Connectivity Analysis in Vehicular Ad-hoc Network based on VDTN

Ahmed Ali Hussein, and Dhari Ali Mahmood

Original scientific article

Abstract— **In the last decade, user demand has been increasing exponentially based on modern communication systems. One of these new technologies is known as mobile ad-hoc networking (MANET). One part of MANET is called a vehicular ad-hoc network (VANET). It has different types such as vehicle-to-vehicle (V2V), vehicular delay-tolerant networks, and vehicle-to-infrastructure (V2I). To provide sufficient quality of communication service in the Vehicular Delay-Tolerant Network (VDTN), it is important to present a comprehensive survey that shows the challenges and limitations of VANET. In this paper, we focus on one type of VANET, which is known as VDTNs. To investigate realistic communication systems based on VANET, we considered intelligent transportation systems (ITSs) and the possibility of replacing the roadside unit with VDTN. Many factors can affect the message propagation delay. When road-side units (RSUs) are present, which leads to an increase in the message delivery efficiency since RSUs can collaborate with vehicles on the road to increase the throughput of the network, we propose new methods based on environment and vehicle traffic and present a comprehensive evaluation of the newly suggested VDTN routing method. Furthermore, challenges and prospects are presented to stimulate interest in the scientific community.**

Index terms—**VANET, VDTN, RSU, Intelligent transportation systems, Vehicle-to-Vehicle, Vehicle-to-Infrastructure.**

I. INTRODUCTION

Vehicle networks such as the Vehicular Ad-Hoc Network (VANET) or Vehicular Delay Tolerant Network (VDTN) offer substantially higher bandwidth. This article focuses on traditional vehicular ad hoc networks (VANETs), which connect vehicles to infrastructure such as roadside. This type of communication aims to improve non-safety and safety applications in vehicles on the road. The primary goal of using VANET is to handle accidents on the road.

The VANET have a wide range of applications for human safety including assisting to drive safely on the roads. The accidents are becoming more frequent with an increase in vehicle numbers; hence, it is critical for the vehicles to get the VANET system incorporated [1]. The high mobility of vehicles on highways might lead to varying delays and losses in communication and limiting the deployment of VANETs [2]. For the problems and challenges of VANET, such as sparse connections, irregular connectivity, high latency, longer delay, high error rates, asymmetrical data rates, and no end-to-end connection, , the Delay Tolerant Networks (DTNs) technology can be used, which is a type of network that allows communication in environments with this problem [3].

The DTN routing protocols can be used in an environment that is confident in delivering packets to their destinations without regard for network delay. DTN does not require a high density of nodes to complete communication. Vehicle networks have a highly dynamic structure and inconsistent and disruptive connectivity. Hence, a complete route usually does not exist in such networks.

VDTN develops technology to address these connection problems and it is based on bundle-oriented connectivity, asynchronous forwarding, and a store-carry mechanism. Moreover, this technology must utilize the most available resources at network nodes to establish a multi-hop route [4]. With connections sparse and intermittent, the routing protocols attempt to address those difficulties, which have grown from basic to the most complex regarding message replication strategies as well as clearing networks for duplicate messages that the final destination has already delivered [5].

At night, fewer vehicles run on highways or even in cities, so creating end-to-end paths may be unfeasible. In such instances, routing in sparse networks must be considered. Networks will typically be sparse in the early phases of vehicular networks when a small number of vehicles are outfitted with radio transceivers [6].

As we mentioned earlier, because of the high driving velocities of vehicles, the fundamental problem in transmitting safety-critical messages is that the required latency is less than 100 milliseconds. As a result, safety messages must be broadcast as soon as possible. Otherwise, the significance of these messages will be lost. VANET latency should be reduced; for that reason, use an RSU may connect with cars through V2I communication while communicating with the leading network via a high-speed backhaul link [7].

A. RSU Deployment

RSUs come in two types: connected RSUs with a direct communication route between them, and disconnected RSUs that cannot communicate with one another [8]. The deployment of RSUs throughout the city can enable the real-

---

Manuscript received January 19, 2023; revised March 29, 2023. Date of publication June 12, 2023. Date of current version June 12, 2023. The associate editor prof. Adriana Lipovac has been coordinating the review of this manuscript and approved it for publication.

Authors are with the Department of Computer Engineering, University of Technology, Iraq (e-mails: ce.20.07@grad.uotechnology.edu.iq, dhari.a.mahmood@uotechnology.edu.iq).

Digital Object Identifier (DOI): 10.24138/jcomss-2022-0166

time and reliable transfer of emergency traffic information over VANET [9].

RSUs are major components in vehicle ad-hoc networks because they send an alarm message from the accident area to the central controller when it is available. It is impossible to implement RSU widely because of high costs and market demand. As a result, determining how to deploy the lowest percentage of RSUs in a specific area becomes a difficult challenge [10]. Therefore, many researchers have investigated the best locations for RSU on roads. RSU placement is defined as identifying the appropriate combination of RSUs in a specific target region based on the criteria to meet the specified goals, such as the best connection, coverage, and low installation cost [11].

Due to the high installation costs, it difficult to deploy a large number of RSUs at the early stage of VAENT. The author in [12] analyzed the RSU deployment method for vehicular communications in a highway environment and each vehicle may reach an RSU in two modes: direct access and multi-hop relaying. There was a comparison of two different RSU distribution systems. The first is the improved Delay Minimization Problem (DMP) instance, while the second is the uniform distribution. This suggested model outperforms uniform distribution in virtually all circumstances, according to simulation findings. The DMP model recommends the optimum RSU deployment approach while keeping the entire deployment budget in mind, so that the network aggregate latency is reduced. This increases in the network overall throughput. In vehicle applications, RSUs are important for routing, connection, and packet delay. Therefore, installing sufficient RSUs to achieve universal coverage in a given region is impossible.

While the author in [13] suggests a safety-based roadside unit placement strategy to reduce message dissemination delays in scenarios where stand-alone RSUs are deployed. The suggested S-BRP method minimizes dissemination latency and improves mesh policy regarding traffic flow following accidents. RSUs are expensive and will be in short supply for a longer period of time as VANETs are gradually deployed.

The author in [14] provides an innovative and powerful RSU Deployment Problem Model (RDPM) comprised of a road-network model and a business model. The road network model in RDPM allows complex road designs while considering major relevant elements such as lane number and popularity. Also, the work suggested a genetic algorithm-based technique to handle an RDPM problem a priori since the best RSU deployment solution is challenging to find.

This paper proposes a new method to replace RSU with VDTN and evaluate VDTN routing algorithms by giving a performance review and a statistical comparison of the effective VDTN routing protocol and finding the best scenario depending on the network environment and the traffic vehicle.

We anticipate increasing the use of VDTN due to the high cost of deploying RSU and difficulties of installing it in some areas, as well as the high mobility of vehicles, which leads to frequent network disconnections and the loss in packets. However, using VDTN, the packet will store, carried, and forwarded as soon as the connection restoration so that the packet will reach the next recipient with a tolerant delay. In some cases where RSUs are already on the road, our method can be utilized these RSUs as fixed DTNs to store packets. The fixed DTN technique provides some benefits, such as collecting data and disseminating the information obtained from the coverage region.

The remainder of the paper is organized as follows. Section II shows problem statement and III gives a brief outline of the VANET. In section IV, a detailed description of the environment is given. It was followed by section V in which DTN technique is showed. Section VI descripts in detail the VDTN, while section VII shows cluster routing. Methodology and routing schemes are shown in section VIII. Section IX shows the results of the analysis. Finally, concluding remarks are provided in section X.

II. PROBLEM STATEMENT

Since RSU installation and maintenance are expensive, deploying a limited number while ensuring outstanding network performance is a significant difficulty. VANETs present various obstacles for RSU installation with regards to data distribution, packet routing, and connection to the network, and coverage needed to provide such performance. However, coverage is one of the primary performance indicators used to analyze the quality of service provided on a network.

The primary purpose of the optimization is to establish a balance between network coverage and pricing. RSU distribution is represented as a restricted optimization process with numerous goals such as enhancing network coverage, optimizing network connections, and decreasing the costs of RSU implementation. We can generally discover many suitable subsets of localities for installing RSUs within a geographic region [11].

RSUs have limitations in terms of their coverage area, and the number of RSUs deployed may not be sufficient to provide complete coverage over long stretches of highway. In such cases, the VDTN approach can be useful, as it provides a way to overcome the challenges posed by intermittent network connectivity in sparse or disconnected networks.

III. OVERVIEW OF VANET

VANETs are simply a group of vehicles and RSUs. It’s identical to MANET up of vehicles and RSUs. Protocols and tools designed for MANETs cannot be immediately linked to field VANETs since they must be upgraded to meet the mobile ad-hoc as well as the operational needs of vehicles.

VANET is an infrastructure-free network without a predefined architecture via which vehicles can interact. Because all nodes are allowed to migrate and form their own networks, they are referred to as "wireless ad-hoc networks." VANET employs dedicated short-range communication (DSRC) based on IEEE 802.11p wireless technology, a multi-hop connection technique that uses geopolitical location to enable information sharing among network elements [15].

A. Type of Connection in VANET

Many types of communication exist in VANET technologies, which are:

A.1. Inter-Vehicle Communication

Direct connection between vehicles occurs in this form, making it rapid, cost-effective, as well as accurate. Wireless technologies have a limited range such as Wi-Fi as well as Wireless Access in Vehicular Environment make this possible. Vehicle is outfitted by specialized electrical devices that allow them to receive and deliver communications [16].

A.2. Vehicle to Infrastructure Communication

In contrast to the V2V communication paradigm, which only allows information to be sent between vehicles, the V2I communication model allows vehicles in transit to interact with the road system. RFID readers, traffic signals, cameras, lane markings, street lighting, signage, and parking meters are among the components. V2I communication is often wireless, and bidirectional and like V2V use Dedicated Short-Range Communication (DSRC) frequencies to convey data. This data is transmitted from infrastructure elements to vehicles, or vice versa, over an ad hoc network. V2I sensors in ITS may collect infrastructure data and give real-time advice to passengers, transmitting data on road conditions, traffic congestion, any accidents on the road, the presence of building sites, as well as the availability of parking [17].

A.3. Hybrid Communication

Inter-road communication often mixed both V2V and V2I connections such as a schema, the car connects with the roadside unit and exchanges data obtained by infrastructure with the other cars. Because there isn’t an immediate connection among them a specialized protocol is utilized for passing packets through one vehicle to the next until it arrives at its destination, establishing many hops in vehicle-to-vehicle connection. Vehicles, in contrast, RSU use to extend communication, forwarding and transferring data from one to another node, or gain from RSU capacity to perform specific applications, establishing V2I communication [18].

B. Challenges of VANET

There are many challenges in a vehicle network, which varies from typical ad-hoc networks because of the high degree of mobility, changeable network architecture, network segmentation, density of nodes, non-persistent connectivity, and so on. Variations in vehicular density are caused by factors such as vehicle speed, driver behavior, road conditions, and traffic congestion. As the density changes, various related issues occur, resulting in the establishment of dynamic needs and limits for parameters like connection, bandwidth, data rate, and so on.

Existing vehicular network architectures are scalable because they enable ad-hoc, cellular networks, and roadside units. Many services are provided by these designs, including intra- and inter-vehicular communication, vehicle-to-vehicle communication, roadside units, and vehicle service [19]. Recent routing has additional problems and challenges in terms of scalability, QoS, security and privacy, energy usage, bandwidth constraints, and broadcasting [20].

If compared with other kinds of MANETs, VANET has distinct properties that impact the architecture of the communication network or its routing protocols. Following are the distinctive characteristics of VANET:

1. High Dynamic of Topology: This is produced by high-vehicle speeds, particularly on highways [21].
2. Varying network density: The traffic volume in VANET is not uniform throughout the day and in all environments; it could be higher during peak hours and during traffic jams in cities, average at other times, or extremely low as in rural transportation [21].
3. Patterns of Movement: VANET can distinguish by possibly a large number of mobile nodes. That high mobility may be necessary because of the type of routes (highways, RSUs, and tiny streets). The cars do not drive randomly; instead, they most likely go in two directions on established roadways [22].
4. Frequent information exchange: The ad-hoc structure of VANET encourages nodes to acquire information from other vehicles and roadside units. As a result, information sharing between vehicles becomes more common [23].
5. Frequent disconnected of network: In the VANET, The rapid speed of the cars displays the dynamic topology of networks since the connection that connects two communicating vehicles is frequently interrupted, which is known as intermittent connectivity [23].

C. Components of VANET

1. On-Board Unit (OBU): is a piece of hardware that is put across every vehicle. The main purpose of an OBU is to allow communication between RSUs and many other OBUs inside vehicles. It also has a transceiver, which is comparable to a radio frequency antenna [24].
2. Road Side Unit (RSUs): embody an antenna, a read/write memory architecture, as well as a processor. RSUs are equipped with Interfaces, both wired and wireless. These units are typically built along roadways. They are also seen in high-traffic places like crossroads and parking lots. There are experiments to optimize RSU location regarding coverage range, data aggregation, and delay management [24].

D. Routing Protocol in VANET

In VANET, the protocols could be categorized into two types: position-based routing protocols and topology-based routing protocols. Fig. 1 [25] illustrates the types of protocols in VANET. They are classified according to the region and application for which they are most suited. Protocols based on topology are divided into three types: proactive, reactive, and hybrid [26].

D.1 Proactive Protocols

The routing table updates or refreshes often because the protocols compute the route on a constant schedule; those protocols use the Bellman-Ford Process, nodes store information about the next node. Protocol examples for this type are Destination Sequenced Distance Vector (DSDV). Optimized Link State Routing (OLSR).

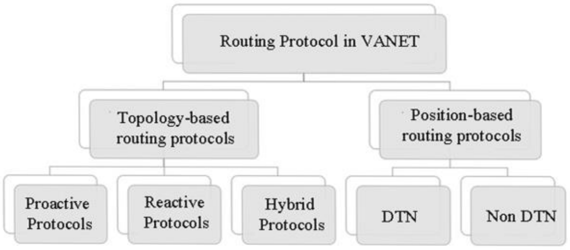

Fig. 1. Routing protocol in VANET [25].

DSDV is a renowned proactive or table-driven routing technology in MANET. The DSDV routing method is defined by the number of hops required to reach the target node, DSDV protocol uses routing tables maintained in each node to send data packets throughout the network, DSDV protocol has three key aspects: reducing the huge routing expense, avoidance of loops and solving the count to infinity challenge. Every mobile node has a routing information table that contains all the routes to destinations as well as other information [27].

OLSR would optimize the process of broadcasting control messages to decrease bandwidth usage by utilizing multipoint-relays (MPR). At broadcasting, each node joins a selection of its surrounding nodes to send its packet. According to the MPR distribution approach, every node in the network obtained the fewest repeats. MPR prevents a subset of nodes from retransmitting a message to remaining nodes and makes network topology determines the size of the subgroup [28].

D.2 Reactive Protocols

This protocol does not include knowledge about most of the nodes. It simply saves the information of nodes that pass through it. Ad-hoc On-Demand Distance Vector (AODV), Dynamic Source Control Routing (DSR), and Dynamic MANET on Demand (DYMO) protocols are examples of this type.

AODV uses a dynamic source routing technique for route discovery and management, as well as Sequence numbers and sequential hop routing. AODV constructs route by executing “route request/route reply” queries [28].

DSR is one type of reactive routing protocol that is launched by the originating node of the network. Every packet in this protocol transports all routing packets and data to all surrounding nodes, which means increased traffic that is unsuitable for massive networks. The degree of the operating protocol overhead grows with network size as measured by the number of nodes, consuming extra bandwidth in high-traffic areas with more extensive networks than that in tiny as well as inactive networks. Although, compared with AODV, this protocol has a significant advantage in small networks, it may perform exceptionally well in tiny networks. One of the benefits of this protocol is that it saves and uses the routing data saved in the protocol route cache, which is used when searching for the following route from the root to the last network node because the route cache includes data on numerous routes between both pairs of nodes [29].

The DYMO routing protocol is the replacement for AODV and works in the same way. DYMO has no additional features, nor is it an extended version of the AODV protocol; instead, the DYMO routing protocol streamlines AODV by preserving the primary operation mode necessary to achieve efficient routing, which is enhanced because it saves each intermediary hop route, whereas AODV produces entries at the table of routing and nodes for the destination and following hop [30].

TABLE I
COMPARISON ROUTING PROTOCOL IN VANET

Title	*Year*	*Techniques*	*Protocol Type*	*Performance Parameters*
[32]	2020	ANN, and SVM	Clustering	PDR, and throughput
[33]	2020	PSO	Geocast	PDR, throughput, delay, NRL, and packet drop ratio
[34]	2019	GA, and K-means clustering	Hybrid	Link reliability
[35]	2019	ABC	Clustering	Delay, PDR, NRL, and packet drop ratio
[36]	2018	SA, and Radial Basis Function (RBF) Neural Network	Clustering	PDR, throughput, route discovery ratio, and NoC
[37]	2018	ACO	Geography	PDR, and delay
[38]	2019	ACO	Geography	PDR, control packet rate, and delay
[39]	2019	Artificial Spider-Web	Geography	& PDR, routing overhead, and delay
[40]	2018	GA	Geography	Delay, and PDR
[41]	2018	PSO	Topology	Packet loss, PDR, NLR, and delay
[42]	2018	Taguchi Optimization	Topology	Delay, PDR, and throughput
[43]	2020	Improved Water Wave Optimization, and Rider Optimization	Clustering	Cluster overhead, routing overhead, PDR, packet drop ratio, throughput, delay, and network lifetime
[44]	2020	PSO	Clustering	PDR, and delay

D.3 Hybrid Protocols

This routing strategy is a hybrid of proactive and reactive routing techniques that decrease delays and overhead that caused by the continuous exchange of topological. The network efficiency and scalability have increased thanks to the hybrid approach. The disadvantage of a hybrid strategy, on the other side, is excessive latency while traveling new routes. Zone Routing Protocol (ZRP) is a typical protocol that uses a hybrid method.

ZRP is designed for wide area networks and uses query-reply to create routes. It employs Interzone and Intrazone routing to allow elastic finding of a route with management in various ad hoc contexts. Interzone routing is handled worldwide via the reactive routing protocol, whereas intrazone routing is performed locally via the proactive routing protocol to retain up-to-date route information [31]. Table I summarizes some protocols developed in the VANET environment.

E. MAC Layer in VANET

The MAC layer in VANETs can be implemented through various mechanisms. Such as the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol, known as the IEEE 802.11p standard. This protocol is designed to allow multiple vehicles to share the wireless channel, while avoiding collisions and minimizing delays. Here are some of the ways in which the MAC layer can be applied:

1. Beaconing is a technique used in VANETs to disseminate information about the network and the surrounding environment. Vehicles periodically transmit beacons containing information such as location, speed, and direction of travel.
2. Quality of Service (QoS) provisioning is essential for VANETs to support different types of applications with varying bandwidth, latency, and reliability requirements. The MAC layer can be used to allocate resources and prioritize traffic based on the QoS requirements of different applications

In order to adjust to the variety in node density and contention severity in VANET, an adaptive mobility variation of RR-ALOHA is presented by the [45]. The suggested schema performs better than RR-ALOHA in several ways by including CSMA into the slot and entirely using the 3-hops channel state. The NS-2 simulation demonstrates that the innovative protocol enhances the quality and speed of Basic Channel (BCH) reservations. The author in [46] Work on increase the effectiveness of controlling packet collisions brought on by rapid mobility in VANETs by extending the R-ALOHA reservation scheme. Terminals have several opportunities every frame to assess timeslot availability inside the two-hop neighborhood because of the architecture of frames with many brief BTSFs. Channel access is thus quicker and more dependable, and mishaps may be recovered more quickly. The suggested protocol's faster channel estimation quickly recovers all reservation losses by rapid network mobility and improves network mobility handling.

IV. ENVIRONMENT

Vehicle networks work and apply in many environments; some are high or medium density, while others low. The density depends Poisson vehicle arrival process, with arrival rate λ (vehicles/second) Different arrival rate values are considered, $\lambda \epsilon \{0.45, 0.65, 0.95\}$ in this case setting the mean arrival rate to a low value leads to very short clusters, that mostly consist of isolated vehicles. On the other hand, by setting it too high, almost all vehicles will be connected into a single cluster.

Also, many other vectors affect environment classification, such as the type of area, which is rural or urban, and the time for measuring the density, which is during the morning peak or during the evening when the traffic low. In this part, we provide three categories of density, which are listed below [47]:

A. Sparse Network

Arrival rates differ during the day, and depending on the vehicle's arrival, all are exponentially distributed when λ is low (0 – 0.45). We call this network sparse, and in this type of network, the connection between vehicles will be poor when we need to propagate messages to all other vehicles on the road, so in this environment, we need to consider some solution to ensure some of the vehicles at least receive the message, such as using VDTN, which means it is possible to create connections in case (V2V). This network has a small number of nodes and a minimal network architecture. As a result, it is possible that not all nodes have communication link.

B. Semi-sparse Network

As mentioned earlier, the density depends on arrival rate λ (vehicles/second), and when it is around (0.46 – 0.65), we call this network semi-sparse. In this network, the connection can apply VDTN and also use Roadside unit (V2V), (V2R).These networks feature further nodes and connections than sparse networks. For example, a small or developed town close to the city has an extra significant number of mobility nodes and base stations providing internet access. Consequently, the possibility of contact between mobile nodes is more significant than in a sparse network and data may be sent with lower latency than in the sparse network.

C. Density Network

In this type of environment, when the arrival rate is high (0.95), most of the vehicles be in one cluster, and the messages will arrive to all vehicles, so we will not need to apply VDTN because the link will not break and can use all connect (V2V) (V2I) (V2R). Almost nodes in this network are linked together; there will be a lot of traffic and strain, network nodes have a high probability of contacting one another. A smart city is an instance of a dense network in which numerous heterogeneous nodes are installed and can communicate with one another.

V. DELAY-TOLERANT NETWORK (DTN)

Due to changes in the arrival rate and topology of the vehicle's network, some network spares and link end to end are not found, as mentioned in section IV, so we can apply DTN. This architecture implements store-and-forward concept by superimposing a protocol layer called a bundle layer. This new layer is intended to offer internetworking on heterogeneous networks that use various transmission modalities. A source node creates and stores a bundle in this network when contact is unavailable. When the source node contacts an intermediate node considered to be closer to the target node, the package has been delivered. After that, the intermediate node stores the bundle and transports it until a new contact becomes available. Such a step is repeated till the package arrives at its receiver. Bundles have a limited lifespan and might be dropped due to buffer overflow [48].

A. *Bundle Protocol*

The purpose of the DTN bundle protocol is to facilitate communication in difficult circumstances. It is based on a new bundle layer, which is put between the application and transport layers as shown in fig 2. Bundled protocol connections to lower levels are known as "convergence layer adapters." It is critical to emphasize that the bundle protocol does not really need to be installed across all nodes in the network except termination points and a few selected transitional nodes [49].

The bundle custom features an overlay network that has the following benefits [50]:

1) Capability to tolerate intermittent connection.
2) Capability to benefit from planned, opportunistic, and expected connections.
3) Retransmission depending on custody.

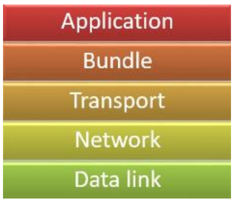

Fig. 2. DTN architecture

B. *Store Carry and Forward*

In contrast to the Internet technique, which is built on the store and forward assumption, the DTN uses new design which includes store, carry, and forward paradigms. This approach allows intermediate nodes to keep bundles in their buffers for a long amount of time, while waiting for the chance to connect with the next node until the packet arrives at its destination or its time to live ends [51]. DTN node is accountable for the bundles it transports till they are delivered or sent to other DTN node. Often that it’s advantageous for a DTN node to delegate responsibility for replicating, modifying, or deleting its transported bundles to another node. [52].

C. *Challenges in DTN*

DTN has several difficulties like routing algorithms, flow control, congestion control, and architecture. These difficulties have a severe impact on DTN performance. These circumstances, however, should not affect the DTN efficiency or performance in [50] briefly explain some of them:

1) Limited buffer size: Because of frequent disconnection, a huge number of packets are stored in the nodes custody.
2) Very lengthy delays: Latencies can be greater and transmission rates which be poorer at times.
3) Connection based on opportunity: Communication is occurring in an ad hoc fashion. As a result, the quantity of data that may be communicated is limited.
4) Disconnections occur frequently: It is challenging to estimate once the next node would be ready for broadcast because node debate is more frequent than node connection due to the significant delays between nodes.

VI. VEHICULAR DELAY-TOLERANT NETWORK (VDTN)

VDTN is a type of DTN that provides authoritative and effective connections. Different routing methods which already employed in VDTN to improve network performance in terms of sending information in the form of packets to their desired locations [53]. Using the VDTN technique reduces dependence on RSU, which is high cost and low effectiveness in some environments like a sparse network or using the hybrid technique (VDTN and RSU) in other types of networks such as semi-sparse, as mentioned in section IV. A and B.

A. *Characteristics of VDTN*

The geographic position, density of nodes, buffer size, target utility, buffer capacity, relay functionality, meeting prediction, and other indicators are used to make routing decisions in VDTN [54]. It is a modern topology comprised of three node types: terminals, relays, and node mobility. Terminal nodes are stationary or mobile nodes that can be the data source or destination. They will provide crucial information regarding road and weather conditions (entertainment and traffic jams). Relay nodes are static nodes with store-and-forward capabilities strategically placed at intersections. Mobile nodes are responsible for physically transporting and forwarding packages from the origin to the destination nodes. As a result, offering a unique routing mechanism enhances the performance of the VDTN, conveys messages more efficiently, and increases the life span of the network [55].

VDTN employs nodes of vehicles to carry packets because it provides for limited opportunistic connections and is characterized by a low value of density, intermittent vehicular activity, and no edge connectivity among nodes. The [56] offers DesCom, a routing protocol for VDTNs in a highly restricted and sparsely populated environment. This protocol bases its choice on the transmission rate, message TTL, and estimation time. Some of the protocols used in the VDTN are summarized in Table II.

TABLE II
COMPARISON ROUTING PROTOCOL IN VDTN

Protocol	*Environment Scenario*	*Target of Protocol*	*Performance Parameters*
REMA [57]	urban, city	The work proposes a VDTN resource management system.	Reduces lost in resources, raises the bundle delivery ratio, and minimizes the ratio of overhead.
GeoDTC [58]	Realistic simulation environment, city	Presented a comprehensive analysis to evaluate this protocol	Performs show benefits of extensive use Custody Transfer.
SNHD [59]	Smart city	Evaluate this protocol against well-known protocols of DTN	Protocol outperforms well-known DTN protocols.
DSO [60]	Rural areas	communicate in rural areas using cellular network	Increased data delivery and an increased delivery completion rate with fewer delivery delays.
EPRIVO [61]	Different scenarios	Evaluation the packet size, the ratio of overhead, average delay	It has very cheap cryptographic costs in general. Furthermore, it displays average improvements ratio of delivery
MACBSA [62]	urban scenarios	create intelligent transportation networks	Increase network quality and efficiently utilizing system resources.
MOPSO [63]	VDTN scenario	Strategies for reducing traffic congestion.	Utilizing the artificial intelligence method.

B. *Challenges in Designing VDTN*

While developing the VDTN routing scheme, we encountered the following difficulties [64]:

1. Data transfer is incomplete when the transmitter and receiver are within each other interface range, data transmission occurs in any way (X2V, V2V, or V2X). As a result, to finish the data transmission, the receiver must remain in the connection range for the transfer duration.
2. Drop a high number of packets directly impacting the routing protocol efficiency. Also, a few packets may be dropped during communication due to a temporary technical problem. With regular packet drops, unwanted packet drops are unlikely to occur because the relay node may drop packets unintentionally owing to route changes or other issues.

C. *Buffer Issue*

DTNs method demands that the bundle be saved in the nodes. As a result, routing protocols must understand how to manage buffer consumption to prevent many needless bundle copies from circulating at intermediate network nodes. This matter occurs with the routing system, where the overhead of bundles in the network is substantial, rendering it unscalable [65].

VII. CLUSTER ROUTING

Clustering is the grouping of vehicles based on correlated geographic distribution and relative velocity, which can be utilized to improve routing scalability and reliability in VANET. Cluster-based systems organize nodes into virtual groups called "clusters." Geographically adjacent nodes are placed in the same cluster according to rules. A cluster typically has three nodes: a cluster head (CH), cluster members (CM), and gateway nodes. In each cluster, a node is chosen or elected as a CH, with extra functions like access to the medium or routing. Clustering appears to be an appealing contender for VANETs in building scalable and durable vehicles in the face of high movement and frequent dynamic topology in VANETs for a variety of reasons. Furthermore, this method of routing avoids conflicts.

This strategy also has drawbacks. Cluster stability is a significant problem. Cluster rearrangements and cluster-head changes are unavoidable in a dynamic environment like VANET, compromising stability. As a result, the ability to build stable clusters is one of the most important criteria for any clustering technology in VANETs [66].

A. *Clustering in Vehicle*

The vehicles are clustered together with their neighbors. Automobiles in the same cluster can link in multiple hops. Vehicle clustering effectively achieves scalability and stability in network processes and control in a VANET with a large number of cars. Clusters are often grouped in a continuous line alongside highways [10].

Whenever vehicles are sufficiently together, only vehicles in the same cluster can exchange messages. However, because of the high price, complexity, and non-cooperation between the government and commercial sectors, RSU implementation is slow [8]. Fig. 3 illustrates how to use the cluster with RSU and two lanes. When there are RSUs on the road, a large enough cluster of cars can fill the gap, moving the message from RSU to RSU farther away from the sender. The symbols (U1, U2, and U3) refer to the RSUs scattered along the road. R denotes the vehicle range, and $\hat{R}$ denotes the RSU range, the $\hat{R} \geq R$. The red circle indicates the beginning of the accident and the start of the message Propagation.

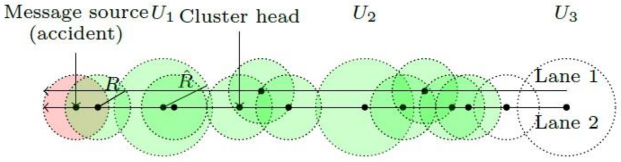

Fig. 3. A snapshot of a road at time t with RSU and informed elements highlighted in green

Fig. 4 shows how to use the cluster with VDTN, the road has two lanes. The route can have a single informed cluster with no RSUs. The system dynamics are simple: at times, only the static message source is aware of the information. When a vehicle enters the radio coverage of the sender, the cluster activated by that vehicle is immediately alerted. However, there will be no informed vehicles on the road when the last car in the cluster leaves the message source. From the figure, we can see a buffer store denoted by black circles inside the green area for the message store because the VDTN uses store carry-forward mechanics to improve communication efficiency. Therefore, we can replace RSU with VDTN and get almost the same performance on the road.

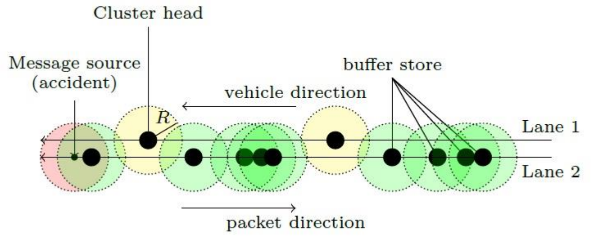

Fig. 4. A snapshot of a road at time t with VDTN and informed elements highlighted in green

A cluster is a group of vehicles formed when these vehicles are within a specific range at a given time (t), and the cluster is recreated with the help of the DTN Node (DTN-N) after that time (t +). With DTN-vehicles, the cluster does not start from R (the vehicle range), and the packet in this case is still available because it is held by DTN vehicles, (g) represents the cluster length. The trajectory of the message propagation distance, D (t), is depicted in Fig. 5. And due to DNT techniques, the packet reaches the longest possible distance, making the message reach the drivers within an acceptable period. When the message arrives at the right moment, it will assist drivers in avoiding accidents by allowing them to choose whether to enter congestion or use a side road. The slope is equal to the velocity (v), and message dissemination distance decreases with velocity; the speed of leaving the cluster is equal to the velocity of the car. And when the last car in the cluster departs the packet source, there will be no informed cars on the road.

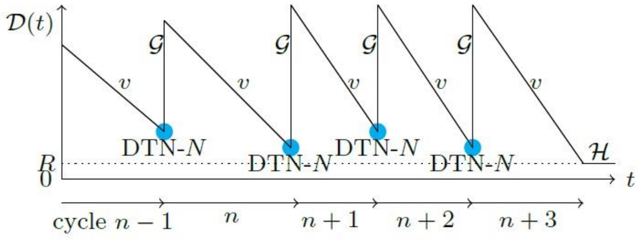

Fig. 5. Trajectory of the information distance D (t)

VIII. ROUTING SCHEMES

In VANETs, the spectrum of frequency is split into six channels (SCH) and one control (CCH), all having a 10 MHz bandwidth. According to the ETSI Research center, every channel is assigned to a specific application type: 5.855 MHz to 5.875 MHz is reserved for intelligent transportation systems, 5.875 MHz to 5.905 MHz is reserved for safety in addition to ameliorating applications while 5.905 MHz until 5.925 MHz is reserved to future intelligent transportation systems applications [67].

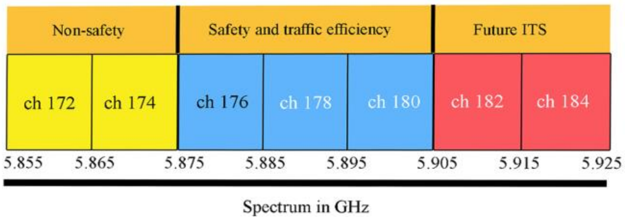

Fig. 6. Multichannel operations for vehicular ad hoc networks [70].

A. Message

Two categories of applications available: safety and non-safety as shown in fig. 6. In VANETs, the safety applications can be used to deliver safety messages, such as warning messages that aid vehicles on the road so that necessary steps may be taken to avoid accidents and save persons from dangerous circumstances, Minimal delay and great reliability are required for these kinds of safety applications. Road accident updates, emergency vehicle alerts, traffic jam alerts, and road construction reports are examples of safety messages for which it is preferred to use RSU, which gives higher reliability and faster message transmission, but it has a drawback.

Therefore, it is possible to exploit the routing protocols for VDTN to deliver the message through this connection, even if additional time has passed.

Non-safety applications, on either side, provide a more efficient and pleasurable driving experience. Two types of non-safety applications: infotainment and traffic control. This type of message can use the VDTN routing protocol to provide the preferred results because it can tolerate delay.

B. Analysis Study

Node density, mobility model, and several other factors all have a substantial impact on the performance of a routing protocol in VANETs. As a result, creating an effective routing system for all VANET application is exceedingly difficult [26]. Therefor depending on the challenges and environment that mentioned earlier, can obtain a comprehensive understanding of the VANET structure. It can use traditional routing protocols with RSU or DTN routing protocols without RSU which depending on many vectors such as environment, network type, and so on.

Our taxonomy applying VDTN or RSU depending on various factors, which shows in Fig. 7. Vehicle networks have a highly dynamic network structure with disruptive and inconsistent connectivity. Therefore, VDTN technology was developed to address these connection problems.

In general, VDTN is based on bundle-oriented connectivity and includes asynchronous as well as store-and-forward routing mechanisms. This technology must utilize the most available resources at network nodes to establish a multi-hop route [6]. protocol is used with fewer vehicles running on rural area or even in cities at night, especially when lack of end-to-end paths. Even in heavily populated metropolitan areas, sparse networks might exist.

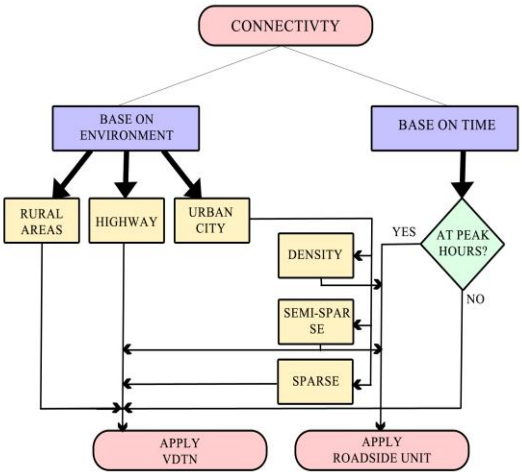

Fig. 7. Our taxonomy

VDTN protocols could be employed in high, medium, and low-density environments and used in the application for non-safety messages that do not require emergency vehicle alerts or a pre-exit connection. While RSU can be used for safety messages because it reduces information delivery time and loss packets, but it is costly compared to VDTN.

Moreover, based on that comparison, hybrid RSU and VDTN will have superior performance according to environment as mention in section IV.C.

IX. ANALYSIS

According to our study analysis on VANET, the main vectors that should be taken into account when designing network topology are:

1. Environment has three types of VANET, as mentioned in section IV. When building network infrastructure, we should consider which type it is to know communication use (V2V, V2R, and V2DTN).
2. Type of protocol.

From our study analysis, the VANET has many problems, such as

1. Message propagation (end-to-end delay).
2. Context-aware navigation for driving safety and collision avoidance.
3. Cooperative adaptive cruise control in an urban roadway.
4. Platooning on the highway.
5. Cooperative environment sensing.
6. Weather condition.

The proposed DTN Protocol and non-DTN Protocol have been evaluated for the network of mobile nodes in comprehensive simulation by utilizing the NS2 Simulators. Table III lists the simulation parameters that were employed.

The experiments in literature review findings reveal that DTN routing methods outperform non-DTN routing protocols regarding throughout and delivery ratio in the spare environment when the arrival rate λ is low. Therefore, DTN protocols are better suited for highways due to packet buffering until an obvious path to a target is available. However, they cause higher average latency owing to buffering. In conclusion, non-DTN protocols are better suited to city environments and network structure alterations are slower than highways.

TABLE III
SIMULATION PARAMETERS

Simulation	NS2 (Network Simulation Version 2)
Code	TCL, OTCL and C++
Simulation Time	30. 0 Second
Discovery Routing Time	Start From: 0 sec. To 1.5sec.
Time to Send Package	Start From 1.5sec. To 30sec
Number of Nodes	(10-250) Mobile Node
Interface Priority Queue (Ifq)	Drop Tail
Antenna Model	Omniantenna
Transmission Range of the Nodes in Cluster	250m
Size of the Message getting Generated	512 KB
Buffer Size of the Nodes in the Network	Maximum Packet in Ifq 50

X. CONCLUDING REMARKS

This paper studies the significant technologies, RSU and VDTN in VANET to achieve the best connectivity for vehicle networks. Specified problems and limitations of both VDTN and RSU. VDTN technology can maintain a continuous end-to-end connection because of the constant movement of nodes. In contrast, RSUs are expensive and challenging to install along a road. This study indicates that a specific system performance depends on the resources and environment in which it operates. Use RSU for the alert message to ensure timely packet delivery, while for non-safety messages, use VDTN, which employs store-and-forward technology. In Future work, we will implement a scenario on the highway with a length of 10 km and design a protocol dealing with high-speed vehicles.

REFERENCES

[1] B. Sharma, M. S. P. Sharma, and R. S. Tomar, "A survey: Issues and challenges of vehicular ad hoc networks (VANETs)," in *Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University Rajasthan, Jaipur-India*, 2019.

[2] E. Cambruzzi, J.-M. Farines, W. Kraus, and R. Macêdo, "A cluster management system for VANETs," *International Journal of Intelligent Transportation Systems Research*, vol. 14, no. 2, pp. 115-126, 2016.

[3] E. Spaho, L. Barolli, V. Kolici, and A. Lala, "Performance Comparison of Different Routing Protocols in Sparse and Dense VDTNs," in *2016 IEEE 30th International Conference on Advanced Information Networking and Applications (AINA)*, 2016: IEEE, pp. 698-703.

[4] R. K. Agarwal, M. Mathuria, and M. Sharma, "Study of routing algorithms in DTN enabled vehicular ad-hoc network," *International Journal of Computer Applications*, vol. 975, p. 8887, 2017.

[5] N. I. Er, K. Singh, and J.-M. Bonnin, "On the performance of VDTN routing protocols with V2X communications for data delivery in smart cities," in *IWSSS 2017-2nd International Workshop on Smart Sensing Systems*, 2017, pp. 1-2.

[6] J. Bernsen and D. Manivannan, "Delay-Tolerant Routing Protocols for Vehicular Ad Hoc Networks: A Critical Comparison and Classification," in *ICWN*, 2008, pp. 149-154.

[7] T. Karunathilake and A. Förster, "A Survey on Mobile Road Side Units in VANETs," *Vehicles,* vol. 4, no. 2, pp. 482-500, 2022.

[8] D. A. Mahmood and G. Horváth, "Analysis of the message propagation speed in VANET with disconnected RSUs," *Mathematics,* vol. 8, no. 5, p. 782, 2020.

[9] Y. Shi, L. Lv, H. Yu, L. Yu, and Z. Zhang, "A center-rule-based neighborhood search algorithm for roadside units deployment in emergency scenarios," *Mathematics,* vol. 8, no. 10, p. 1734, 2020.

[10] C. Liu, H. Huang, and H. Du, "Optimal RSUs deployment with delay bound along highways in VANET," *Journal of Combinatorial Optimization,* vol. 33, no. 4, pp. 1168-1182, 2017.

[11] A. Guerna, S. Bitam, and C. T. Calafate, "Roadside unit deployment in internet of vehicles systems: a survey," *Sensors,* vol. 22, no. 9, p. 3190, 2022.

[12] Z. Ahmed, S. Naz, and J. Ahmed, "Minimizing transmission delays in vehicular ad hoc networks by optimized placement of road-side unit," *Wireless Networks,* vol. 26, no. 4, pp. 2905-2914, 2020.

[13] A. Jalooli, M. Song, and X. Xu, "Delay efficient disconnected rsu placement algorithm for vanet safety applications," in *2017 IEEE Wireless Communications and Networking Conference (WCNC)*, 2017: IEEE, pp. 1-6.

[14] Z. Gao, D. Chen, N. Yao, Z. Lu, and B. Chen, "A novel problem model and solution scheme for roadside unit deployment problem in VANETs," *Wireless Personal Communications,* vol. 98, no. 1, pp. 651-663, 2018.

[15] R. J. Mousa, Á. Huszák, and M. A. Salman, "Enhancing vanet connectivity through a realistic model for rsu deployment on highway," in *Journal of Physics: Conference Series*, 2021, vol. 1804, no. 1: IOP Publishing, p. 012104.

[16] M. Tahira, D. Ather, and A. K. Saxena, "Modeling and Evaluation of Heterogeneous Networks for VANETs," in *2018 International Conference on System Modeling & Advancement in Research Trends (SMART)*, 2018: IEEE, pp. 150-153.

[17] F. Arena and G. Pau, "An overview of vehicular communications," *Future Internet,* vol. 11, no. 2, p. 27, 2019.

[18] A. Zekri and W. Jia, "Heterogeneous vehicular communications: A comprehensive study," *Ad Hoc Networks,* vol. 75, pp. 52-79, 2018.

[19] S. Anand and M. V. Ramesh, "Impact of network density on the performance of delay tolerant protocols in heterogeneous vehicular network," in *2019 International Conference on Wireless Communications Signal Processing and Networking (WiSPNET)*, 2019: IEEE, pp. 293-298.

[20] A. Ahamed and H. Vakilzadian, "Issues and challenges in VANET routing protocols," in *2018 IEEE international conference on electro/information technology (EIT)*, 2018: IEEE, pp. 0723-0728.

[21] A. Bengag and M. El Boukhari, "Classification and comparison of routing protocols in VANETs," in *2018 International Conference on Intelligent Systems and Computer Vision (ISCV)*, 2018: IEEE, pp. 1-8.

[22] M. M. Hamdi, L. Audah, S. A. Rashid, A. H. Mohammed, S. Alani, and A. S. Mustafa, "A review of applications, characteristics and challenges in vehicular ad hoc networks (VANETs)," in *2020 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, 2020: IEEE, pp. 1-7.

[23] M. Kumar, A. K. Nigam, and T. Sivakumar, "A survey on topology and position based routing protocols in vehicular ad hoc network (VANET)," *International Journal on Future Revolution in Computer Science & Communication Engineering,* vol. 4, no. 2, pp. 432-440, 2018.

[24] T. K. Bhatia, R. K. Ramachandran, R. Doss, and L. Pan, "A comprehensive review on the vehicular ad-hoc networks," in *2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO)*, 2020: IEEE, pp. 515-520.

[25] N. J. Patel and R. H. Jhaveri, "Trust based approaches for secure routing in VANET: a survey," *Procedia Computer Science,* vol. 45, pp. 592-601, 2015.

[26] M. R. Ghori, A. S. Sadiq, and A. Ghani, "VANET routing protocols: review, implementation and analysis," in *Journal of Physics: Conference Series,* 2018, vol. 1049, no. 1: IOP Publishing, p. 012064.

[27] F. T. AL-Dhief, N. Sabri, M. Salim, S. Fouad, and S. Aljunid, "MANET routing protocols evaluation: AODV, DSR and DSDV perspective," in *MATEC web of conferences*, 2018, vol. 150: EDP Sciences, p. 06024.

[28] G. D. Singh, R. Tomar, H. G. Sastry, and M. Prateek, "A review on VANET routing protocols and wireless standards," *Smart computing and informatics,* pp. 329-340, 2018.

[29] T. H. Sureshbhai, M. Mahajan, and M. K. Rai, "An investigational analysis of DSDV, AODV and DSR routing protocols in mobile Ad Hoc networks," in *2018 International Conference on Intelligent Circuits and Systems (ICICS)*, 2018: IEEE, pp. 281-285.

[30] D. Sharma, S. Chaudhary, and S. Aggarwal, "PERFORMANCE ANALYSIS OF AODV AND DYMO ROUTING PROTOCOLS IN WI-MAX NETWORKS."

[31] M. A. Shyaa, H. M. Ibrahim, A. Meri, M. Dauwed, and A. Flayh, "The impact of node density over routing protocols in manet by using NS-3," *J. Adv. Res. Dyn. Control Syst,* vol. 11, no. 5 Special Issue, pp. 184-191, 2019.

[32] C. Dutta and D. Singhal, "A hybridization of artificial neural network and support vector machine for prevention of road accidents in VANET," *International Journal of Computer Engineering and Technology,* vol. 10, no. 01, 2019.

[33] A. Husain, S. P. Singh, and S. Sharma, "PSO optimized geocast routing in VANET," *Wireless Personal Communications,* vol. 115, no. 3, pp. 2269-2288, 2020.

[34] H. Bello-Salau, A. Aibinu, Z. Wang, A. Onumanyi, E. Onwuka, and J. Dukiya, "An optimized routing algorithm for vehicle ad-hoc networks," *Engineering Science and Technology, an International Journal,* vol. 22, no. 3, pp. 754-766, 2019.

[35] A. Lakas, M. E. A. Fekair, A. Korichi, and N. Lagraa, "A multiconstrained QoS-compliant routing scheme for highway-based vehicular networks," *Wireless Communications and Mobile Computing,* vol. 2019, 2019.

[36] H. Bagherlou and A. Ghaffari, "A routing protocol for vehicular ad hoc networks using simulated annealing algorithm and neural networks," *The Journal of Supercomputing,* vol. 74, no. 6, pp. 2528-2552, 2018.

[37] G. Sun, Y. Zhang, D. Liao, H. Yu, X. Du, and M. Guizani, "Bus-trajectory-based street-centric routing for message delivery in urban vehicular ad hoc networks," *IEEE Transactions on Vehicular Technology,* vol. 67, no. 8, pp. 7550-7563, 2018.

[38] F. Goudarzi, H. Asgari, and H. S. Al-Raweshidy, "Traffic-aware VANET routing for city environments—A protocol based on ant colony optimization," *IEEE Systems Journal,* vol. 13, no. 1, pp. 571-581, 2018.

[39] C. Chen, L. Liu, T. Qiu, K. Yang, F. Gong, and H. Song, "Asgr: An artificial spider-web-based geographic routing in heterogeneous vehicular networks," *IEEE Transactions on Intelligent Transportation Systems,* vol. 20, no. 5, pp. 1604-1620, 2018.

[40] G. Zhang, M. Wu, W. Duan, and X. Huang, "Genetic algorithm based QoS perception routing protocol for VANETs," *Wireless Communications and Mobile Computing,* vol. 2018, 2018.

[41] N. M. Al-Kharasani, Z. A. Zulkarnain, S. Subramaniam, and Z. M. Hanapi, "An efficient framework model for optimizing routing performance in VANETs," *Sensors,* vol. 18, no. 2, p. 597, 2018.

[42] M. Elshaikh, M. N. B. M. Warip, N. Yaakob, O. Lynn, A. K. Yousif, and Z. Ishwar, "Taguchi methods for ad hoc on demand distance vector routing protocol performances improvement in VANETs," in *International Conference of Reliable Information and Communication Technology*, 2017: Springer, pp. 163-170.

[43] M. Raja, "PRAVN: perspective on road safety adopted routing protocol for hybrid VANET-WSN communication using balanced clustering and optimal neighborhood selection," *Soft Computing,* vol. 25, no. 5, pp. 4053-4072, 2021.

[44] X. Bao, H. Li, G. Zhao, L. Chang, J. Zhou, and Y. Li, "Efficient clustering V2V routing based on PSO in VANETs," *Measurement,* vol. 152, p. 107306, 2020.

[45] R. Liu, Y. Xiang, and Y. Yang, "MARR-ALOHA: A mobility adaptive variety of RR-ALOHA for vehicular ad-hoc networks," in *2012 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet)*, 2012: IEEE, pp. 3304-3309.

[46] S. Asadallahi and H. H. Refai, "Modified R-ALOHA: broadcast MAC protocol for vehicular ad hoc networks," in *2012 8th International Wireless Communications and Mobile Computing Conference (IWCMC)*, 2012: IEEE, pp. 734-738.

[47] S. Anand and M. V. Ramesh, "Performance Analysis of Delay Tolerant Network Routing Protocols in a Heterogeneous Vehicular Network," in *2018 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*, 2018: IEEE, pp. 1-6.

[48] V. N. Soares, F. Farahmand, and J. J. P. Rodrigues, "Impact of vehicle movement models on VDTN routing strategies for rural connectivity," *International Journal of Mobile Network Design and Innovation,* vol. 3, no. 2, p. 103, 2009.

[49] C. Caini, "Delay-tolerant networks (DTNs) for satellite communications," in *Advances in Delay-Tolerant Networks (DTNs)*: Elsevier, 2021, pp. 23-46.

[50] P. Godha, S. Jadon, A. Patle, I. Gupta, B. Sharma, and A. K. Singh, "Architecture, an efficient routing, applications, and challenges in delay tolerant network," in *2019 International Conference on Intelligent Computing and Control Systems (ICCS)*, 2019: IEEE, pp. 824-829.

[51] M. Benamar, S. Ahnana, F. Z. Saiyari, N. Benamar, M. D. El Ouadghiri, and J.-M. Bonnin, "Study of VDTN routing protocols performances in sparse and dense traffic in the presence of relay nodes," *Journal of Mobile Multimedia,* pp. 078-093, 2014.

[52] A. Hamza-Cherif, K. Boussetta, G. Diaz, and F. Lahfa, "Performance evaluation and comparative study of main VDTN routing protocols under small-and large-scale scenarios," *Ad Hoc Networks,* vol. 81, pp. 122-142, 2018.

[53] P. Kamal and N. Singh, "A new approach buffer-efficient disruption tolerant protocol in vehicular delay-tolerant network," *Journal of Information and Optimization Sciences,* vol. 41, no. 6, pp. 1395-1405, 2020.

[54] A. Ali, M. Shakil, H. Rafique, and S. M. Cheema, "Connection Time Estimation between Nodes in VDTN," *International Journal of Advanced Computer Science and Applications,* vol. 10, no. 1, pp. 339-345, 2019.

[55] S. Parameswari, "Opportunistic Routing Protocol for Resource Optimization in Vehicular Delay-Tolerant Networks (VDTN)," *Turkish Journal of Computer and Mathematics Education (TURCOMAT),* vol. 12, no. 11, pp. 3665-3671, 2021.

[56] A. Ali, J. Li, A. Tanveer, M. Batool, and N. Choudhary, "DesCom: Routing Decision using Estimation Time in VDTN," *International Journal of Advanced Computer Science and Applications,* vol. 10, no. 11, 2019.

[57] J. A. Dias, J. J. Rodrigues, N. Kumar, V. Korotaev, and G. Han, "REMA: A resource management tool to improve the performance of vehicular delay-tolerant networks," *Vehicular Communications,* vol. 9, pp. 135-143, 2017.

[58] A. Hamza-Cherif, K. Boussetta, G. Diaz, and F. Lahfa, "GeoDTC: A New Geographic Routing Protocol Based on Distance, Time and Custody Transfer," in *International Conference on Internet of Vehicles*, 2018: Springer, pp. 27-45.

[59] M. Tsuru, W. N. Cahyo, and P. A. Brastama, "Performance of Delay Tolerant Network Protocol in Smart City Scenario," in *Journal of Physics: Conference Series*, 2020, vol. 1569, no. 2: IOP Publishing, p. 022056.

[60] Y. Teranishi, T. Kimata, E. Kawai, and H. Harai, "Hybrid cellular-DTN for vehicle volume data collection in rural areas," in *2019 IEEE 43rd Annual Computer Software and Applications Conference (COMPSAC)*, 2019, vol. 1: IEEE, pp. 276-284.

[61] N. Magaia, C. Borrego, P. R. Pereira, and M. Correia, "ePRIVO: An enhanced privacy-preserving opportunistic routing protocol for vehicular delay-tolerant networks," *IEEE Transactions on Vehicular Technology,* vol. 67, no. 11, pp. 11154-11168, 2018.

[62] F. Farooq and N. Bibi, "Message Admission Control along with Buffer Space Advertisement to Control Congestion in Delay Tolerant Networks (DTNs)," *EAI Endorsed Transactions on Energy Web and Information Technologies,* vol. 5, no. 17, 2018.

[63] V. Chourasia, S. Pandey, and S. Kumar, "Optimizing the performance of vehicular delay tolerant networks using multi-objective PSO and artificial intelligence," *Computer Communications,* vol. 177, pp. 10-23, 2021.

[64] A. K. Singh and R. Pamula, "An efficient and intelligent routing strategy for vehicular delay tolerant networks," *Wireless Networks,* vol. 27, no. 1, pp. 383-400, 2021.

[65] J. Gonçalves Filho, A. Patel, B. L. A. Batista, and J. C. Júnior, "A systematic technical survey of DTN and VDTN routing protocols," *Computer Standards & Interfaces,* vol. 48, pp. 139-159, 2016.

[66] B. Marzak, H. Toumi, E. Benlahmar, and M. Talea, "Analysing Clustering Routing Protocols Performance for Vehicular Networks," in *Proceedings of the 2nd international Conference on Big Data, Cloud and Applications*, 2017, pp. 1-7.

[67] F. D. Da Cunha, A. Boukerche, L. Villas, A. C. Viana, and A. A. Loureiro, "Data communication in VANETs: a survey, challenges and applications," 2014.

Ahmed Ali Hussein received his B.Sc. Degree in Computer Engineering from the University of Technology, Iraq, in 2013. He is a member of the Iraqi Engineers Association. He is currently a M.Sc. student at the University of Technology, Department of Computer Engineering, Iraq. His research interests are computer engineering, Wireless networks, ad-hoc wireless networks and VANET.

Dr. Dhari Ali Mahmood is currently a Lecturer at the Department of Computer Engineering, University of Technology, Iraq. Received a B.Sc. degree in computer engineering from University of Technology, Baghdad, Iraq, in 2005 and M.Sc. degree in computer engineering from GGSIP University, India in 2014. He obtained his Ph.D. in Computer Engineering from Budapest University of Technology and Economics, Hungary in 2021. Research interests mainly focus on Mobile Ad-hoc Network (MANET), Vehicular Ad-hoc Network (VANET), Queueing performance and Computer Networks.