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Facilitating Digital Experience Sharing Among Vehicles through Utilisation of Pre-existing Communication Infrastructure

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Abstract - Vehicular communication applications are expanding quickly because of the approach of related technologies, such as vehicular cloud and the Internet of Vehicles (IoV). The combination of the Internet of Things (IoT) and smart transportation is the Internet of vehicles. Data related to infotainment, safety, and effectiveness with different vehicles and the Sustainable framework of vehicles can be exchanged. However, after the appearance of such empowering advancements, a huge number of ideas still need research. Data sharing (related trips and navigation) of new/old models and other new/old model vehicles with the owner's agreement should be taken care of. This paper proposes a novel technique, which is a digital experience-sharing system. With the proposed system, vehicles can share their experience with different vehicles depending on the owner's authorizations. The technique of digital experience sharing will give vehicles the ability to share and reestablish past information and data (related trips and navigation). A traffic trace containing the information of the vehicle: longitude, latitude, trip information, time, and location. Open street map (OSM) and simulation of urban mobility (SUMO) tools have been used to simulate the proposed technique. Further, the structure of the message for productive communication is provided with implementation details in this work. Additionally, the application is used in the vehicle, and the information related to the start, stay, and end points of the journey is stored in a cloud. After some time, the same place is visited by the same vehicle, and the application displays a notification about previous visit information.

Keywords—Internet of Vehicles, Digital Experience Sharing, Vehicular Cloud, Communication, Vehicular Ad-hoc Network

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1. INTRODUCTION

By 2025, it is expected that 75 billion things will be associated with the vehicles arranged as a main part of focus. The increasing number of vehicles related to Internet of Things (IoT) [1] is unsurprising as to why Vehicular Ad-hoc Networks (VANETs) [2] will change into the Internet of Vehicle (IoV) [3], [4]. In the associated vehicle framework, a high limit of data and basic information is exchanged through roadside units [5] and onboard transceivers to expand

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the traveling and driving experience. In these days Internet is global phenomenon. Devices become more Internet inviting and traffic management becomes simpler in transportation. Additionally, the observation of speed limits, contamination checks and reactions to road accidents make life more simpler than today [6]. Traditional manual driving and single-vehicle-based intelligent driving [7] are limited in their ability to acquire real-time and precise information about the current driving conditions and intentions of surrounding vehicles, which results in vehicles maintaining sufficient safe distances from each other. On the other hand, vehicle ownership expanded at an exponential rate, resulting in higher traffic management issues.

Two basic parts, networking and computing models, are upheld in VANET services and applications, which is proficiently supported by information-centric networking (ICN) and vehicular cloud computing (VCC). The coordination of ICN and VCC brings about another idea, which is vehicular cloud networking (VCN). VCN make collaboration between cloud members [8]. Cloud computing systems are isolated into two sections: back-end and front-end. These sections are associated with the system. The user is the front-end focused, while the back-end includes computing services, data storage and a server.

In the context of a smart city, numerous physical objects, specifically 'smart' entities equipped with their own processors, computation capabilities, and communication functionalities, can engage in interactions. The term IoT [1] encompasses these intelligent objects, contributing to the creation of a secure and intelligent environment through improved connectivity and interoperability. The realm of traffic management has been a focal point of research for many years, leading to the development of smart infrastructures designed to handle various aspects, including violation detection. In recent times, there has been a notable focus on leveraging the IoT and, more specifically, the IoVs [3] for traffic management. IoVs represent a specialised iteration of IoT tailored for enhancing traffic management, expanding the functionalities beyond traditional VANET [2]. The literature has frequently used the term Intelligent Transportation System [9] interchangeably to describe such advanced infrastructure [10].

IoV is the combination of intelligent transportation and IoT. IoV can exchange data with different vehicles and infrastructures easily because of advancements in wireless sensor systems. Thus, IoV significantly improves the safety of fuel utilisation and has an extraordinary effect on numerous businesses (Toyota, Honda and so on) [11]. Different IoV advantages include theft, accident avoidance, traffic management, autonomous vehicles, and emergency response. Nowadays, IoV is a significant part of the world, and IoV system is adopted in almost every country.

Social IoV (SIoV) is the advanced development of IoV [12]. The units of SIoV engage each other by sharing data of basic consideration, for example, traffic data, road conditions, vehicle parking spots and infotainment services. In VANET, SIoV is communication between vehicle to vehicle, vehicle to infrastructure and vehicle to Internet communication. To connect with different vehicles and roadside units (RSUs), vehicles use on-board units (OBUs) [13].

The existing vehicular structure includes a rich arrangement of devices and technologies in order to provide state-of-the-art services and applications, spreading from safety-related applications to infotainment services. However, the current structure, technologies, and tools related to the present-day vehicular environment may also be misused to actualise novel thoughts.

Modern vehicles may provide shared information using existing communication infrastructure among vehicles. The major part of the existing communication infrastructure provides infotainment and safety-related services. Vehicles share information and data. However, the existing communication infrastructure abilities are not fully utilised. For occurrence, sharing of experience between vehicles is not considered a key service. Few communication infrastructures emphasise on vehicle's social networks, but no study yet provides the capability of using existing infrastructure.

2. LITERATURE REVIEW

Traditional IoV frameworks provide information related to safety, infotainment, and efficiency with other vehicles and infrastructure [3], [6], [13]-[16]. Some strategies deal with social networks [17], [18]. With [19] the increasing complexity of connected vehicle functions, the volume and variety of data generated during driving are on the rise. Data sharing among connected vehicles can enhance the driving experience and alleviate traffic congestion. However, data sharing can also lead to the leakage of users' private information, potentially harming their interests and even endangering their lives. Additionally, the quality of data collected by vehicles varies. High-quality data sharing can provide more reliable services, while low-quality data can reduce service reliability, degrade the driving experience, or even cause traffic accidents. Consequently, developing an effective and highly reliable privacy protection scheme for shared data is an urgent issue. Moreover, since data sharing requires low latency, introducing a privacy protection mechanism without significant delay is also a challenge. In this paper, the authors propose a decentralised federated learning-based data-sharing scheme that offers strong privacy protection for data and enhances the system's robustness. Specifically, they decouple the data request process from the data sharing process to improve sharing efficiency. They also propose a TOP-K-based node selection scheme to enhance the accuracy of trained models and ensure data reliability.

The progress [20] of VANET technology has given rise to an expanding network of interconnected devices, such as edge devices, which produce a large amount of data. The data generated by vehicles is then shared with other devices, like RSUs. Nevertheless, ensuring secure data sharing is a major challenge due to the risk of data breaches. Lately, Federated Learning (FL) has attracted a lot of attention in the research community. It allows data owners to jointly learn a shared prediction model while keeping all their training data private. However, traditional FL-based methods are vulnerable to inference and gradient leakage attacks. This paper introduces a framework for private data sharing in VANETs using FL combined with local differential privacy. In the first layer, vehicles use local differential privacy techniques on their data before sharing it with the RSU. The second layer is in charge of training model parameters at the RSU and updating the trained weights with the training server. To evaluate the performance of our system, we assess it based on accuracy and simulation time for both local and global parameter sharing. Moreover, the authors measure each client's performance by calculating accuracy measures during each iteration. The experimental results show that our framework not only provides security against inference and gradient leakage attacks but also achieves higher efficiency than other similar frameworks.

The expanded number of vehicles in recent years, vast level of traffic jams and considered capable mishaps on the roads [17], [21], [22]. SIoV resolved these issues. SIoV comprises six parts: OBUs, RSUs, home base unit (HBU), User Interface, tNote message and tNote cloud. Vehicles can communicate with one another by using these parts. VANET Cloud [18], [23] is a model for Vehicular ad-hoc networks that give stages to VANET users requiring at little cost and digital services. Further, this model improves safety by detecting, assembling and sending traffic information to RSUs and vehicles for fitting activity in unfortunate traffic circumstances. Besides, the model also offers incomes by assigning their onboard computing resources to vehicle drivers. Independent vehicles exchange data, among others, providing more safety and having the least effect on the environment [3]. Vehicles outfitted with sensors and created a lot of information. Radio Frequency Identification (RFID) labels and implanted microcontrollers is road instrumented parts. These different parts are called vehicle networks. Vehicular cloud gives computing and communication conditions. Cloud computing [16] depends on network computing. Cloud computing provides three types of cloud: hybrid cloud, public cloud, and private cloud. Everybody gets information in the public cloud from the cloud. Information shared within associations in private cloud and in hybrid cloud data shared among clouds.

This study [24] provides algorithms for exchanging driving experience at intersections in infrastructure-assisted vehicle-to-everything networks. Millimeter-wave (mmWave) technology is used for this purpose because it provides multi-Gbps data rates, which are useful for dealing with users' short stay times at junctions, as well as spatial reuse due to high beam directionality, which is helpful in avoiding interference among densely deployed vehicles at junctions. To facilitate on-the-road experience sharing, the proposed algorithms prioritise collaborative resource allocation and scheduling for 3GPP-compliant multiple unicast vehicle-to-vehicle (V2V) communications in 3GPP Mode 4 [25], with vehicles acting as group leaders (GLs). Resource allocation refers to the allocation of RSUs to planned V2V GL lines, where RSUs are mostly required to overcome blockages through two-hop relaying. Because vehicles only stop at crossings for a short length of time, this study presents two approaches, one with and one without delay consideration.

Blockchain [26] technology has seen rapid growth and use in intelligent transport systems [9] due to its legitimacy and traceability. However, the rising number of Intelligent Transportation System (ITS) devices presents significant issues in terms of privacy protection and effective data sharing. Recent research has proven that adding searchable symmetric encryption onto the blockchain allows for privacy-preserving data sharing across ITS devices. However, previous methods are limited to single-keyword searches on encrypted ITS data on the blockchain and suffer from privacy and performance difficulties when used to multi-keyword cases. The authors present a bloom filter-based multi-keyword search strategy for ITS data that improves performance while protecting privacy. Authors create a bloom filter to identify a low-frequency term from among the various keywords entered by the ITS data owner. The low-frequency phrase can remove a substantial amount of ITS data from the search results, considerably lowering computing costs. Furthermore, a pseudorandom tag is applied to each identifier-keyword combination, allowing a search operation to be completed in a single round. There are no intermediary rounds or outcomes; thus, privacy is protected. In addition to the multi-keyword search protocol, authors provide the addition and deletion protocols, which enable dynamic data record updates.

Auction theory provides provisioning services requiring little to no effort with the least measure of the data uncovered to support providers and with low provisioning idleness [14]. Auction members are service providers (SP) [25], vehicle drivers (VD), and trusted third parties (TTP). The best vehicle SP and TTP coordination in the vehicular cloud is delivered by auction-driven quality of Experience-based provisioning (AQoEP). There are three layers of auction-driven Quality of Experience (QoE) based software architecture: TTP, SP and VD layers. Top VD layer associated with grid through a mobile application. The application spares the user time to pick the best TTP with best services The layer TTP contains four parts: QoE SP, storage, negotiation server and computation. SP layer incorporates various sorts of service structures, such as storage, platform, application, communication, and computation. Social vehicular network (SVN) method comprises of Vehicular Cloud (VC), RSUs and Internet Cloud [25] parts [15]. Vehicular cloud sets up the association with RSUs. VC communication with IC by RSUs. VC or vehicle transfers data on Internet cloud of any congestion or accident on the road. Data as voice, video and pictures are Navi Tweets; that is, the present state of the road, which is stored on the Internet cloud. At the point when any vehicle needs information of any road, digest gives an exceptional perspective on the traffic conditions.

3. RESEARCH METHODOLOGY

3.1 Framework

This section describes the framework of the digital experience-sharing technique as shown in Figure 1. The structure combines the social network and IoV. The vehicle owner makes an Id (Owner and vehicle) on a cloud which includes the vehicle owner's information and vehicle along with the owner’s friend list. Owners have friend category (friend, coworker and family members), and all of these friends can also create their vehicle and their Ids on cloud.

Initially, vehicle navigational and sensory data will be stored in the vehicular cloud. After that, this data will also be stored in the cloud. If any one of the vehicle owners changes his vehicle, they use the same owner id in new vehicle, so that the previous data of an old vehicles can be restored in the new vehicle. The data of old vehicle (related trips and navigational data) is restored in new vehicle. The level of sharing of information (related navigation, trips data) with friend is based on the approval of vehicle owner.

3.2 Digital Experience Sharing Among Vehicles Message Structure

This section describes the detailed message structure of the digital experience-sharing. Owner and vehicle, friend and vehicle message structure are shown in Figure 2. This message structure shows how the message shared with Vehicle owner and owner's friend about navigational and trip information.

The relationship between owner and friend consists of contact and categories. Friend contact consists of (contact information and identification) and friend categories consist of (coworker, family members and friends). Friend uses owner vehicle experience with permission from the owner.

The relationship between friend and vehicle shows that if the friend uses a vehicle or the owner's vehicle, the data is shared with friends with the permission of the vehicle owner. Ownership change consists of status and contact. When an owner changes their vehicle, they use the same ID for the new vehicle. They restore all data from cloud in the new vehicle. If the owner sells his vehicle to another user, that user does not get the navigational data from cloud.

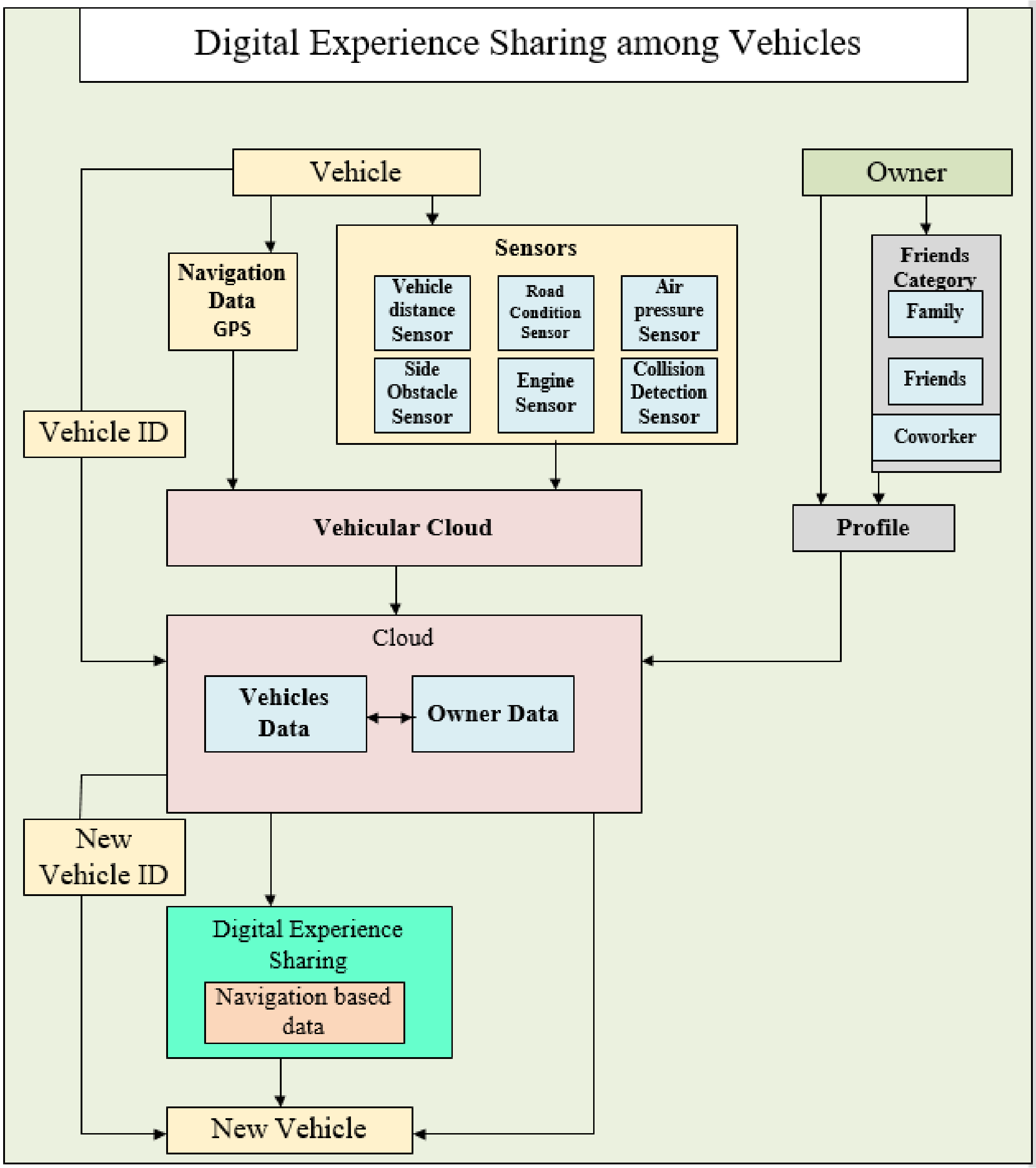


Figure 1. Digital Experience Sharing Framework

Vehicle experience consists of identification, status, and vehicle experience. Vehicle status consists of (user, height, size and category). Vehicle experience consists of experience Message. Experience messages consist of message identification, time and navigation messages. Navigation messages consist of start, stay and endpoint messages. When an owner starts the journey on the vehicle and stays in the hotel, a few months later, the owner again visits the same hotel, the vehicle shows a message (you are revisiting this place).

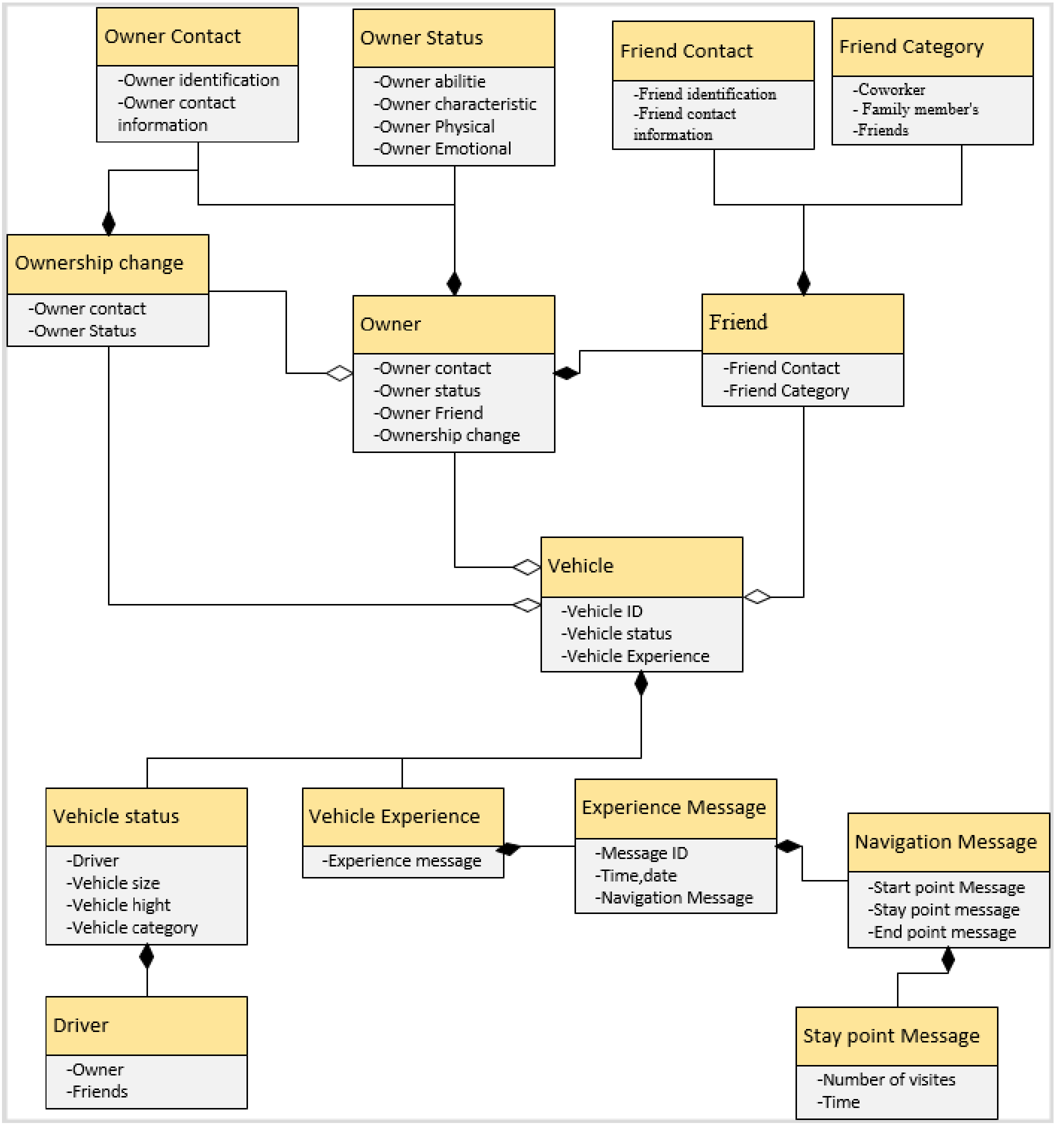


Figure 2. Message Structure of Digital Experience Sharing among Vehicles

3.3 Design Consideration

Different vehicles move on the road and communicate with each other. When a new vehicle comes on the road, it needs some data related to navigation for its purpose. Vehicles move on the road, and they store their data in the cloud or share information with each other. Vehicles move and break (for stay) on roads. This GPS data is stored on the cloud, and this information is shared with the owner's friends (Family members and coworkers) with the approval of the vehicle's owner. When an owner changes his vehicle, old vehicle data is restored in the new vehicle from the cloud by using the owner's ID. A new car gives a notification when an owner visits the same.

4. RESULTS AND DISCUSSIONS

4.1 Formal Specification of Experience Sharing

This formal specification defines a Digital Experience Sharing System for vehicles, outlining how ownership and navigational experience data are managed. It starts by defining vehicles, owners, and experience data, followed by processes for registering vehicles, gaining experience through navigation, and transferring ownership. When a vehicle is transferred, ownership records are updated and depending on whether the new owner is a friend or an unknown person, navigational experience may be retained or removed. Additionally, the system allows experience data from an old vehicle to be shared with a new one, ensuring continuity. This approach enables efficient tracking of ownership and experience-sharing among vehicles while maintaining data integrity.

Algorithm 1 depicts the formal specifications of experience sharing among vehicles.

Algorithm 1: Formal specification of vehicle sharing

Let VEHICLES be a set of all vehicles:

[*VEHICLES*]

Let OWNERS be a set of all owners of vehicles:

[*OWNERS*]

___*Digital Experience Sharing*_______

1. *Username* : ℙ *UNAME (username of vehicle user)*
2. *Vehicles* : ℙ *VEHICLE (Vehicle which used for travel)*
3. *Ownership* : *UNAME→VEHICLE (Owner name who uses the vehicle)*
4. *Friend* : ℙ *UNAME (Name of Friend)*
5. *Ndata* : ℙ *NAVIGATIONDATA (Navigational data)*
6. *Exp* : *VEHICLE→NAVIGATIONDATA (Exp is the experience of Vehicle navigational)*
7. *Username* = dom *Ownership (Dom ownership is vehicle owner name)*
8. *Vehicles* = dom *Exp (Dom exp is the vehicle navigational data information)*

*Initialization*_______

9. ∆*Digital experience sharing*
10. *Username* = ∅ *(Firstly Ø represent the no owner of the vehicle)*

___*Register Vehicle*_

11. ∆*Digital experience sharing*
12. *User* ? : *UNAME (User Name with vehicle id)*
13. *Vehicle* ? : *VEHICLE (New vehicle registration)*
14. *Username′* = *Username* ∪ {*User* ?} *(Username' is the registered user)*
15. *Ownership′* = *Ownership* ∪ {*User* ? ↦ *Vehicle* ?} (*Ownership′* is the owner of vehicle which *are registered for vehicle)*

*Gain Experience*____

16. ∆*Digital experience sharing*
17. *Trip Exp* ? : *NAVIGATIONDATA (Trip Exp ? is the navigational data of vehicle where they visited)*
18. *Vehicle* ? : *VEHICLE (Vehicle ? is vehicle which are used for trip)*
19. *Exp′* = *Exp* ∪ {*Vehicle* ? ↦ *Trip Exp* ?} *(Exp' store the all the navigational data)*

*Change Ownership Unhnown*_

20. ∆*Digital experience sharing*
21. *Newowner* ? : *UNAME (New owner of Vehicle)*
22. *Oldowner* ? : *UNAME (Oldowner information about vehicle)*
23. *Vehicle* ? : *VEHICLE (Vehicle which is use for ownership change)*
24. *Ndata* ? : *NAVIGATIONDATA (Navigational data of previous vehicle)*
25. *Ownership′* = *Ownership* – {*Oldowner* ? ↦ *Vehicle*?} ∪ {*Newowner* ? ↦ *Vehicle* ?} *(Ownership′* is the all the information which are used in old vehicle restore in new vehicle)
26. *Exp′* = *Exp* – {*Vehicle*? ↦*Ndata*?} *(Exp' Experience of Navigational data removed)*

*Change Ownership Friend*___

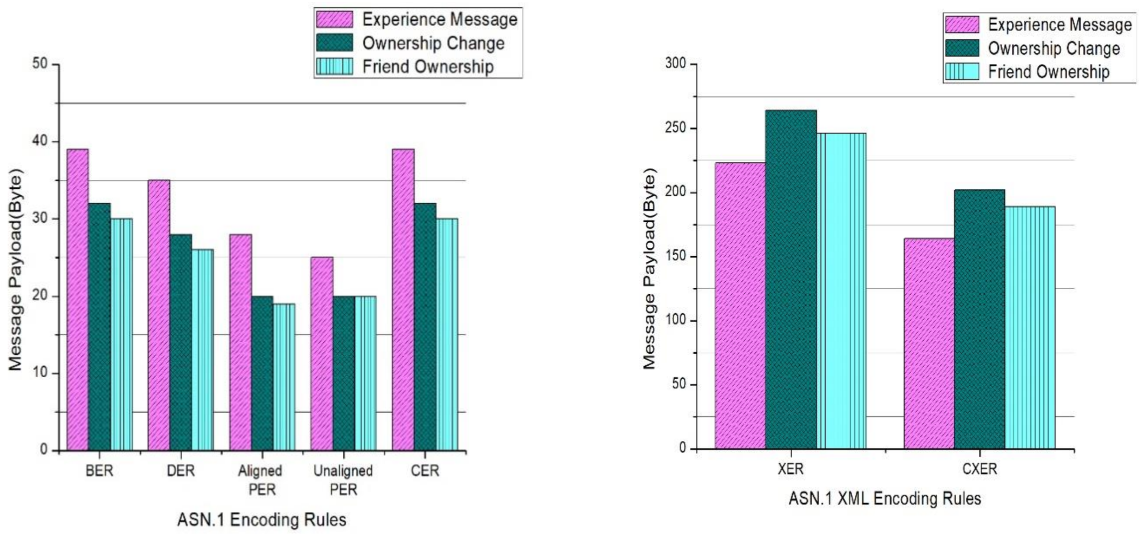
27. ∆*Digital experience sharing*
28. *Newowner* ? : *UNAME (Friend as a newowner)*
29. *Oldowner* ? : *UNAME (Actual Owner of Vehicle)*
30. *Vehicle ? : VEHICLE (Vehicle used for Ownership change)*
31. *Ownership′* = *Ownership* – {*Oldowner* ? ↦ *Vehicle*?} ∪ {*Newowner* ? ↦ *Vehicle* ?}

___*Share Experience*

32. ∆*Digital experience sharing*
33. *Newvehicle* ? : *VEHICLE (Navigational Data resotre in newvehicle)*
34. *Oldvehicle* ? : *VEHICLE (Navigational Data of oldvehicle)*
35. *Exp′* = *Exp* ∪ {*Newvehicle* → *Exp* (*Oldvehicle*)} *(Experience of oldvehicle data in newvehicle)*

4.2 Digital Experience Sharing Message

OSS Nokalva ASN.1/C++ used for representing the message of digital experience-sharing by using ASN.1. To observe the influence of payload for different encoding rules, an experimental study has been conducted. The Canonical Encoding Rule (CER)/Distinguished Encoding Rule (DER) [27]. Basic Encoding Rule (BER) [28] type encodings track tag, length and value for relating any content where length ids the length of the value, Id is represented by the Tag and value part of the message contain by the value. Figure 3 shows the payload size of message using encoding rules BER, CER and DER for friend ownership, ownership change and experience-sharing messages. BER and DER is larger than the packed encoding rule [29] and analysis shows that PER is the smallest payload size. VANET communication uses the DER Encoding rule [30]. The Canonical XML Encoding Rules (CXER) and XML Encoding Rules (XER) is XML encoding rules that present the same information in text format, which consume the high bandwidth, however, it is easy to process [17] these rules.



(a) (b)

Figure 3. Experience Sharing Message Payload Size (a) using ANS.1 Encoding Rule and (b) using ANS.1 XML Encoding Rule

4.3 Simulation Setup

Open street map [31] and simulation of urban mobility (SUMO) tool has been used for simulation of proposed technique. A city map is export from Open street map (OSM) than imported in SUMO and total two hundred vehicles traffic has been generated. Out of the total available traffic, one hundred of the vehicles have equipped with experience sharing capability. Figure 4 shows the experience sharing among vehicles by using SUMO. A traffic trace containing the information of vehicle: longitude, latitude, trips information, time and location in the form of xml file has been obtained as output generated by SUMO and then stored in the cloud.

Our proposed technique provides many features. The comparison of proposed technique shown in Table 1. Compared proposed technique with other studies.

- S1: Share routes
- S2: Experience sharing among vehicles
- S3: Social IoV
- S4: Restore data
- S5: Scalability

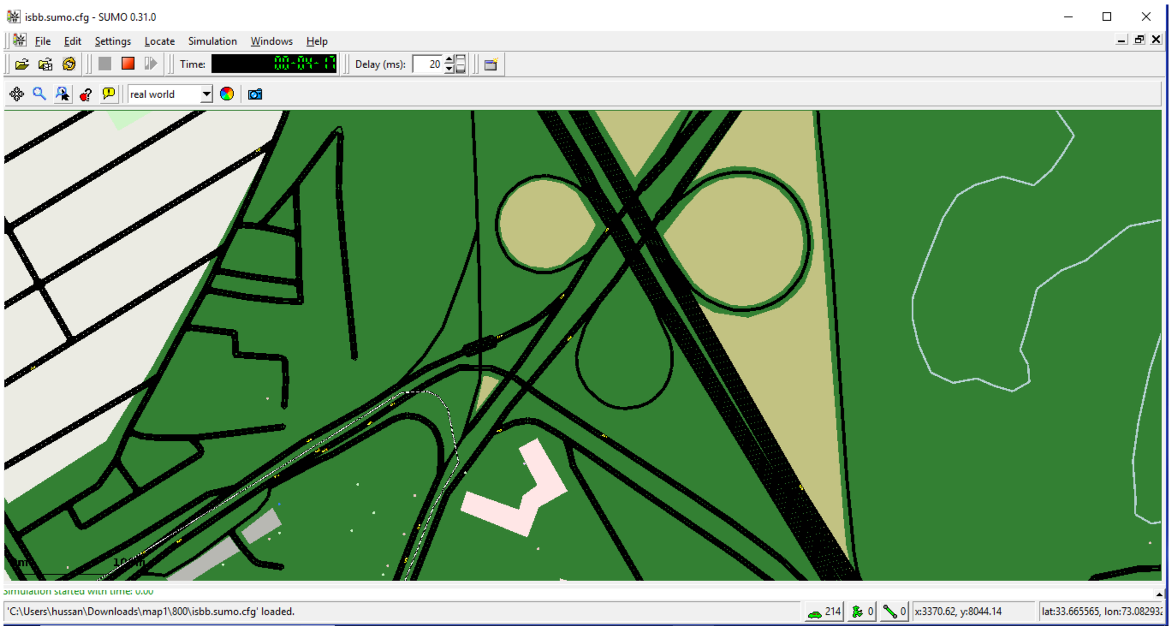


Figure 4. Experience Share Among Vehicles

Table 1. Features Comparison

Features	[18]	[17]	Digital experience sharing technique
S_1	No	No	Yes
S_2	No	No	Yes
S_3	Yes	Yes	Yes
S_4	No	No	Yes
S_5	Yes	No	Yes

4.4 Real-World Implementation

For real-world implementation, we create an application. This experience-sharing application (Get location GPS) is use by different users. Firstly, a user registers himself and his vehicle, then user saves his location, which is stored on the cloud. The information of registered users (ownership change, owner friend and vehicle owner) and vehicles data stored on the cloud.

When this application is used in a vehicle, the information related to start, stay and end points of journey is stored on cloud. After some time, the same place is visited by the exact vehicle, a notification about previous visit information is displayed by the application shown in Figure 5. This information can share by owner with friends related trip information and navigational data. When an owner changed his vehicle then restored his old vehicle data in new vehicle and visited the same place again. New vehicles show a notification about a previous visit with detailed information of the visit. Vehicle owners handle all the permissions with other related digital experience sharing information.

5. CONCLUSIONS

This work proposed a novel sustainable technique (digital experience sharing) that can play an important role. Data sharing (related trips and navigation) of one new/old model vehicle with other new/old model vehicles with the permission of the owner. Vehicles can communicate with one another through an appropriate framework and can share experience. Vehicles can likewise reestablish their old data (experience). A structure of the experience message is additionally given in this work, which can demonstrate the advanced experience-sharing among vehicles. ASN.1

tool used for message encoding. Encoded message used to share experience among vehicles. Implementation details using IoV simulator SUMO, OSM and implementation in real world using application (Get location GPS) is explained in this work.

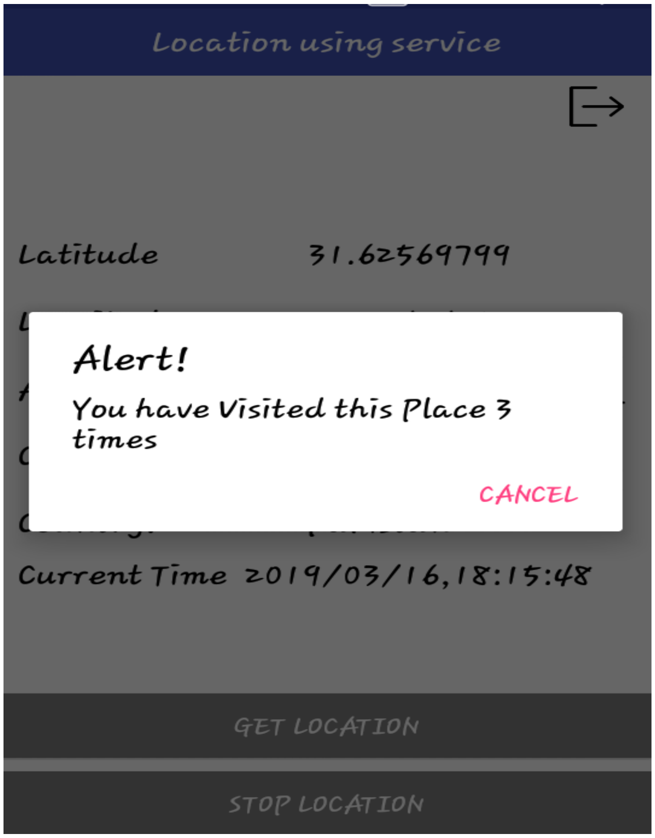


Figure 5. Experience Sharing Application

A traffic trace containing the information of vehicle: longitude, latitude, trips information, time and location in the form of xml file has been obtained as output generated by SUMO and then stored in the cloud. Our proposed technique provides many features such as shared routes, experience sharing among vehicles, social IoV, restore data, and scaleability.

Vehicles are becoming smarter with the advancements in technology. Nowadays, the Internet is a world global phenomenon. Future work will target the vehicle sensory data along with navigational data in digital experience sharing.

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AUTHOR CONTRIBUTIONS

Asad Hussain: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Umar Farooq: Project Administration, Supervision, Writing – Review & Editing;
Ihsan Rabbi: Project Administration, Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/.

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