

Fast Charging

As the name infers, the fast charging mode overcomes the limitations offered by the conventional charging mode, i.e., the charging time. The fast-charging infrastructure is designed to use a large amount of current to make the charging process quicker. With this mode, EVs can be charged in a few minutes. But this way of charging might end up harming the battery life. Fast charging mode can meet the needs of some sudden emergencies. Still, the fast charging mode adopts high-strength current charging. The battery life has a greater impact. The infrastructure investment requirements will be higher than the conventional charging mode to achieve a more conventional formula (Yan, 2016).

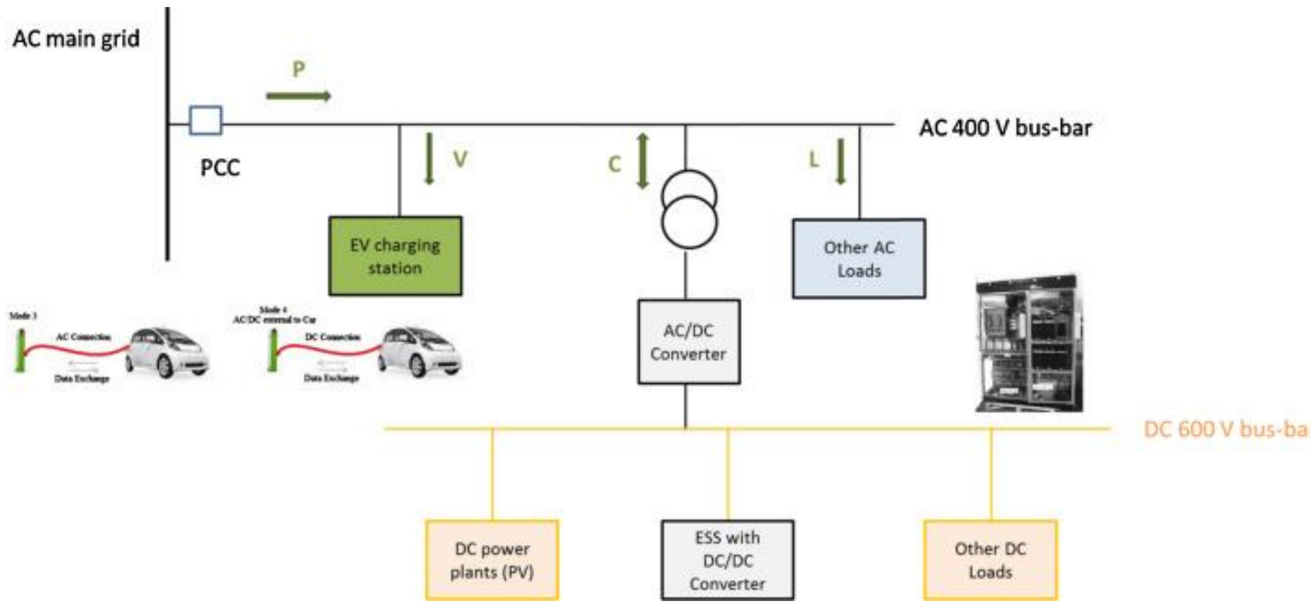

Figure 2: A Fast EV charging model

As shown in Fig 2, the fast charging model works by changing AC load to DC load, providing a greater current flow to the charging station. The vehicle's charging will complete in approximately 10 minutes, making EV charging efficient than the conventional model.

Cloud-Based Charging Infrastructure

Cloud computing has recently emerged as a technology enabler for smart cities, smart health, smart transportation, and smart environment, as well as for smart gird (Saqib et al., 2017). In the Electric Vehicle Market, Cloud computing has found its place in assisting seamless monitoring and Management for EV charging. This new smart way of electric vehicle charging system provides virtual storage spaces and reduces the high costs and duties of investments and productions (Chimakurthi, 2020). Cloud-based charging on electric vehicles has increased the demand for EVs as their commercial value increases. In this work, the remote xEV charging management system is proposed and analyzed based on its commercial service and effectiveness.

METHODOLOGY

For a systematic and efficient charging module, the method of xEV charging is idealized from the dynamics of cloud computing. It mainly follows the principles of duplex power and the energy trade mechanism for charging electric vehicles. Prototype software is used to input customer data parameters, including the current location, battery state, etc. The data is analyzed, and the vehicle is directed to a suitable EV charging station.

This proposed system (fig 3) xEVs Charging Management System demonstrate the significance of a cloud-based paradigm focused on deploying a smart and coordinated charging management framework for xEV fleet (Saqib et al., 2017). This prototype software provides an optimal solution to xEV customers, acting as a smart charging system connecting vehicles to their desired charging stations, maintaining information, and managing energy supply simultaneously.

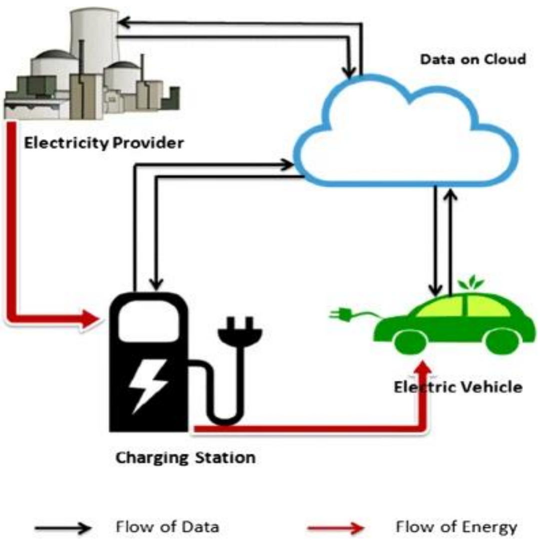

Figure 3: Data and Energy Flow on a cloud-based xEV system

Hardware Implementation of Load Management System

The main components of the load management system include:

- Embedded Computer System: The computer network provides a communication route for the client and the server. It also handles application and control operations.
- Periphery Controller Board: The controller board administers the local hardware control.

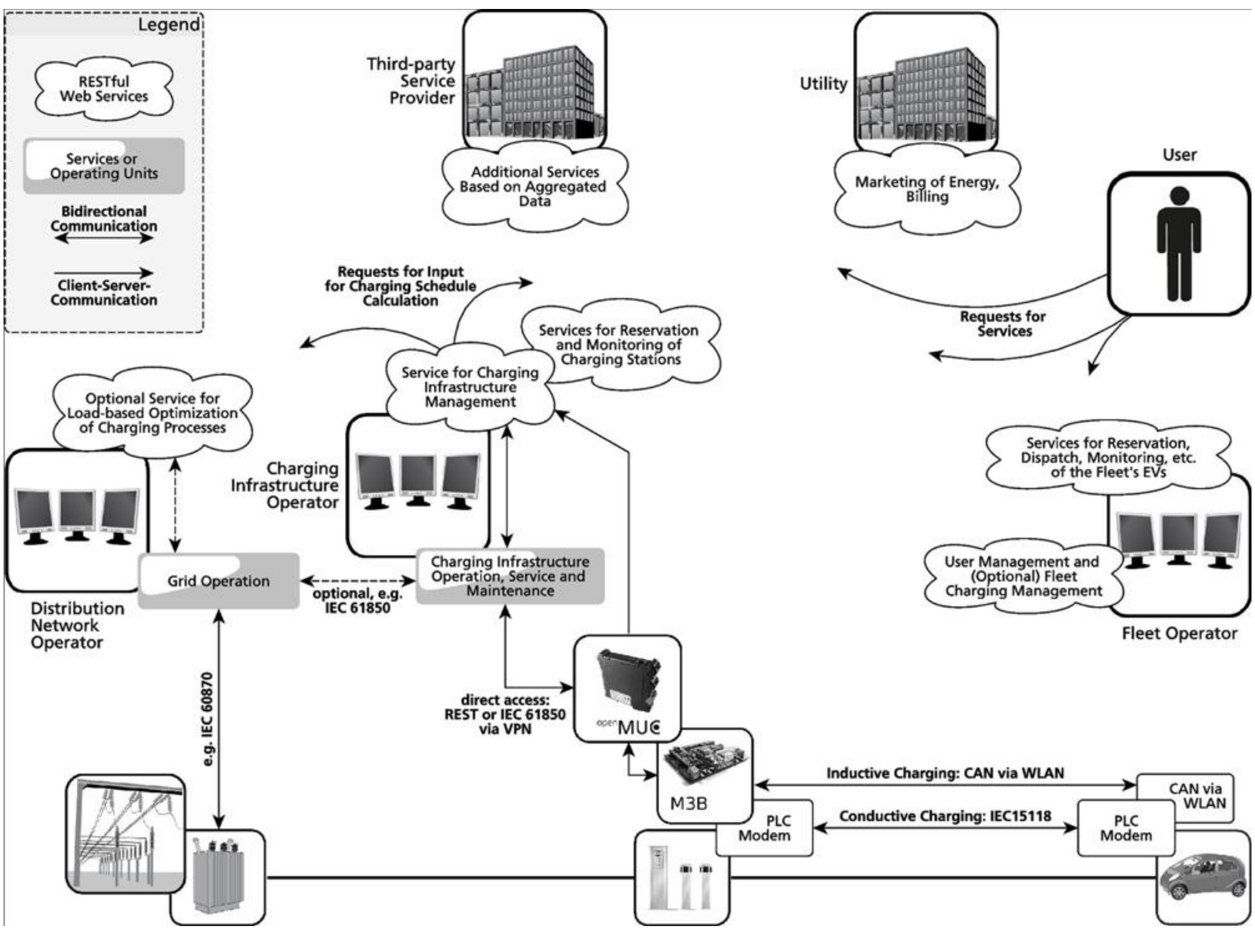

Figure 4: Overview of the Load Management System

Fig 4 gives an overall view of how the system works and how each channel is connected through interfaces. The proposed system follows the Representational State Transfer (REST) approach, which the cloud-based implementation and charging control algorithms. The system works when the client requests EV charging, which is processed by each channel and responded to by the server. The resources involved in the system play a crucial role in identifying the flow of data and energy and should be strategically designed. Focusing on the server's resources simplifies the implementation of these interactions, compared to the explicit declaration of services available to a client (Mierau et al., 2013).

The center's charging infrastructure operator is considered a pivot, responsible for managing every charging process within the system. The charging station requires a service to allow client data into the system as input. Since the charging infrastructure interacts with a single backend unit, the backend unit is responsible for providing the charging schedule to the charging station, using reference input to charge the client EV. The CIO carries on this charging infrastructure. The CIO then schedules the charging according to the stakeholder strategies and information. This way, a CIO is able to pool many charging stations and control their aggregated load in order to provide services like control energy (Mierau et al., 2013). Only the charging infrastructure has direct access to the charging stations in the system. Hence, the infrastructure works as a pivot in passing client information from the charging station among the system interface.

PROPOSED SYSTEM AND ITS IMPLEMENTATION

The proposed client-server system works on the E-mobility and infrastructure projects to devise an efficient cloud-based charging solution for electric vehicles. The project focuses on the energetic and IT interfaces between users, vehicles, and infrastructures of future urban mobility concepts revolving around shared usage of mobility resources (Mierau et al., 2013). Besides managing and monitoring EV charging stations and clients, the cloud-based charging module also assists in other technological advancements. The proposed project can implement the demonstrator system for tech-related cloud tasks. These include inductive charging infrastructure design, navigation cloud services, and vehicle positioning structures.

The two main applications for the proposed system for cloud-based EV charging are:

Client to Cloud Server Connection

The REST server directly connects the client requests to the cloud server in this implementation. Hence, the charging station is referred to as client-only. This client communication provides the main functionality of a controlled and managed charging system. Once the request is sent, the EV sends the CIO's client information, credentials, and charging parameters. The CIO now interacts with client services and calculates a charging schedule with a P(t) curve, communicated back to the EV.

Remote Server Connection

The local HTTP contains a REST-Servlet to cater to connections from remote applications. Such connections can only be maintained and catered through a Virtual Private Network (VPN) between the CIO and its connected charging stations. The charging station operator can administer the system behavior along this communication route. HTTP-PUT (sending data to the server to create or update a resource) and HTTP-GET (request data from the specified source) operations can be implemented on the communication channels connecting to the charging station. These channels are accessed through directory-like URLs. The incoming requests are integrated to blocked function calls, activating the functions on the locally attached components such as the periphery control device.

DATA RETRIEVAL DEVELOPED ON CHARGING DATA

The data mining process depending on the charging data is done through the clustering process where for each object belonging to the cluster, the λ neighborhood will have objects either greater or equal to the given value. As soon as the condition satisfies, the process of clustering continues to cluster all objects in the neighborhood. The density can be calculated through the number of λ neighborhood of objects. The process can be divided into the formation of several clusters where each cluster has a similarity measure upon completion. Similarity between clusters is identified with respect to the attributes of the particular object in the neighborhood. These attributes can also assist in finding out the density, connectivity or distance. To measure the efficiency of the process, it is devised that the higher similarity among different clusters, the better clustering.

This process can be described through a fixed algorithm. The information from the database is kept in a 0-1 matrix to generate frequent item sets using the pre-defined steps:

Step 1: 0-1 frequent sets are obtained by scanning all processors parallel to the databse.
Step 2: Analyzing the unused vector areas and erasing them from the matrix.
Step 3: Generate a set of candidate k such that there are k-1 sets with their own internal connection
Step 4: Processing to develop large item sets of k from the k sets
Step 5: Checking if the k set is empty. If found empty the algorithm ends, else going back to step

Before the algorithm is run, the database contains evenly distributed objects to all processors. As the scan starts, the position of the processor to its corresponding object is placed in the 0-1 matrix. This way after all processors are scanned, a complete matrix is obtained. Any empty vector spaces are removed from the matrix. The matrix formed contains rows representing data items and rows representing transactions. These steps are similar to the BOM algorithm where if there are "k" data items in "I" transactions then the matrix "CH" is formed as CH[1,i], CH[2,i], CH[3,i]…. CH[k,i] which will be initialized as 1. Empty spaces are initialized to 0 forming the complete 0-1 matrix.

Resource Allocation through Mobile Cloud Computing

Resource scheduling and allocation can be used for optimization and after optimization tasks such as the cost implementation etc.

Considering the task "t" is done in "T" time. Computational requirement for this task is "C." This can be computed using the formula,

$$\mathbf{T = C/(P^*\rho);} \tag{1}$$

P is the computing ability of sum of nodes, ρ is the proportion to fulfill the task in capacity node. The total time for the Transaction can be calculated as,

$$\mathbf{TT' = D/\beta;} \tag{2}$$

$$\boldsymbol{PT' = T' + \sum_{i=1}^{k} TT' * s} \tag{3}$$

Here" T'" represents the time at the ith position in the matrix and the final equation represents the nodes utilized for resource allocation and complete the computational tasks for all k nodes. "s" represents the ratio of time taken by each node.

The resource mapping for the computational task can be divided into the total time and total cost taken for its execution. The speed and direction of the search is used to define a particle which is discovered using local optimal and optimal solution. The algorithm for the search of each particle can be calculated with the direction and speed of search. It can be done using the following formulae:

$$\boldsymbol{x(n+1) = x(n) + v(n)} \tag{1}$$

$$\boldsymbol{v(n+1) = \lambda\, v(n) + \beta r\big(x'(n) - x(n)\big) + \beta' r'(x'(n) - x'(n))} \tag{2}$$

λ represents the proportion of search speed r and r' represent two randomly generated numbers for adjusting direction β and β' are two acceleration factors of the particle x(n) represents the position solution for the search whereas x'(n) represents the optimal solution for the search

For the algorithm to work efficiently, the key component i.e. the orientation matrix should be correctly formed. The direction of the orientation matrix represents the optimal solution of the global optimal solution. Hence, the importance of two goals should be precisely compared, analyzing the goal which is closer to the global optimum. This comparison of goals helps in forming the orientation matrix. Given below the general representation:

$$CH = \begin{bmatrix} 0 & \cdots & c1n \\ \vdots & \ddots & \vdots \\ cn1 & \cdots & 0 \end{bmatrix}$$

In this matrix, the direction can be represented by taking -1,0 and +1 as element value. For the result to be closer to the optimal solution the value is +1, however, if it is towards 0 then it will be assigned -1. Thus, the orientation matrix representation helps in identifying their relationship between the derived result and the optimal solution.

Current Charging Business

While assessing companies working in the EV charging market, asset ownership plays a key role in defining the business models and policies. Some companies, like ChargePoint and SemaConnect, focus on installing and operating a network in the charging stations, but do not retain ownership of the network. Maintaining a network but selling actual hardware to host sites is referred to as network-operator model. On the opposite side, the owner-operator model is the approach where the charging company invests in hardware infrastructure and makes profits as clients approach them. Companies like EVGo and Blink Network develop, operate, and own their charging networks.

Apart from these two major approaches, there are better-integrated approach methods followed by companies like Tesla. These companies work all four functions: manufacturing equipment, setting networks and hardware, and generating revenues. These companies are required to calculate their revenues and their investment costs. Large equipment manufacturers that produce, own, and operate charging equipment may also find that managing a fully integrated EV value chain does not function well alongside traditional operations (Hossen et al., 2021). These are the conventional business models working on the Electric vehicle charging infrastructure to make a sustainable and profitable charging station and management.

An intelligent business operation model is a more systematic approach to electric vehicle charging methods. This charging system uses an interface, business, and application layer stratification. An M2M network is used within the interface layer to recognize the connection between the station area management, vehicle area network management, and LAN management gateway. The second layer, i.e., the application layer, is responsible for transmitting complex calculations on the retrieved data using efficient algorithms to the operation support system. The data obtained can be referred to as the intelligent service operation data. The application layer also has special features such as battery detection and identification, vehicle security analysis, user data analysis, account status, and billing prompts. The data is then assisted through the business layer, where intelligent business operations are applied, such as intelligent scheduled charging. The charging business model layers operate on functions that help achieve business intelligence.

Charging Process of each Vehicle

The Internet of vehicles (IOV) has equipped the emergence of electric vehicles in the real world. IOV has a network that connects vehicles with various sensors, software and other technologies. The IOV approach has provided a way for efficient charging system integrating the studies of cloud computing and mobile technology forming a cloud based charging system for EV clients. This system works on cloud principles, where it stores information from the client request, run algorithms on the provided information and then directs the client to a suitable charging station.

As a vehicle enters the charging station, the RFID identification receiver gets a signal automatically (Hossen et al., 2021). The RFID passes information to the EV network getaway communication, and the intelligent identification system identifies relevant information such as vehicle number, license pin, etc.

The next step is battery identification. When the vehicle enters the charging station, the RFID signal automatically passes to the EV physical domain network gateway communication. An intelligent identification algorithm runs to determine vehicles' battery details such as model, manufacturer, number, etc.

After the vehicle and battery identification, the charging station undergoes a power detection process. While the vehicle is in the station, the charging station is automatically detected by the RFID receiver, and the information is communicated to the EV network area getaway. Safety inspection also plays a crucial role in the EV charging management process. When the vehicle is in the start state, safety detection is carried out. The vehicle working state, battery status, average electricity consumption, and discharging capability is tested in this process.

After the vehicle has passed the identification processes and safety checks, its charging position is determined. The charging position selection is based on the relevant information collected earlier, such as the battery, power station and empty station slots, etc. In case the selected charging position is found unsuitable for the clients' vehicle, a choice of changing the location is provided. The account status is also checked during verification, where arrear status and card information is verified before proceeding with the charging process.

After finalizing the power station and charging location, the charging preparation begins. The remaining power capacity is analyzed. Now the battery is ready to be charged or replaced with the same type of batter and transferred to the electric position where it is replaced. As soon as the charging process terminates, the billing events are automatically generated through the billing trigger.

Intelligent Security: security intelligence realized in the running process of the vehicle and do the whole safety of electric vehicle detection, including working state of the vehicle, battery status, instrument working state, remaining power, average power consumption, when electricity consumption, temperature, humidity, law etc., and comprehensive analysis with similar models of historical data security and on vehicle and driver of security early warning, to ensure the safe operation of the electric vehicle. This method of charging electric vehicles, where it enters the power station and completes the entire charging process is referred as intelligent charging.

This intelligent business model differs from the conventional charging system management, where the client has to go to the charging station and manually charge their vehicles. The process is time-consuming and less efficient. With Intelligence business models, the dynamics of electric vehicle charging have evolved

CLOUD-BASED CHARGING EV DEMAND RESPONSE

The case study, namely, "Electric Vehicle Managed Charging Demand Response" provides an insight into the market evolution of transportation as the dynamics of electric vehicles incur. While managed charging also faces some barriers, solutions are in process and could help prepare a solid foundation for V2G (Saqib et al., 2017). The future of fully electricity-operated transportation is near, and better-optimized solutions for their maintenance and charging management. Analyzing the February 2017 sales of EVs, it was discovered that 580,000 electric vehicles were sold in the US alone. This has readily increased the electricity consumption, predicted to rise at the rate of 33 Terawatt hours annually by 2025. The market growth of EVs escalates the demand for a charging monitoring and management system that is efficient.

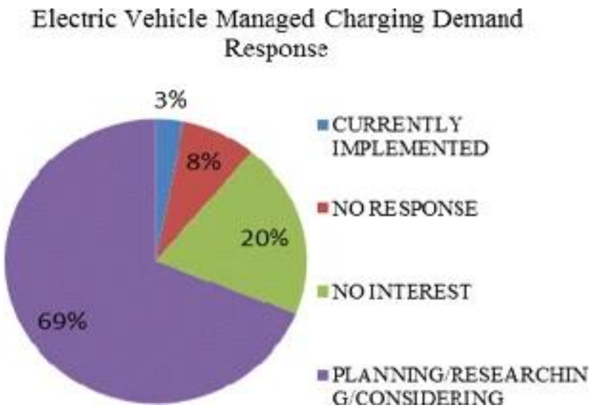

Figure 5: Utility Demand Response Survey, 2017

Figure 5 presents the statistics gathered by the Utility Demand Response Survey by Smart Electric Power Alliance (SEPA). The survey was to discover the prospects of finding a coherent and beneficial charging management system regarding the market and its stakeholders. Sixty-nine percent of the respondents were interested in planning, researching, or considering Demand Response (DR) programs to incorporate a managed and monitored charging system for electric vehicles.

Current Global Electric Vehicle Statistics

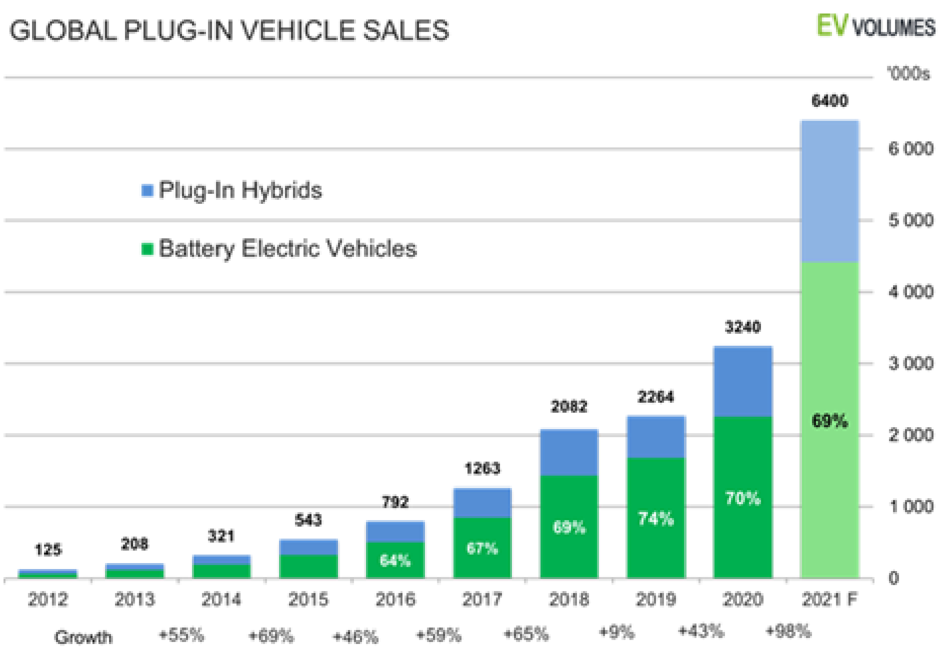

Figure 6: Trends in Electric Vehicle Sales Globally

Analyzing the recent trends of EV sales in Fig 6, it is discovered that the use of EVs increased exponentially in 2021. Moreover, the electric vehicle models, i.e., the Plug-in Hybrid and Battery EVs ratio, fluctuate. In recent times, the maintenance and charging and electric vehicles and charging stations have been hindering the sales and growth of the industry. Energy storage technology costs need to decrease so that EVs can financially compete with fuel-efficient 'normal' vehicles (Saqib et al., 2017). As a result of the survey, electric two-wheelers were seen to break the record of four-wheeler users. From a broader perspective, the sales that have reached a positive 98 percent mark in 2021 are expected to rise in the future as well. The US Information Administration (EIA) predicts the growth of light-duty electric vehicles globally up to 31 percent by 2050, a massive growth for the industry.

What needs to be addressed is efficiently managing EV clients' data and charging stations. The cloud-computing solution involving algorithms, smart simulations, quick data retrievals, etc., would be an optimal solution for EVs, increasing their worldwide deployment. The plug-in and battery electric vehicles can be accommodated through the cloud system by making easily accessible servers that clients can use to avail smart charging services. Mobile cloud computing will assist each client request to cater their vehicle to the referred charging station based on calculating client and vehicle information. The cloud charging system creates a seamless possibility of a long-term sustainable environment brought by electric vehicles, replacing conventional fuels such as diesel and natural gas. It will also replace the conventional methods of waiting for hours to fully charge the EV battery with a quick charging system, charging the vehicle fully in a few minutes.

Conclusion

In this paper, an insight into electric vehicle charging dynamics has been discussed, and a proposed system for an efficient cloud-based charging system is studied. The EV charging market is expected to expand in the near future. The main enabler for this market to develop is the data acquired, shared, and processed via the various services of the mobility data cloud. With the simulation developed and algorithms analyzed, a system of cloud-based EV charging and management is established that integrated into the business models prove to enhance the market growth. Two server methods, i.e., client-to-cloud and remote connections, accommodate every possible client. The data retrieving scheme and service-providing approach on client data are presented, becoming the foundation of mobile cloud computing for vehicle management.

References

Azam, M. A., Mittelmann, H. D., & Ragi, S. (2021). UAV Formation Shape Control via Decentralized Markov Decision Processes. *Algorithms*, *14*(3), 91. https://doi.org/10.3390/a14030091

Chen, Y. W., & Chang, J. M. (2018). Fair Demand Response with Electric Vehicles for the Cloud Based Energy Management Service. *IEEE Transactions on Smart Grid*, *9*(1), 458–468. https://doi.org/10.1109/tsg.2016.2609738

Chimakurthi, V. N. S. S. (2017). Cloud Security - A Semantic Approach in End to End Security Compliance. *Engineering International*, *5*(2), 97-106. https://doi.org/10.18034/ei.v5i2.586

Chimakurthi, V. N. S. S. (2020). Digital Asset Management in the Communication of Product Promotional Activities. *Asian Business Review*, *10*(3), 177-186. https://doi.org/10.18034/abr.v10i3.587

Choma, E. F., Evans, J. S., Hammitt, J. K., Gómez-Ibáñez, J. A., & Spengler, J. D. (2020). Assessing the health impacts of electric vehicles through air pollution in the United States. *Environment International*, *144*, 106015. https://doi.org/10.1016/j.envint.2020.106015

Efthymiou, D., Chrysostomou, K., Morfoulaki, M., & Aifantopoulou, G. (2017). Electric vehicles charging infrastructure location: a genetic algorithm approach. *European Transport Research Review*, *9*(2). https://doi.org/10.1007/s12544-017-0239-7

Hossen, M. A., Diwakar, P. K. & Ragi, S. (2021). Total nitrogen estimation in agricultural soils via aerial multispectral imaging and LIBS. *Scientific Reports, 11*, 12693. https://doi.org/10.1038/s41598-021-90624-6

Hossen, M. A., Zahir, E., Ata-E-Rabbi, H. M., Azam, M. A., and Rahman, M. H. (2021). Developing a Mobile Automated Medical Assistant for Hospitals in Bangladesh. 2021 IEEE World AI IoT Congress (AIIoT), 0366-0372, https://doi.org/10.1109/AIIoT52608.2021.9454236

Khayyam, H., Abawajy, J., Javadi, B., Goscinski, A., Stojcevski, A., & Bab-Hadiashar, A. (2013). Intelligent battery energy management and control for vehicle-to-grid via cloud computing network. *Applied Energy*, *111*, 971–981. https://doi.org/10.1016/j.apenergy.2013.06.021

Litzlbauer, M. (2012). Grid integration of electric vehicles considering the mobility needs. *World Electric Vehicle Journal*, *5*(3), 629–634. https://doi.org/10.3390/wevj503062

Manavalan, M., & Chisty, N. M. A. (2019). Visualizing the Impact of Cyberattacks on Web-Based Transactions on Large-Scale Data and Knowledge-Based Systems. *Engineering International*, *7*(2), 95-104. https://doi.org/10.18034/ei.v7i2.578

Mierau, M., Fey, S., Kohrs, R., & Wittwer, C. (2013). Communication Solutions for a Cloud-Based Charging Management System for a Fleet of Shared-Use Electric Vehicles. *World Electric Vehicle Journal*, *6*(4), 1125–1135. https://doi.org/10.3390/wevj6041125

Saqib, M., Hussain, M. M., Alam, M. S., Beg, M. M. S., & Sawant, A. (2017). Smart Electric Vehicle Charging Through Cloud Monitoring and Management. *Technology and Economics of Smart Grids and Sustainable Energy*, *2*(1). https://doi.org/10.1007/s40866-017-0035-4

Yan, Z. (2016). Research on Mobile Cloud Computing Services for Electric Vehicle Charging Facilities. *International Journal of Grid and Distributed Computing*, *9*(7), 225–236. https://doi.org/10.14257/ijgdc.2016.9.7.23

--0--