ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 11, Issue 4, April 2024

A Novel Routing Protocol for Vehicular Ad Hoc Networks (VANETs) that Prioritizes-Efficiency in Distance, Connectivity, and Traffic Density Stability

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Abstract*— In recent years, Vehicle Ad-hoc Networks (VANETs) have received a lot of interest due to their ever-changing topology, high vehicle mobility, frequent link failures, and demanding latency specifications. The dynamic nature of VANETs adds to the overhead of control traffic, necessitating effective routing algorithms to assure reliable transmission. This paper proposes a unique Traffic Density Stable Routing Protocol based on Connection- and Distance (TDSRP-DC) to reduce data packet collisions at junctions and adaptively pick routes in real time. Our technique, based on vehicle-to-vehicle communication, enables cars to determine optimal pathways by detecting acceptable next junctions and permitting multi-hop transmissions to receivers. Periodic data exchanges between cars allow for real-time traffic fluctuation estimation, which is aided by processes including network construction, neighbour discovery, fitness value prediction, and routing methodology. Critical parameters such as node distance, speed, azimuth, link stability, and dependability guide the path optimisation procedure. Our protocol uses vehicle-to-vehicle communication, in which ground vehicles find the best next junction and relay data packets to their intended receivers, resulting in optimal multi-hop pathways. Real-time traffic changes are estimated by frequently exchanging data between cars. This approach's key stages include network construction, neighbour detection, fitness value prediction, and routing mechanism. Parameters including node distance, speed, azimuth, link stability, and reliability are critical in finding the best path.

Keywords: Vehicle Ad Hoc Networks, Routing Protocol, Traffic Density, Connection-Based Routing, Distance-Based Routing, Multi-hop Transmission, and Real-Time Traffic Estimation.

I. INTRODUCTION

Automotive communication stands at the forefront of contemporary vehicle technology research, with a focus on both hardware and software development for communication systems, which are pivotal in establishing novel vehicle networks. The paramount objective of these burgeoning networks is to ensure passenger safety and curtail the frequency of accidents. The escalating number of vehicles on the roads correlates directly with the surge in road accidents, necessitating advancements in vehicle communication technology. Such technology facilitates the exchange of crucial information among vehicles, encompassing traffic updates and safety alerts. The proliferation of vehicle networks has been spurred by a burgeoning user base and the escalating incidence of accidents.

Quality of Service (QoS) enhancement in Vehicle Ad Hoc Networks (VANETs) has emerged as a crucial and transformative pursuit in recent decades. VANETs are characterized by rapid dynamic routing, high mobility, and frequent node failures. However, a noteworthy drawback of VANET networks pertains to their susceptibility to network insecurity, which undermines overall network efficiency. VANET technology stands as a cornerstone in managing Intelligent Transport Systems (ITS). The determination of the most connected road segments towards a destination relies on the periodic exchange of Hello packets among vehicles, facilitated by Vehicle-To-Vehicle (V2V) communication as an anticipatory oversight mechanism.

The inherent wireless network within vehicles enables data transmission via a multi-hop method, traversing through successive vehicle nodes. Building upon this concept, authors establish a foundational backbone through the selection of specific nodes and the acquisition of position data concerning rapidly changing nodes. Additionally, a cluster-based approach emerges as a standard model for vehicle communication, organizing nodes into clusters where a designated cluster header oversees communication within and across clusters. VANET, a cornerstone of Intelligent Transport Systems (ITS), facilitates vehicle-to-vehicle communication, essential for enhancing road safety and reducing accident rates.

In pursuit of improving VANET Quality of Service (QoS) performance, various advanced routing protocols have been developed, including AODV variants based on cluster, location, distance, and fitness. Research in VANET applications encompasses areas such as data security, QoS enhancement, scalability, resilience, efficient routing, node mobility, and fault tolerance. To address challenges posed by faulty nodes and malicious hardware attacks, protocols like Cluster-Based Lifecycle Routing Protocol (CBLTR), VANET Intersection Dynamic Routing Protocol (IDVR), and Control Overload Reduction Algorithm (CORA) are proposed, each targeting specific aspects of VANET performance enhancement.

Furthermore, VANETs contribute significantly to road safety by disseminating time-sensitive traffic information and route guidance, potentially enabling autonomous driving capabilities in vehicles. Beyond safety applications, VANET technology finds utility in intelligent transportation systems, infotainment, passenger convenience, and various other domains. Leveraging VANET capabilities, vehicles can establish decentralized networks with self-handling and self-organization functionalities, eliminating the need for centralized control.

The effectiveness of VANET functionalities heavily relies on mobility constraints, high-speed communication, and anticipatory behavior. Routing protocols play a pivotal role in ensuring dynamic routing and minimal time delay in information exchange, essential for security and real-time applications. The proposed Traffic Density Stable Routing Protocol based on Distance and Connection (TDSRP-DC) aims to mitigate data packet collisions at intersections and introduces a novel routing schedule based on real-time selection, thereby improving VANET QoS performance. Key contributions of the proposed research include the analysis of communication processes in VANETs, development of a novel TDSRP-DC routing algorithm to enhance QoS performance, experimental validation of QoS parameters, and comparative analysis against conventional algorithms such as TFOR, CRPV, GPSR, and GSR. These contributions collectively contribute to advancing the state-of-the-art in VANET research and application.

II. RELATED WORK

Related work in the subject of vehicular ad hoc networks (VANETs) includes numerous routing protocols and algorithms that aim to improve network performance, dependability, and efficiency. Here, I will provide a full explanation of each referenced publication and its significance to the evolution of VANET technology. Improved the AODV Routing Protocol:

Liu et al. [1] suggested an Improved AODV routing protocol for large-scale VANETs that relies on controlled broadcasting by communication zones. This protocol seeks to increase routing performance in VANETs by enabling restricted broadcasting within communication zones, which is especially useful in large-scale VANET deployments. Li et al. [2] proposed a probabilistic prediction-based reliable and efficient opportunistic routing algorithm for VANETs. This approach uses probability prediction to improve the routing reliability and efficiency in VANETs particularly useful in dynamic and unpredictable traffic scenarios.

Adaptive Relay Selection Scheme: Al-Kharasani et al. [3] proposed an adaptive relay selection scheme to improve network stability in VANETs. This technique dynamically picks relay nodes to increase network stability, ensuring reliable communication even in demanding VANET situations. Suganthi and Ramamoorthy [4] suggested an Advanced Fitness-Based Routing Protocol to improve QoS in VANET. This protocol uses fitness-based routing to optimise Quality of Service (QoS) parameters including packet delivery ratio and network throughput, improving overall VANET performance.
Purkait and Tripathi [5] proposed a Fuzzy Logic-Based Multicriteria Intelligent Forward Routing for VANET. This routing strategy uses fuzzy logic to generate intelligent forwarding decisions, taking into account numerous variables, to increase routing efficiency and reliability in VANETs.Wagh and Gomathi [6] suggested a route discovery method for vehicular ad hoc networks based on the Modified Lion Algorithm. This technique uses a modified lion algorithm to effectively discover routes in VANETs, which improves route formation and maintenance in dynamic network conditions.

Bello-Salau et al. [7] proposed an optimized routing algorithm for vehicle ad hoc networks. This algorithm optimizes routing decisions to improve overall network performance in VANETs, taking into account aspects such as traffic load and network structure. Zhang, Zhang, and Liu [8] introduced a novel self-adaptive routing service algorithm for VANET applications. This method tailors routing services to real-time network conditions, ensuring efficient and reliable communication in VANETs. Patil and Ragha [9] developed an Adaptive Fuzzy-Based Message Dissemination and Micro-Artificial Bee Colony Algorithm Optimized Routing Scheme for Vehicular Ad Hoc Networks. This system optimizes message dissemination and routing in VANETs using fuzzy logic and a micro-artificial bee colony algorithm, resulting in improved network performance and dependability. Abuashour and Kadoch [10] focused on improving the performance of the cluster-based routing protocol in VANET. Their research seeks to improve the performance of cluster-based routing protocols in VANETs, specifically in terms of communication efficiency and scalability.

Dua, Kumar, and Bawa [11] conducted a systematic review of routing protocols for VANETs. Their research provides a thorough overview of existing routing methods, analyzing their merits. Eiza, Owens, and Ni [12] proposed a multi-constrained QoS-aware routing algorithm for VANETs that is both safe and robust. This algorithm prioritises quality of service criteria while ensuring the security and dependability of data transmission in virtual networks. Goudarzi, Asgari, and Al-Raweshidy [13] proposed a traffic-aware VANET routing system tailored to metropolitan contexts. This protocol uses ant colony optimization to make routing decisions based on real-time traffic conditions in urban locations. Al-Mayouf et al. [14] created a real-time intersection-based segment aware routing algorithm specifically designed for urban traffic networks. This method optimises routing pathways based on intersections and road segments, which increases network efficiency and reliability in metropolitan areas. Alsharif and Shen [15] introduced iCAR-II, an infrastructure-based connection aware routing technology for VANETs. This protocol uses infrastructure support to improve connectivity-aware routing, resulting in more efficient and reliable communication in vehicle networks. Li et al. [16] proposed hierarchical routing for VANETs using reinforcement learning techniques. This method optimises routing decisions using hierarchical structure and reinforcement learning, hence boosting network performance and scalability. Each of the studies cited provides useful insights and ways to solving the specific issues of routing in VANETs, such as quality of service optimization, traffic awareness, real-time decision-making, and infrastructure support. These contributions extend the state-of-the-art in VANET technology by proposing solutions for efficient and dependable communication in vehicular networks.

III. METHODOLOGY

The Distance and Connection-Based Traffic Density Stabilization Routing Protocol (TDSRP-DC) seeks to discover dependable road segments with the shortest and most accessible points, as determined by cars constantly calculating points at intersections of adjacent road segments. TDSRP-DC obtains a global perspective of surrounding intersections through Vehicle-to-Vehicle (V2V) communication, allowing it to determine the road segment with the greatest connections based on intersection scores. Hello messages sent between automobiles at crossroads aid in this procedure. If a car notices a higher score computed by another vehicle at a separate intersection, it can use that intersection as the gearbox node rather than the present road segment. TDSRP-DC improves overall Quality of Service (QoS) performance in VANETs by focusing on measures such as Packet Delivery Ratio (PDR), Packet Loss Ratio (PLR), Delay, and Network Throughput.

3.1. System Model:

Each vehicle comes with a wireless Wi-Fi interface for V2V communication. Communication between automobiles on different routes facing away from each other is impossible owing to barriers. Vehicles can communicate with any V2Vs within their gearbox range. V2Vs can function independently of human intervention. To ensure communication between all vehicles and V2Vs, regular intervals are maintained. Data transport to the destination takes four steps: route selection, greedy forwarding, back-and-forth storage, and V2V communication. TDSRP-DC uses Greedy Forwarding and Carry & Forward techniques for data transport, depending on network conditions. Routing decisions are only made at intersections, taking into account traffic intensity and the fastest route to the destination. Drones deliver packets if another junction has a higher score or there is no connectivity segments are available elsewhere that method can be used to rapidly determine the score for the road segment as given Eqn. (1)

$$score_i = \frac{TNoV}{D_w}(L_j \times R_j)$$

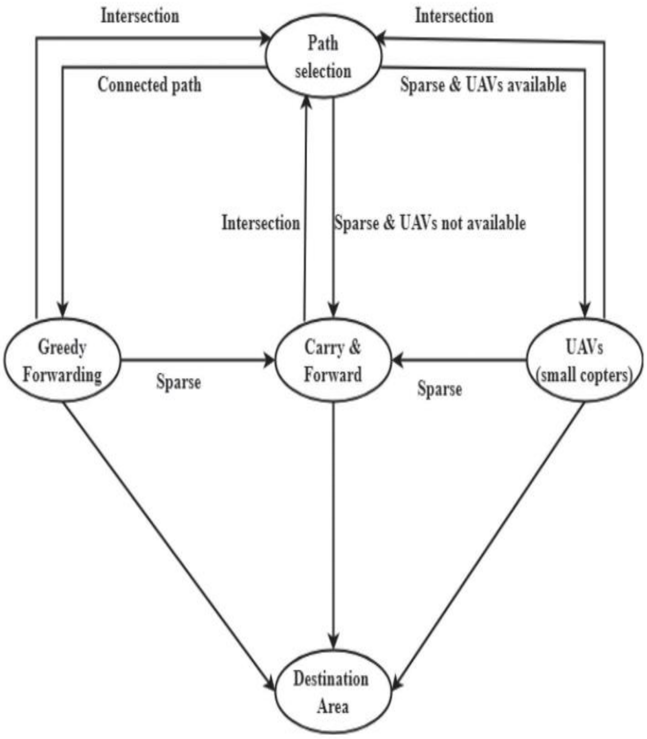


Figure 1: The proposed model

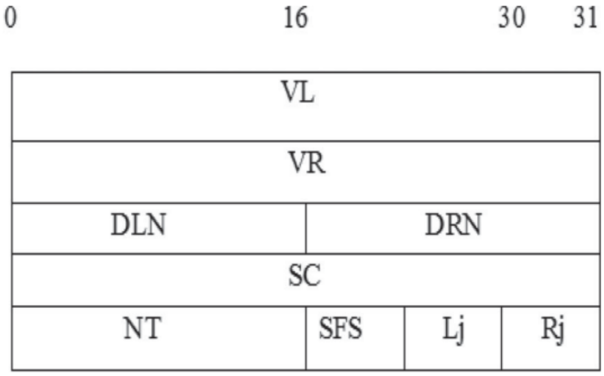
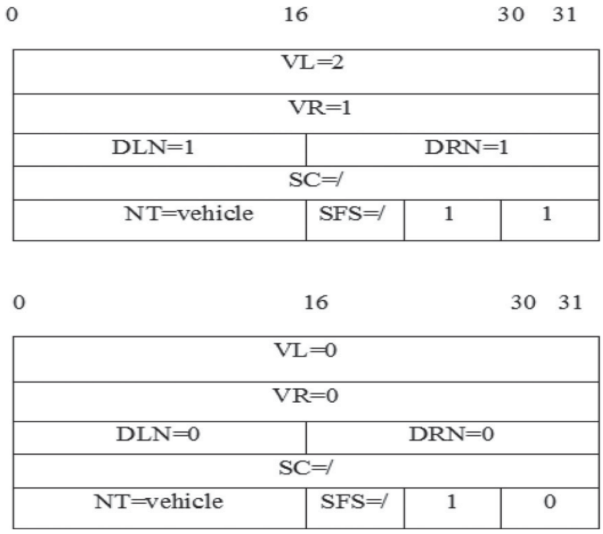


Figure 2: Additional fields in the hello packets

Based on the provided information, the Time to Next Vehicle (TNoV) is determined using data on Vehicle Left (VL) and Vehicle Right (VR) gathered from Hello messages received by the vehicle. The formula for TNoV is calculated as follows:

TNoV = (VL or VR) + 1.

Each vehicle provides information regarding its ability to make left and right turns. When the vehicle receives Hello signals from its far left and right neighbours, it calculates and broadcasts the number of vehicles. This process continues until the Hello message reaches the end of the road stretch, usually at the intersection of Lj and Rj. When the source vehicle intercepts the road segment at the intersection, our method accurately estimates its gradient.



0	16	30	31
VL=2			
VR=1			
DLN=1	DRN=1		
SC=/			
NT=vehicle	SFS=/	1	1

0	16	30	31
VL=0			
VR=0			
DLN=0	DRN=0		
SC=/			
NT=vehicle	SFS=/	1	0

Figure 3: calculation of Score

3.2. Architecture and Routing of Proposed TDSRP-DC:

The new TDSRP-DC routing system prioritizes controlling the most connections from available channels while avoiding easily unplugged ones. Because of the great mobility of vehicles, link pathways are built and updated as they hit impediments. Based on traffic density and vehicle connections on the road segment, the track with the most connections is considered the most trustworthy. Track connection can be measured in several ways:

1. Vehicles exchange hello messages on a regular basis

If no routing path is available, the data packet is sent directly to a V2V in range and then forwarded. If the destination is inside the vehicle's transfer territory, it can be reached directly. Otherwise, the car arrives at the most convenient intersection with an open connecting route leading to the destination.

2. Assumptions for the routing method to function properly include:

- All cars and V2Vs have an integrated Global Positioning System (GPS) and a digital roadmap for locating adjacent intersections.
- Access to the Grid Location Service (GLS) and understanding of the destination.
- All vehicles and V2Vs perform regular maintenance and updates to the surrounding table.
- Support for V2V and line-of-sight communication with other cars.

A new field in the Hello Message format allows vehicles to count the total number of vehicles, get a global picture of the relationship between successive junctions, and share this information with other V2V vehicles. The vehicle at the intersection (source/freight forwarder) then chooses a path based on this information.

Path Selection:

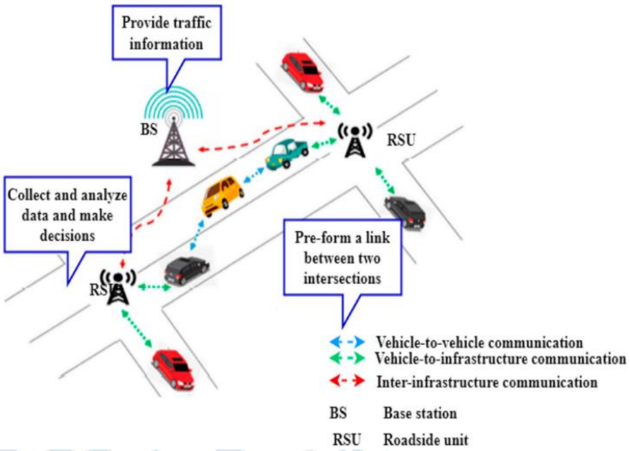


Figure 4: DCBDSR protocol routing protocol Architecture

The TDSRP-DC protocol relies heavily on optimal path selection. This method is very difficult because route decisions are only decided at road junctions, where the shortest connecting route is selected. Figure 4 illustrates the architecture of the planned TDSRP-DC. The path-selection process is outlined in the following steps:

1. Score Calculation: At each intersection, all vehicles continuously compute scores for the road segments that surround them.
2. Choice of Best path: The segment with the highest score is picked as the best path to the destination.
3. V2V Communication: V2V communication involves the regular transmission of Hello messages, allowing flying vehicles (V2V) to grab the highest score established for each intersection in the vicinity.
4. Comparison: If a vehicle at an intersection detects a V2V, scores from V2Vs are collected and compared to the highest computed score.
5. Decision Table: Vehicles at junctions (source/transponder) generate decision tables to find the most appropriate next intersection.

Pseudo Code Algorithm:

```
R ← Vehicle of destination;
P ← Present vehicle;
IJ ← Present intersection;
Nc← The set of one hop neighbors of C;
 If P = R then
Received data;
 else
if R ∈Nc then
Transmitted data (R)
```

```
else if
Posi.(P) ∈Intersection region then
for each Segment i
do
Score i = J ←Max of all (Segment, Score i);
 If J ≥ SC then SFS ←vehicle;
 Transmit (SFS, Packet)
else SFS ←UAV;
Transmitted data (SFS, Packet);
Wait Destination () or intersection;
```

6. Packet Delivery:

- The data packet is sent to the section or drone that has the highest score.
- In the event of a transponder/source vehicle, after getting the highest score, it sends the data packet to the target car based on predefined criteria.
- The car then sends the data packet to the vehicle at the highest-scoring junction (e.g., intersection 3).
- The data packet is subsequently routed to junction 3 via the road segment closest to the destination, where there are enough automobiles to make connections.

These steps outline the procedure for selecting the optimal path in the TDSRP-DC protocol, ensuring efficient and reliable data packet delivery in vehicular ad hoc networks.

3.3 Proposed TDSRP-DC Algorithm

In vehicular ad hoc networks (VANETs), the Traffic Density Stable Routing Protocol based on Distance and Connection (TDSRP-DC) serves as a reactive transmission mechanism. VANET functions as a location service, allowing communication between the source vehicle (S) and target vehicle (D). Once detected, Vehicle-to-Vehicle (V2V) sequences are cached to ensure reliable data packet transfer between intermediate nodes and for routine maintenance processes.

3.3.1 Routing Process:

When the Route Request (RREQ) arrives at destination d, a timer is started, allowing a predetermined amount of time (e.g., up to 500 milliseconds) to learn about all available pathways in that timeframe. After the waiting period, all incoming RREQs are rejected, and routing decisions are made by sending Route Reply (RREP) packets to the source node via the best path with the greatest score. TDSRP-DC is self-contained, therefore waiting time has no effect on the system's real vehicle distribution computation. A point is calculated for each observed V2V sequence using the information provided by the RREQ. The destination remains aware of these sequences and their specific properties, which are used in decision-making. The destination's RREP packet contains information about its physical location as well as the route chosen.

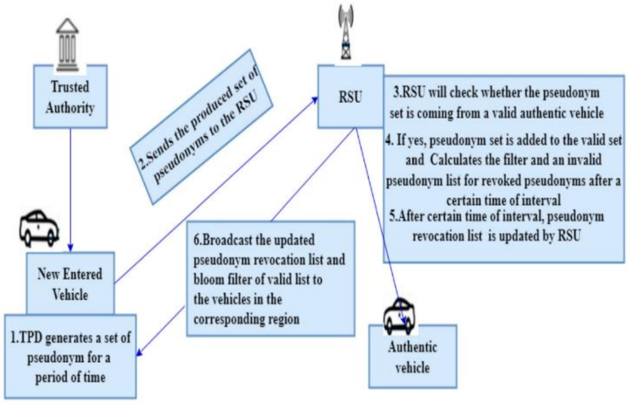


Figure 5: authentication scheme in Conditional privacy preserving (VANET)

3.3.2 Data Packet Delivery

Data packet transfer takes place either by V2V transmission in the air or vehicle transmission on the ground. The present vehicle begins the discovery process via V2V, capturing potential RREP packets if a V2V link exists. Based on score comparison, the vehicle selects the optimum path segment and delivers using the approach with the highest score. TDSRP-DC takes precedence, transmitting the data packet immediately to the recipient if Scores are greater than zero. However, if Scores = 0, indicating weak V2V connections or no path to the destination, TDSRP-DC searches for another acceptable intersecting point for packet delivery. Routing pathways are gradually constructed at each crossing to ensure effective data packet delivery.

3.4 Conditional Privacy Preserving Authentication

VANET infrastructures use fixed Road-Side Units (RSUs) and an online Trusted Authority (TA) to communicate. Each vehicle has an On-Board Unit (OBU) that allows communication with both cars and infrastructure. The suggested system provides conditional privacy protection, non-repudiation, and unlikability while ensuring non-framability and quick authentication. Vehicles must perform mutual authentication with RSUs when entering a new domain, with RSUs broadcasting critical information to vehicles within their coverage. OBUs generate short-term pseudonyms, which RSUs authenticate for validity. TA keeps track of authenticated vehicles and updates the public parameters and master keys of RSUs to ensure security and exclude revoked vehicles. The TA distinguishes actual identities from pseudo-identities to ensure secure authentication on VANETs.

IV. SIMULATION RESULTS

Simulation findings show that TDSRP-DC outperforms standard algorithms, especially in complex traffic circumstances. TDSRP-DC outperforms conventional TFOR algorithms in both packet delivery rate (by 10%) and overall performance (by 35%). These findings highlight the significance and usefulness of the proposed routing strategy, which improves service quality in virtual area networks during the flight.

Table 1: Simulation setup

Parameters	Values
Simulation Platform	NS 2
Simulation Area	Manhattan (2000 m×2000 m)
Maximum vehicle speed	40 kmph
No of nodes	0–100
Channel bandwidth [MHz]	10
MAC and PHY layer	IEEE 802.11p
Data rate [Mbps]	6
Frequency [GHz]	5.9
Communication range [m]	400m
Packet size [byte]	4
Hello packet interval	1s
Simulation time	50s

Table 1 shows the simulation parameters used in the investigation. In traffic density study, TDSRP-DC outperforms other advanced routing protocols. The studies included vehicle flows ranging from 70 to 400 nodes, demonstrating TDSRP-DC's effectiveness, particularly in medium to high density scenarios, as shown in Figure 5. The evaluation compared TDSRP-DC to existing protocols such as TFOR, CRPV, GPSR, and GSR, as well as AODV and NS-2.34 implementations. The testing included a variety of vehicle densities, ranging from simple to complex traffic scenarios. Each vehicle's gearbox distance was set to about 300 meters, with a 100% chance of effective ground connection. The transmission distance for V2V communication was set at around 1000 meters, with an 80% communication probability. Furthermore, when vehicles communicate using V2V, their gearbox distance is around 1000 meters, with a 70% success rate.

Several evaluation parameters were considered to enhance the proposed algorithms' performance:

4.1 Packet Delivery Ratio (PDR)

This section investigates delivery rates for various vehicle and drone densities during the evaluation process. Figures 9-10 and Tables 2-4 show that the V2V-based strategy achieves much greater delivery rates than earlier routing protocols, increasing the accuracy of path selection calculations. TDSRP-DC has a modest advantage over CRPV in this regard. While CRPV does not use automobiles for data packet transmission, its reliance on V2V assures a constantly strong connection due to its larger size.

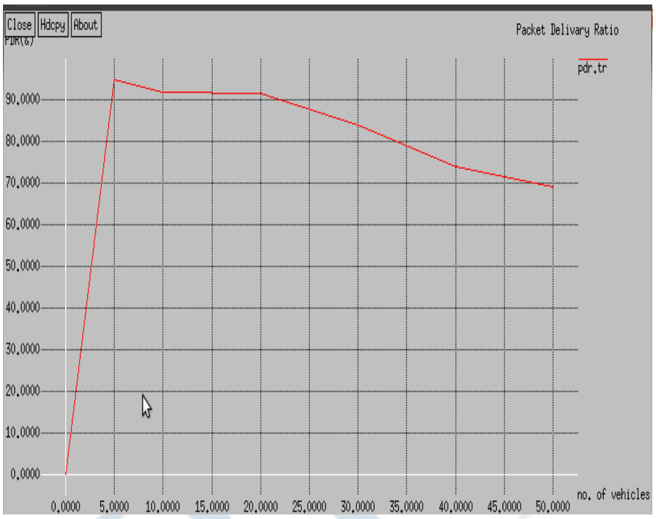


Figure 1: Packet delivery ratio vs. number of vehicles

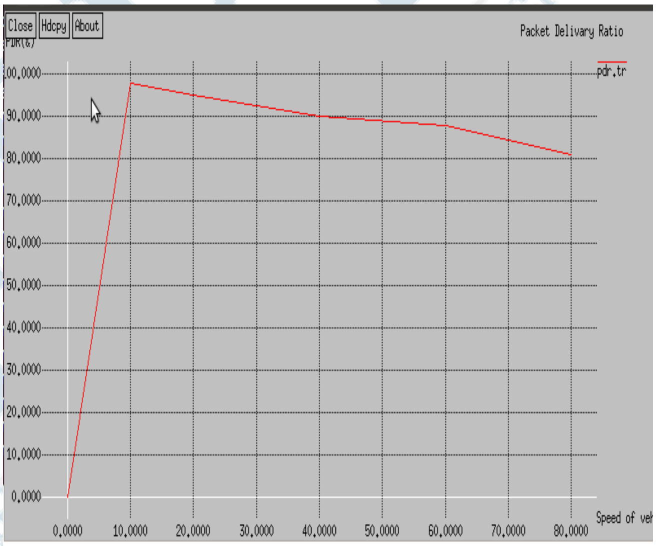


Figure 2: Packet delivery ratio VS Vehicle Speed

This technique has the lowest PDR across all vehicle densities. This is due to the need to account for the vehicle's quick motion when computing the entire routing path, which results in higher packet loss frequency.

4.2 Average Throughput

The graph depicts the network throughput at various node densities. Tables 5 and Figure 14 demonstrate that, with the exception of GSR, increasing node density improves throughput across all protocols. In high-density environments, the suggested solution outperforms conventional routing techniques in terms of network throughput. The proposed approach seeks to identify a reliable forwarding node and assure the delivery of RREQ packets within the sharing point. Furthermore, TDSRP-DC has lesser stability than the proposed protocol, resulting in increased routing.

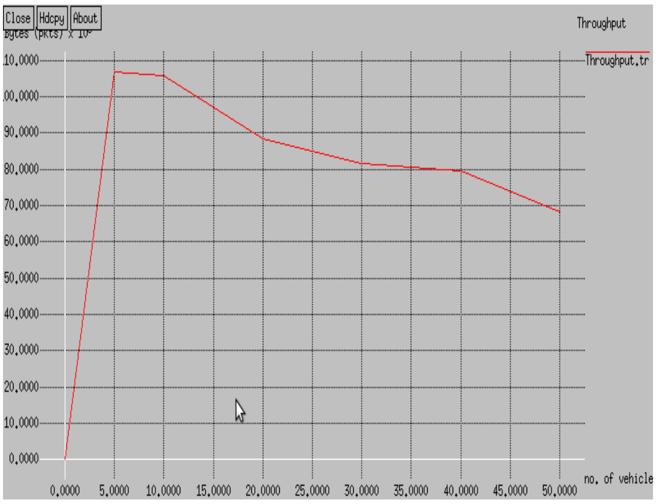


Figure 3: Average throughput w.r.t. no. of vehicles for dense

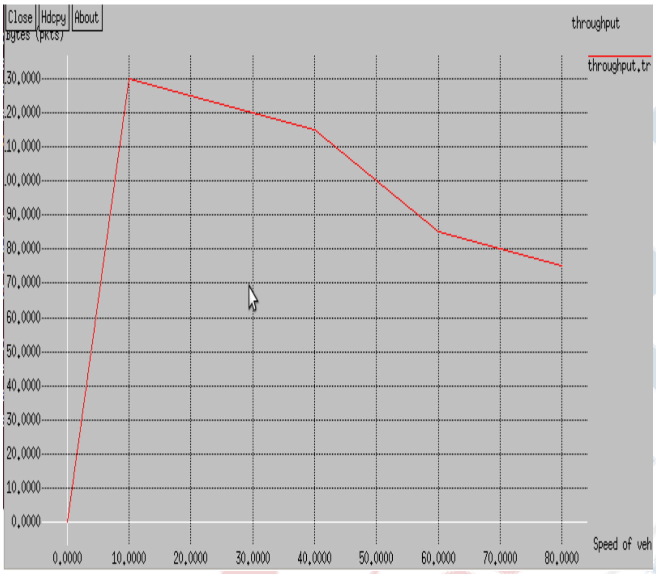


Figure 4: Average throughput vs. speed of vehicles

4.3 End-to-End Delay

The average end-to-end delay for various vehicle and V2V densities is depicted in the diagram. TDSRP-DC consistently exhibits the lowest average latency and outperforms other evaluation protocols, maintaining a delay of 1s for 500 vehicles, as demonstrated in Figure 15. Notably, the delay decreases as density increases, as illustrated in the graph. TDSRP-DC consistently exhibits the shortest and most stable delay across different vehicle densities.

There are several factors contributing to TDSRP-DC's superior performance in terms of delay. Firstly, leveraging existing V2V communication ensures precise score calculations, facilitating accurate selection of the optimal road segment for each transmission. Secondly, the relatively short distance traveled by the packet to reach its destination significantly reduces the average waiting time. Furthermore, by initiating the discovery process prior to each data delivery, any additional time required can be promptly identified and mitigated, contributing to efficient routing decisions.

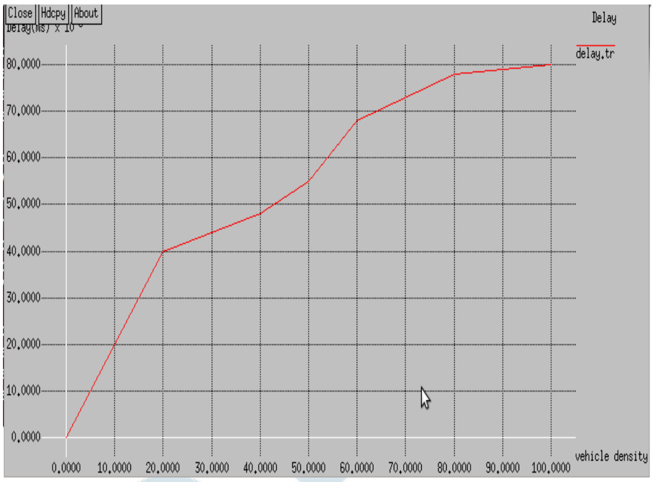


Figure 5: End to end delay vs. vehicle density

In contrast, protocols such as GPSR and TFOR demonstrate inferior performance compared to TDSRP-DC and CRPV. The use of back-and-forth technology in these protocols leads to additional delays, particularly when road segments are separated. The high mobility of vehicles and inaccurate computations exacerbate these delays. Additionally, the sole reliance on vehicle collaboration in GSR results in heightened collision probabilities, further contributing to increased delay.

V. CONCLUSION

To summarize, the suggested Traffic Density Stable Routing Protocol based on Distance and Connection (TDSRP-DC) offers a viable option for improving the performance of Vehicular Ad hoc Networks (VANETs). TDSRP-DC outperforms previous routing protocols thanks to unique features such as efficient path selection based on traffic density analysis and dependable data packet delivery via Vehicle-to-Vehicle (V2V) communication. The comparison of TDSRP-DC to existing protocols such as TFOR, CRPV, GPSR, and GSR demonstrates its effectiveness in terms of packet delivery ratio, end-to-end delay, and overall network performance. TDSRP-DC regularly outperforms these protocols, providing better delivery rates, lower latency, and improved stability at different vehicle densities.

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