Charging Support communication System based on Vehicle-to-Vehicle Communication for Electric Vehicles

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***Abstract*—Due to the long charging duration and the increased number of Electric vehicles (EVs), the issue of EV charging is becoming more challenging. Establishing an efficient communication framework between EVs and charging stations to select an appropriate charging station is becoming of utmost importance. However, when EVs simultaneously send vehicle status parameters i.e., charging requests, state of charge, and distance to the charging stations; the network becomes dense and causes problems like packet collisions, data thrashing, and broadcast storms. The goal of this study is to support the charging management system for electric vehicles that efficiently selects the charging station based on vehicle-to-vehicle communication while preventing broadcast storm problems. The simulation results show that the proposed system outperforms the centralized scheme in terms of message penetration delay, message delivery ratio, and network overhead.**

***Index Terms*—Electric Vehicle, Charging Management, Vehicular Ad-hoc Networks, Broadcast Storm**

I. Introduction

With increasingly stringent criteria for economic growth and environmental protection, the widespread utilization of electric cars/vehicles (EVs) has become a foregone conclusive for the advancement of new energy resources, with the benefit of conservation of energy and a slight decrease in the outflow. EVs are recommended over gas-powered automobiles because they can effectively minimize pollution caused by non-renewable sources of energy such as coal and oil. Generally, an EV uses around 10-kilowatt hours with every fifty to sixty kilometers it journeys. Currently, around 3.2 million electric vehicles (EVs) are on the roads around the world and about 750,000 of these are in the United States [1]. Using EV provides a lot of benefits that are not available in conventional vehicles. Although electric motors react immediately, EVs seem to be very reactive and have much more torque. EVs are far more digitally advanced than conventional automobiles, with multiple EV charging stations provided to be monitored via a mobile application. EVs create significantly lower greenhouse gas emissions than internal combustion engine automobiles [2].

Since EVs movement relies on chargeable batteries, therefore, it is a more challenging task to properly manage the battery lifespan so that it can last for the maximum period. Therefore, the researchers have proposed many EV charging management schemes to avoid unnecessary battery consumption. EV charge management is the method of selecting the most appropriate charging station (CS) for EV charging among available CSs. In general, the EV charging management scheme can be divided into centralized and decentralized methods. In the centralized method, the charging monitoring is handled by a centralized controller named centralized charging management scheme (CCMC) which is comprised of Electric Vehicles, Charging Stations, Road Side Units (RSUs), and a communication network. When an EV's state of charge (SoC) goes below a certain threshold, it sends charging requests along with information (vehicle ID, SoC, position, speed, etc.) to a centralized controller through Wi-Fi, mobile service, or Bluetooth. SoC estimation is very important to monitor and optimize the performance of the batteries by controlling their charging and discharging. Accurate SOC estimation can tell that how long an EV can drive before charging [3]. The centralized controller will also receive CSs data (such as charging capacity and queue length). Therefore, the controller analyses the massive amount of data in real-time. Afterward, the controller selects an optimum route where an EV can charge its battery to continue its journey with the least cost and time delay [2].

In the decentralized method, the charging management is carried out individually by each vehicle. The RSUs and charging stations communicate with each other to share vehicle and charging station information. Therefore, When a particular vehicle residing within the com-

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munication range of RSU wants to recharge a battery, it receives all the charging station information from RSU and chooses the best suitable charging station from the list. The decentralized method has higher privacy sensitivity and data security.

The main contribution of this research is to create a charging management system for electric vehicles that will decrease the charging station selection time based on vehicle-to-vehicle communication while preventing broadcast storm problems. Using the received charging station information, a vehicle under the proposed EV charging plan intelligently avoids broadcast storm problems and selects an appropriate charging station. EVs receive charging station information which is periodically broadcasted by the charging station to nearby electric vehicles. The charging station information is then shared by EVs using vehicle-to-vehicle communication. We can list our contributions as follows:

- Developing an algorithm to broadcast the charging stations' status information to nearby vehicles.
- Applying broadcast suppression mechanism by implementing slotted-1 persistence scheme to reduce broadcasting overhead. In slotted-1 persistence scheme, When a node receives a packet for the first time and hasn't received duplicates before its assigned time slot, it rebroadcasts it with certainty of 1. Otherwise, the packet is discarded.
- Enable EVs to utilize vehicle-to-vehicle communication to increase the dissemination distance of messages in an urban vehicular environment.
- The shared CSs status information can be utilized to find an optimum charging station while simultaneously reducing overcrowding at charging stations.

The rest of the paper is arranged as follow: Section II briefly describes and introduces the background and related works. The proposed methodology is briefly explained in Section III. The results and performance metrics are discussed in Section IV and finally, we conclude the proposed research in section V.

II. Literature Review

Many studies have been conducted on the issue of EV charging monitoring in an effort to mitigate the drawbacks of broad EV adoption and fully investigate possible advantages of EV integration. Numerous EV charging planning domains, including traffic flow analysis, the EV charging market, operational planning, and coordinated charging, have been the subject of many research works. However, charging control management for electric cars is now a study area that is becoming more and more important. The choice of charging stations to manage charging schedules and the creation of an efficient communications network between charging stations and EVs are important technological concerns. This section includes a comprehensive literature analysis to aid readers in understanding the most recent academic research on EV charging management.

Pastorelli et al. [4] designed and proposed a tool that detects the charging options available along a route by simulating a trip in an electric vehicle to assess the charging station planning in an area and highlight the major issues. A smart EV charging suggestion methodology, as well as a mobile edge computing (MEC) framework, is proposed in [5]. The global controller is used which acts as a centralized cloud server to check CS capacity and EV charging reservation to estimate CS charging availability. MEC servers offer information access control, aggregation, mining, the charging recommendations based on EV's charging reservation as well as parking deadlines. Bautista et al. [6] presented an effective charge management system for EV charging. The proposed scheme utilizes an advanced communication infrastructure based on geographic routing techniques to reserve a charging slot. Elghitani et al [7] presented a technique for efficiently assigning EVs to charge stations as a result of which the overall average service duration time is reduced. They have made use of the ”resource sharing” idea, in which a charging station supplies electricity to EVs from neighboring sites in addition to the cars in its immediate neighborhood.

Vehicle-to-grid (V2G) charging and renewable energy generation techniques with a range of energy output, energy tariffs, and service types were adopted by Tang et al. [8]. In this scheme, each EV client must decide which route to take in order to finish their journey with the least amount of cost and delay, as well as what and where to charge their battery at the charging sites along that route. To make charging reservations and route planning more practical, Cao et al. [9] proposed a charging reservation decision-making model that considers traffic conditions, charging resources, and pricing, as well as the traveling capacity and charging capabilities of electric cars. George et al. [10] proposed a method that enables the controller to interchange various information like the battery's state of charge, the location of the closest charge terminals, and the degree of congestion at charging points. Moreover, GSM, GPS, and a separate website have been used in their proposed approach to offer actual information to consumers through a website link. Danish et al. [11] proposed a blockchain-based (Block-EV) efficient CS selection system for EVs that ensures information privacy, dedicated time slots at CSs, excellent Quality of Service (QoS), and enhanced Electric vehicle consumer satisfaction.

Gan et al. [12] have suggested an optimum decentralized charging (ODC) algorithm for scheduling EV charging. To change EVs charging profiles, a utility provider transmits a control signal to all EVs. The utility solely utilizes control signals, such as power costs, to aid EVs in selecting charging profiles. The decentralization means that instead of being directed by a centralized infrastructure, all EVs select their own charging profiles. Furthermore, at the start of the scheduling horizon, all EVs are accessible for discussion and both the EVs and the utility company use an iterative technique to estimate the charging rates for each time slot in the future. EVs adjust their charging profiles autonomously in response to the utility's control signal and communicate the revised charging profiles to the utility. The utility modifies the control signal based on the charging profile supplied. Every iteration, each EV adjusts its charging profile, and every iteration, the utility updates the control signal. The drawback of the proposed ODC is that all the EVs communicate with utility provider to update their charging profiles which eventually increases the message propagation delay and reduces delivery ratio due to largest congestion over wireless communication medium.

Paudel et al. [13] have introduced a fully decentralized cooperative approach (DCA) that facilitates charging coordination management through cooperation among charging station entities, eliminating the need for a centralized coordinator and ensuring the privacy of EV owners. Each charging station comprises multiple nodes, including transformers and EV chargers (EVC) equipped with charging outlets. These nodes are equipped with local controllers capable of communication and computations with neighboring nodes. The charging station is organized into two layers: the physical layer, which encompasses the electrical connections between nodes and smart chargers that regulate charging current for EVs, and the virtual layer, which facilitates communication among nodes. The proposed EV charging algorithm is executed at the start of each interval, maintaining a consistent outcome throughout that period. Agents interact with neighboring agents to execute the iterative algorithm outlined in the paper. At each time interval, the algorithm commences with the initialization and broadcasting of initial variable values, which significantly impact the convergence of the algorithm. In contrast to the ODC algorithm by Gan et al. [12], the proposed DCA scheme eliminates the necessity for a central coordinator in charging management. Instead, it enables collaboration among neighboring EVs within a single charging station. However, a drawback of this proposed scheme is the lack of cooperation between different charging stations, and the EVs within the network have no information about the availability status of other charging stations.

Cai et al. [14] address the challenge of efficiently transmitting small data sizes in frequent Electric Vehicle (EV) and charging station control messages. Their proposed solution involves employing both Vehicle-to-Vehicle (V2V) communication and network coding (NC). This strategy aims to enhance transmission efficiency within scheduled resource blocks. In the downlink scenario, where control messages are sent to individual EVs, a Base Station (BS) utilizes network coding to combine packets for vehicle groups, which are then broadcasted. A mature vehicle in the group, having received sufficient linear combinations, takes charge of data delivery. This leverages spatial diversity through V2V/V2I transmissions, boosting spectrum efficiency. Network coding also reduces control and feedback overhead by requiring the BS to ensure that at least one vehicle in the group receives adequate linear combinations. This optimizes downlink transmission resources and enhances overall data transmission efficiency. Wang et al. [15] focus on investigating an innovative smart grid model, termed a VANET-enhanced smart grid, which integrates vehicular ad-hoc networks (VANETs) to facilitate real-time communication between road-side units (RSUs) and mobile electric vehicles (EVs). This communication aids in collecting instantaneous vehicle mobility data and making charging decisions. They introduce a mobility-aware coordinated charging approach for EVs, designed to optimize energy consumption while averting power system overload. Additionally, it tackles the range-related concerns of individual EVs by reducing their average travel costs. The strategy accounts for two factors affecting mobility-incurred travel costs: the distance between an EV's current location and a charging station, and the transmission delay for receiving charging instructions via VANETs.

Experts have developed a keen interest in Vehicular Ad-hoc Networks, or VANETs, because of their numerous benefits, which include enhanced road safety through the interchange of emergency alerts among vehicles [16]. The infrastructure of these networks is not fixed, because network topologies are changing all the time. VANETs can utilize stable cellular gateways, WLAN wireless routers, and any availability of internet link infrastructure; hence shouldn't have to depend on a complete ad hoc networking infrastructure. Vehicles are equipped with onboard modules that allow them to communicate with one another. Short messages can be delivered via Vehicular communications to boost traffic safety. Vehicles travel at significantly faster speeds than nodes in the other forms of MANETs, and the topology of the network alters frequently. Broadcast Storm happens in VANETs while all cars broadcast messages over the shared wireless channel at almost the same instant. Due to the common channel, a broadcast storm would develop when all the vehicles rebroadcast the data at the same instant. However, if only just a few vehicles repeat

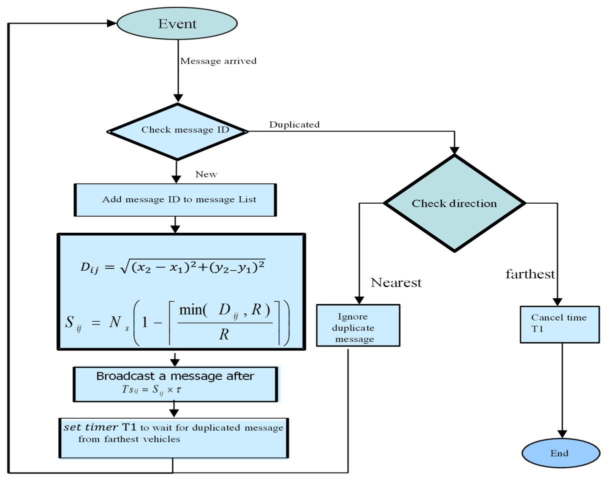

Fig. 1: Flow chart of Proposed CSS-V2V Scheme

the information, it will be enough to deliver the message in the target location [17].

III. The Proposed Methodology of CSS-V2V

The methodology of the proposed Charging Support communication System based on Vehicle-to-Vehicle Communication for Electric Vehicles (CSS-V2V) is presented in this section. Some key elements are utilized by this scheme so that the average waiting times of EVs to reach CSs can be minimized. Key elements of the proposed CSS-V2V scheme are as follows:

- Charging station (CS): CSs are used to provide charging facilities to EVs. These stations continuously broadcast messages to the passing EVs. These messages contain CS sender ID, message ID, position information, charging capacity, vehicle queue lengths, and available parking slot information.
- Electric Vehicle (EV): EVs are electric vehicles that are moving along the road at different velocities. Each EV is equipped with GPS and communicates with other vehicles using Dedicated Short Range Communication (DSRC) [17] standard. The message transmitted by CSs is received by EVs and then shared with other EVs using V2V communication.
- Vehicle to Vehicle communication (V2V): V2V communication is utilized by EVs to disseminate CSs information among neighbor vehicles.

This research focuses on a city environment in which vehicles are well-connected. A charging station (CS) at a specific location broadcasts a message to approaching EVs continuously. Generally, a message like this can only benefit vehicles that need to charge their batteries. As a result, the proposed CSS-V2V protocol publishes CSs information to several vehicles to help them locate CSs in the shortest time possible.

The CS broadcasts a message to all surrounding EVs continuously. The Sender ID, message ID, position information, charging capacity, vehicle queue lengths, and available parking slots are included in the CS message format. The sender ID shows the specific ID of the CS that is sending the message, the message ID shows the specific ID of each produced message, the position information shows the GPS location of CS, the charging capacity shows the capacity of CS to recharge the EVs battery packs, the vehicle queue lengths shows the number of EVs waiting for charging facilities at CS, and the number of parking slots shows the total number of EVs that can be compensated by CS.

When EV receives a message from either CS or a nearby EV, it examines the ID of the received message to see whether it's a fresh message or a duplicate message as shown in Figure 1. If the message is new, it is placed on the message list, after which the EV rebroadcasts it. The messages are not re-transmitted simultaneously by all listening vehicles; instead, each vehicle uses a slotted 1-persistence [17] strategy to rebroadcast the message at a particular time slot T. If a node receives a packet for the first time and has not received any duplicates before its given time slot, it rebroadcasts with probability 1 at the allocated time slot (Ts_{ij}) given in Eq. 1 where τ is the estimated one-hop delay, which includes the medium access delay and propagation delay, and S_{ij} is the assigned slot number determined using Eq. 2. However, if it is the duplicated packet, then it is discarded.

$$Ts_{ij} = S_{ij} * \tau \tag{1}$$

The transmission range is spatially split into five equal circular slots, where the vehicles positioned in the farthest slots have a lower waiting time and the nearest slot has a higher waiting time. It means that the vehicles in the farthest slot can send messages with higher priority than the nearest slots. However, if due for some reason vehicles in the furthest slot cannot send the message then the vehicles in the second last slots send that message accordingly. The slot numbers (S_{ij}) [17] are determined by using Eq. 2 where the relative distance between nodes i and j is denoted by (D_{ij}), the maximum transmission range is denoted by R and the predefined number of slots is denoted by (N_s).

$$S_{ij} = N_s(1 - (\frac{min(D_{ij}, R)}{R})) \tag{2}$$

The circular broadcast suppression mechanism is illustrated in Figure 2, where the vehicles positioned in the farthest slots have a lower waiting time. Vehicles in slot 0, i.e. vehicles A & B rebroadcast the message with probability 1 at slot time T=0. All vehicles in the other four slots terminate their rebroadcasting timers upon

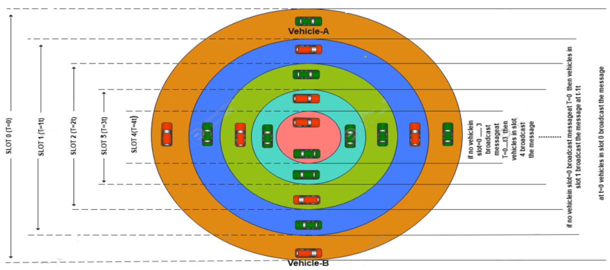

Fig. 2: Circular Broadcast Suppression mechanism

receiving a duplicated message, as the farthest vehicles, A, and B, have already been informed of the incident.

IV. Results Discussion and Performance Evaluation

In this section, the performance of CSS-V2V is compared with a centralized scheme [8], ODC [12] and DCA [13] using simulations of various traffic conditions.

A. Simulation Environment

The presented CSS-V2V protocol is implemented using Network Simulator-2 (NS-2, version 2.35). Vanet Mobisim [18] is used to generate mobility traces that provides different mobility models for city environment. Graph Walk model is used to generate mobility models of vehicle traces using network graph defined by the user. In our targeted VANET mobility scenario set in an urban area, we utilize a 10 km^2 area graph created using the Graph Walk model. To facilitate accurate comparisons, the 10 km^2 is subdivided into four 5 km^2 areas, where data is collected independently for each section and later averaged to compare various metrics. A total of 100 charging stations are strategically positioned within the network graph, with 25 charging stations in each 5 km^2 area, and each charging station occupying a 1 km^2 area. For seamless interaction, each charging station broadcasts a CS message to approaching vehicles every 10 seconds. The vehicles in the network move at different speeds, ranging from a minimum vehicle speed of 10 km/hr (Vmin) to a maximum vehicle speed of 80 km/hr (Vmax). This variance in vehicle speeds allows us to observe the system's behavior and performance under realistic conditions. All the vehicles communicate with each other by utilizing dedicated short-range communication (DSRC) that uses IEEE 802.11p as a protocol for medium access. In the proposed CSS-V2V scheme, the transmission range for Electric Vehicles (EVs) and Roadside Units (RSUs) is set to 250 meters.The vehicles are deployed within the city environment in seven different vehicle densities ranging from 1500 to 10500 vehicles. The timer T1 in the proposed CSS-V2V is set to 2.5 ms after finding an optimal value via various experiments. Each charging station generated 1000 CS messages to collect results for each vehicle's density. For every vehicle density, a simulation time of 10,000 seconds was set. The results presented are averaged over 5 simulation runs for each vehicle density.

B. Performance Metrics

The performance of the proposed CSS-V2V protocol is evaluated through a comparison with existing schemes [8], [12], [13], utilizing the following metrics to assess its effectiveness: message penetration delay, message delivery ratio, and network overhead. These metrics serve as crucial indicators in determining how well the CSS-V2V protocol performs in comparison to the already established approaches.

- Message penetration delay: The average time taken by a message generated by CS to reach all the vehicles within 5 km^2 area. The 5 km^2 area is deliberately chosen to restrict the penetration of broadcast messages. Opting for a 10 km^2 area for broadcast message propagation would exacerbate the broadcast problem, and there would be no significant advantage in searching for charging stations situated at a distance of 10 km.
- Message delivery ratio: It is the percentage of vehicles that received the CS message successfully within 5 km^2 area.
- Network overhead: It is the average amount of duplicated messages transmitted by vehicles in the proposed CSS-V2V scheme. Additionally, the overhead encompasses not only the request messages from vehicles and status update messages from RSUs in a centralized scheme [8] but also messages generated by utility providers and EVs in ODC [12], as well as messages exchanged among neighboring EVs within individual charging stations in DCA [13].

C. Simulation Results

1) Message penetration delay : In Figure 3, the comparison of message penetration delay for CSS-V2V with three other schemes is depicted, considering seven distinct vehicular densities. The assessment in Figure 3 is based on vehicle speeds ranging between 10 km/hr and 80 km/hr. The graphical representation of the centralized, ODC, and DCA protocols illustrates that as the vehicle density increases, the message penetration delay also increases.This trend can be attributed to the fact that in centralized and ODC schemes, messages are only transmitted from RSUs and utility providers, respectively, to passing EVs, due to the absence of V2V communication. Consequently, delays escalate with growing vehicle density, stemming from the heavier load on central infrastructure. The DCA protocol, on the other hand, sees its delay increase as the number of vehicles within a charging station expands, leading to higher communication overhead among neighboring vehicles due to the lack of broadcast suppression mechanisms. However, for the proposed CSS-V2V scheme, the message penetration delay decreases with the increase in vehicle density. This is because in the proposed CSS-V2V scheme, broadcast suppression mechanism is applied where vehicles in slot 0 transmit immediately causing vehicles in the remaining slots to stop their re-transmissions. This suppression mechanism reduces the broadcast storm problem and collision among neighboring vehicles which eventually reduces the message penetration delay.

Furthermore, the message penetration delay for CSS-V2V surpasses other schemes in sparse networks (e.g., 1500 vehicles). In the CSS-V2V scheme, transmission range is divided into five fixed slots, with vehicles in slot 0 transmitting without delay. However, in a sparse network, vehicles are spread over larger distances, resulting in numerous empty slots that subsequently elevate the message penetration delay for the CSS-V2V protocol. However, in dense vehicular scenarios (4500 to 1400 vehicles), the message penetration delay for CSS-V2V is lower than that of the centralized and ODC schemes, as discussed previously.

Notably, the DCA protocol consistently demonstrates lower delay than centralized and ODC schemes across all vehicle densities, and in four vehicle densities (1500 to 6000), it outperforms the CSS-V2V scheme. This stems from the DCA protocol's removal of central coordination and fostering collaboration among neighboring vehicles within a single charging station. As a result, the DCA algorithm incurs less delay by focusing on fewer vehicles collaborating with a single charging station compared

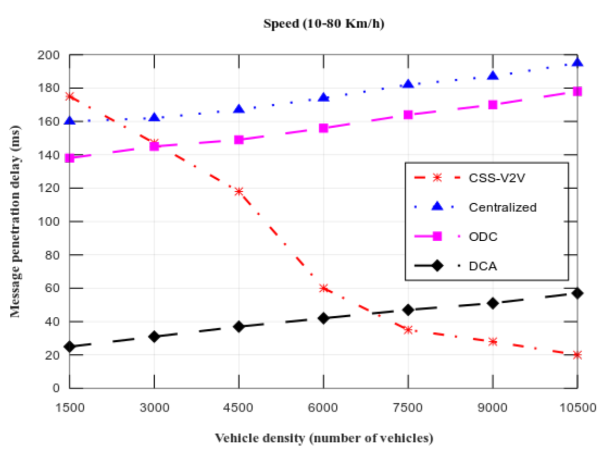

Fig. 3: Comparing CSS-V2V with Centralized, ODC and DCA schemes in terms of message penetration delay.

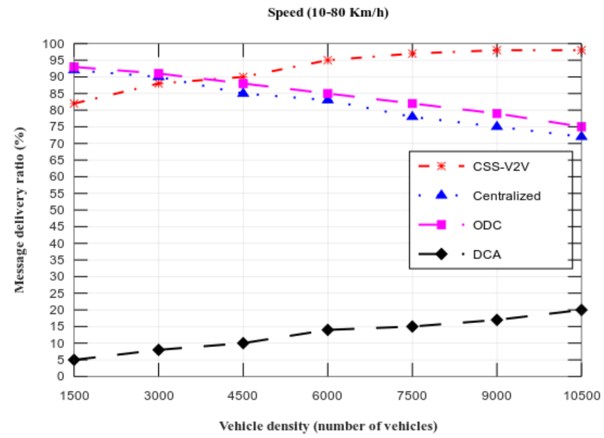

Fig. 4: Comparing CSS-V2V with Centralized, ODC and DCA schemes in terms of message delivery ratio

to the widespread communication in the CSS-V2V and other schemes. Furthermore, the DCA protocol attains reduced delay by sacrificing communication with other charging stations in the network, limiting EVs' access to optimal charging station information, which impacts the overall significance of the DCA protocol.

In summary, CSS-V2V generally exhibits a marginally higher message penetration delay compared to centralized and ODC schemes at a density of 1500. Nevertheless, in denser vehicular scenarios, it showcases significantly lower delay, far outperforming the centralized and ODC schemes. The DCA protocol consistently achieves lower delays due to its unique approach, although it operates with limited information exchange among charging stations and EVs.

2) Message Delivery Ratio: In Figure 4, a comparison is presented between the proposed CSS-V2V scheme and three other schemes across seven distinct vehicular densities. The graphical representation highlights a trend where the centralized and ODC protocols experience a decrease in message delivery ratio as the vehicle density increases. This decline can be attributed to the fact that in centralized and ODC schemes, messages are exclusively transmitted from RSUs and utility providers to passing EVs due to the absence of V2V communication. Consequently, as vehicle density grows, the absence of V2V communication leads to increased delays and a heavier load on central infrastructure, resulting in collisions within the wireless medium that cause message drops.

However, in the case of the proposed CSS-V2V scheme, there is an upward trend in the message delivery ratio with the rise in vehicle density. This positive correlation can be attributed to the application of a broadcast suppression mechanism within the CSS-V2V scheme. As per this mechanism, vehicles occupying slot

0 initiate immediate transmissions, prompting vehicles in the remaining slots to cease their re-transmissions. This strategic suppression strategy effectively mitigates broadcast storm issues and minimizes collisions among adjacent vehicles. Consequently, the instances of message drops decrease, leading to an enhanced message delivery ratio within the CSS-V2V framework. In scenarios with a low vehicle density, specifically at 1500 and 3000 vehicular counts, the delivery ratio within the proposed CSS-V2V scheme exhibited a decline. This decrement can be attributed to specific circumstances where certain vehicles failed to receive CS messages. Such instances occurred due to two main factors: firstly, disconnected neighboring vehicles encountered a timeout before a new approaching vehicle came into proximity; and secondly, during the broadcast, no other vehicle fell within the transmission range. The aforementioned conditions combined to contribute to a lower delivery ratio within the CSS-V2V scheme, particularly in scenarios characterized by limited vehicular presence.

In a similar vein, within the DCA scheme, the delivery ratio showcases an upward trajectory as vehicle density increases. This phenomenon is rooted in the DCA protocol's unique characteristic of eliminating central coordination, thereby promoting collaboration among neighboring vehicles situated within a singular charging station. Consequently, the DCA algorithm encounters reduced contention, as it prioritizes a more limited number of vehicles collaborating with a single charging station, as opposed to the broader communication scope observed in the CSS-V2V and other schemes. Nevertheless, it's important to note that the delivery ratio achieved by the DCA scheme remains comparatively modest when contrasted with other schemes.. This divergence is attributed to the inherent nature of the DCA scheme, wherein collaboration is limited to neighboring EVs exclusively within a single charging station's scope. This means that no collaborative interaction takes place among different charging stations within the network. Consequently, EVs within the network lack information about the availability status of charging stations beyond their immediate vicinity, which has a direct impact on the delivery ratio of the DCA scheme.

3) Network Overhead:: Figure 5 presents a comparison of the network overhead across CSS-V2V, centralized, ODC, and DCA schemes in terms of network overhead. As depicted in the figure, both the centralized and ODC schemes exhibit a linear increase in network overhead as vehicular density rises. This phenomenon can be attributed to the elevated volume of charging station information requests generated by vehicles in the centralized scheme, which escalates with denser traffic. Furthermore, the network overhead in these schemes includes the additional load of status messages generated by RSUs to update the centralized controller. Comparatively, the ODC scheme demonstrates a slightly lower network overhead than the centralized scheme. This reduction can be attributed to the direct communication between EVs and the utility provider, bypassing the communication overhead associated with RSUs.

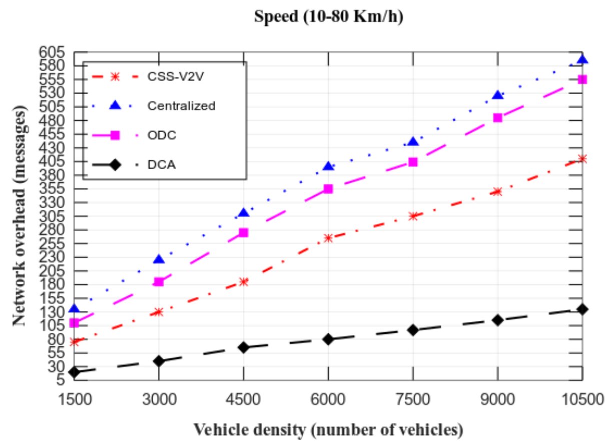

Fig. 5: Comparison of CSS-V2V and centralized scheme with respect to network overhead (40-80 km/h)

In contrast, the proposed CSS-V2V scheme boasts a reduced network overhead due to its slotted scheme. This approach suppresses broadcast messages and prevents individual vehicles from rebroadcasting the same message. Remarkably, the network overhead of the DCA scheme is notably lower than that of other schemes. This can be traced back to the DCA protocol's core principle of eliminating central coordination in favor of promoting collaboration among nearby vehicles within a single charging station's domain. Consequently, the DCA algorithm incurs diminished network overhead by focusing on a smaller subset of vehicles engaged with a single charging station. This contrasts with the broader communication scope seen in the CSS-V2V and other schemes.

In summation, the proposed CSS-V2V scheme surpasses alternative schemes in terms of network overhead. It achieves this through the dissemination of comprehensive charging station information to every vehicle within the network, effectively enhancing performance in this aspect.

V. Conclusion

In this research work, a charging support communication system using vehicle-to-vehicle communication for vehicular ad-hoc networks named CSS-V2V is proposed. The goal of CSS-V2V is to alleviate a broadcast storm problem in the city environment while broadcasting charging stations information. The proposed scheme is fully distributed and relies on V2V communication provided by one-hop neighbors. In the proposed scheme, the transmission range of the vehicle is divided into five slots based on receiving vehicle's position from the sender vehicle. This protocol consists of two main elements: (a) Sending CS messages, and (b) broadcast suppression. The charging stations continuously broadcast a CS message after every 10 seconds and the receiving vehicle forward it to one-hop neighbors by applying a broadcast suppression mechanism.

The proposed CSS-V2V scheme, with its broadcast suppression mechanism, offers a unique advantage. It demonstrates a reduction in message penetration delay as vehicle density increases. The CSS-V2V scheme showcases an upward trend in the message delivery ratio as vehicle density increases, contrasting with declining ratios in centralized and ODC schemes. The broadcast suppression mechanism in the CSS-V2V scheme mitigates broadcast storm issues, collisions, and message drops, contributing to an enhanced delivery ratio. Network overhead is compared across schemes, with centralized and ODC schemes showing linear increases with vehicular density due to charging station information requests and status messages. The ODC scheme's lower overhead results from direct communication between EVs and the utility provider, bypassing RSUs. The CSS-V2V scheme boasts lower overhead due to its slotted approach, effectively suppressing broadcast messages. The DCA scheme demonstrates the lowest network overhead by focusing on collaboration within single charging stations. The CSS-V2V scheme outperforms other schemes in terms of network overhead by providing comprehensive charging station information to all vehicles within the network.

In conclusion, CSS-V2V demonstrates a promising approach with its ability to manage message penetration delay effectively, particularly in dense vehicular scenarios. While it may experience slightly higher delay in sparse networks, its overall performance stands out as advantageous, offering an innovative solution for efficient V2V communication. The CSS-V2V scheme also offers improved message delivery ratio with denser traffic and reduced network overhead due to its unique mechanisms, making it a promising solution for vehicular communication systems.

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