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Adaptive Infrastructure Based Geographical Routing for Vehicular Ad Hoc Networks

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Abstract: Creating a smart city requires intelligent infrastructures and components. Smart transportation is one of the essential structures of a smart city that, by utilizing vehicular networks and data communications between vehicles and infrastructure, enables citizens to request high-quality services. However, the increase in these communications can lead to a decrease in network service quality. In this paper, an adaptive geographic routing method is proposed to establish a connection between two vehicles in a way that maintains service quality by creating a stable route despite increasing network load and vehicle mobility. To achieve this, three types of connections are considered: a multi-hop connection that only utilizes vehicles along the route, a single-hop infrastructure connection that seeks to connect source and destination RSUs, and a hybrid connection that leverages both types. The type of connection is selected based on mobility parameters and network load. The proposed method is compared with the most widely-used geographic routing in VANETs, namely GPSR, as well as its improved version, MMGPSR. Evaluation results indicate that the proposed method reduces end-to-end delay and also improves data delivery rate.

Index Terms: Geographic Routing, Multi-Hop Communication, Roadside Unit, Stable Communication, VANETS.

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I. INTRODUCTION

Nowadays, billions of devices are connected to the Internet of Things (IoT) around the world, a figure expected to nearly double within the coming years. Vehicles constitute a significant part of these devices. With the increasing number of vehicle s equipped with IoT, Vehicular Ad Hoc Networks (VANETs) are transforming into the Internet of Vehicles (IoV) [1]. The Internet of Vehicles is a subset of IoT, as well as a more developed and comprehensive form of VANETs. While VANETs focus primarily on communications between vehicles and road infrastructure units (RSU), IoV takes these communications to a new level. It expands the integration of data and systems, providing significant improvements in vehicles' safety, efficiency, and comfort [2].

The Internet of Vehicles has a wide range of applications that are either real-time or delay-sensitive. These include emergency communications, vehicle safety, traffic prediction, precise localization, and security information. For example, in case of an accident, emergency communications are of utmost importance to ensure information is quickly transmitted between vehicles and central systems. It facilitates necessary actions to assist the involved vehicles and injured individuals. Likewise, traffic prediction and security information require high-speed and real-time data transmission to improve safety and efficiency of vehicles. Therefore, end-to-end delay is considered the most critical Quality of Service (QoS) parameter in these applications, demanding wireless networks with high performance and sufficient bandwidth.

Moreover, with the growing use of vehicles and the constantly changes in wireless communications, end-to-end delay has emerged as one of the main challenges in these networks. To address this issue, it is essential to select a stable connection for data transmission. Connection stability can play a key role in reducing delay and, subsequently, increasing throughput rate (by reducing control overhead). However, selecting an appropriate connection in this dynamic and complex environment presents challenges. While trying to minimize delay, it is important to remember that it does not necessarily mean decreasing the number of hops along the path. Solving this challenge will improve the ability of data transmission and communication between vehicles and road infrastructure, thereby enhancing the quality of services. To reduce delay in real-time applications, it is possible to predict vehicle movements and select more stable connections, using mobility parameters. Additionally, efficient load distribution across roadside units (RSUs) and cloud infrastructure enhances the stability of multi-tier heterogeneous communications.

II. RELATED WORKS

Vehicular Ad Hoc Networks (VANETs) are a special subset of Mobile Ad Hoc Networks (MANET), in which vehicles act as mobile nodes, operating and communicating directly with each other and with road infrastructure [3]- [4].

Finding a robust and stable routing algorithm for delay-sensitive applications has become one of the significant and dynamic research topics in both MANETs and VANETs.

In VANETs, various routing protocols are designed based on specific applications to meet diverse needs [5]. These protocols serve as a fundamental part in the communication between vehicles and infrastructure, helping to optimize data transmission and reduce delay.

One of the location-based routing protocols that is very popular in VANETs is GPSR [6]. In this protocol, nodes obtain location information from the positioning system and store their neighbors' information. The forwarding methods in this protocol include greedy forwarding and perimeter forwarding. Nodes send their location information to their neighbors periodically. After receiving new neighbor information, the node updates its neighbor list. In the process of forwarding packets, the node obtains the location of the destination node through the location service and then creates the route using greedy and perimeter forwarding methods. In this protocol, there is no need to maintain the routing table when forwarding packets and it also performs well with frequent topology changes.

Despite the numerous advantages of this protocol and its use of local information for routing, this protocol has significant limitations. In sparse networks, where nodes are few and far apart, GPSR may have difficulty in finding the appropriate next hops, which leads to routing inefficiencies.

Many improvements have been made to overcome the disadvantages of GPSR. To solve the instability in communication resulting from changes in the position of nodes during forwarding phases, the Maxduration-Minangle GPSR (MMGPSR) protocol has been proposed. This protocol operates based on maximum cumulative communication duration and minimum angle [7].

In [8], Improved Segment-based Routing (ISR) protocol is introduced to improve communications in dynamic vehicular networks. This protocol divides roads into segments and uses the head nodes at the corner of each segment for routing purpose. ISR reduces network overhead by eliminating beacon messages and selects stable routes in highly mobile urban environments using distance, traffic density, direction, and link stability criteria.

The W-PAGPSR protocol is a modified version of PA-GPSR for VANETs. It uses GPS and OBU data to select stable routes based on criteria such as Euclidean distance, density of reliable nodes, packet delivery angle, and cumulative communication duration. By optimizing both greedy and perimeter forwarding strategies, this protocol reduces network overhead, thereby mitigating packet loss rate and end-to-end delay in low-density urban scenarios [9].

A hybrid location-based routing protocol with cloud assistance is proposed to improve communications in software-defined vehicular networks (SD-VANETs). This protocol uses cloud services and roadside units to manage routing in four main scenarios. First, when destination is within the sender's transmission range, the sender communicates directly. Second, if the destination is within the RSU's range but outside the sender's range, the RSU processes the route information and sends it to the sender. Third, when the destination is within a neighboring RSU's range, and finally, when it is not reachable in any RSU's ranges, the RSU sends a routing request to the cloud to obtain the necessary data. Moreover, RSUs store vehicle information and register their entrance to the transmission range to establish more stable and *efficient* communication [10].

A VANETs-based multi-hop dissemination method for 5G environments has been proposed that leverages vehicle-to-everything (V2X) connectivity to increase reliability. This method reduces vehicle localization errors by integrating GPS data and map matching techniques. Moreover, it selects *efficient* forwarders using a fitness function that takes into account the various mobility and social factors [11].

The IGCR protocol is a multi-hop geo-routing protocol for Internet of Connected Vehicles (IoCV) networks. This protocol identifies stable routes at urban intersections using gateway nodes and assessing criteria such as location, direction, speed, and traffic density. To increase data delivery rates and reduce latency, it calculates 3D distances for complex environments (e.g., overpasses). Moreover, it enhances network performance by reducing overhead, and updating node information using GPS and digital maps [12].

Fog computing improves the performance of routing protocols by reducing delay, increasing reliability, improving resource management, and supporting scalability. Particularly, this technology is useful for delay-sensitive applications. For example, in case of a network that requires immediate data processing, vehicles can process data collected by sensors using fog computing.

A framework called vFog has been proposed that allows vehicles to provide computational services without the need for roadside units. It also can improve PDR by managing churn behavior and supporting multi-hop communication [13].

A network architecture based on fog computing, cloud computing, and software-defined networking (SDN) is proposed. It consists of four layers: the user layer (including vehicles), the fog computing layer (including roadside units and base stations), the SDN control layer (for controlling data flow and cloud-fog network), and the cloud computing layer. Relying on load balancing strategy, this architecture ensures delay reduction and efficient communications [14].

5G technology, which provides high bandwidth and low latency, can improve IOV communications significantly. To reduce transmission delays in these networks, a new architecture for VANETs has been proposed. Incorporating technologies such as SDN, Cloud RAN (CRAN), and 5G, this architecture optimizes resources allocation. It also employs fog computing at the edge of the network to reduce the number of connections between vehicles and RSUs. The results suggest reduced transmission delay and improved system capacity [15].

In [16], a design is investigated to select reliable relay for routing emergency messages. This approach leverages vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications to support routing purposes. In addition, position prediction and other mobility factors are used to select relays. Using changes in relative position between vehicles over a specific time interval, it predicts relative position of neighboring vehicles, allowing the system to remove unstable vehicles from the candidates list. Moreover, reliable relay is selected by taking into account criteria such as distance, direction of movement, and speed variations.

In [17], an intelligent power control approach was proposed for cognitive radio networks operating in non-stationary environments. The authors employed a bio-inspired Particle Swarm Optimization (PSO) algorithm to solve a constrained nonlinear optimization problem aimed at minimizing transmission power and bit error rate while maximizing data transmission capacity. Their model dynamically adapts to channel variations and modulation indices, ensuring reliable performance and maintaining the quality of service for primary users. Simulation results demonstrated that the proposed

PSO-based scheme achieves fast convergence and improved performance in dynamic channel conditions. This work provides valuable insights for applying swarm intelligence or machine learning-based approaches to routing in VANETs, particularly under non-stationary channel conditions where link stability and power control are major challenges.

In [18], a bio-inspired distributed beamforming technique was proposed for cognitive radio networks operating in non-stationary environments. The authors employed PSO algorithm to solve a constrained multi-objective optimization problem aimed at minimizing transmission power and bit error rate while maximizing channel capacity. The proposed model integrates both pre- and post-beamforming vectors at the transmitter and receiver to enhance spectral efficiency and reduce interference, ensuring the required QoS for primary users. Simulation results demonstrated that the PSO-based adaptive approach efficiently adjusts beamforming parameters and Lagrange multipliers, achieving fast convergence and accurate performance under dynamic channel conditions. This work provides an important foundation for using bio-inspired and intelligent algorithms in resource management and routing of VANETs, especially in non-stationary wireless environments where link stability and interference control are critical challenges.

III. NETWORK MODEL

We consider a network model with three main types of nodes for the IoV:

◇ Roadside Units (RSUs)

◇ On-Board Units (OBUs)

◇ Cloud Infrastructure

Therefore, 4 types of communication are used in the proposed model, as shown in Fig. 1. They include:

◇ Vehicle-to-vehicle (V2V): vehicles can communicate with other vehicles within their transmission range using OBUs.

◇ RSU-to-RSU (R2R): RSUs within the same transmission range can communicate with each other. Fog computing layers are formed by interconnected RSUs.

◇ Vehicle-to-RSU (V2R, R2V): Communication between RSUs and vehicles or vice versa.

◇ Cloud-to-Fog (C2F, F2C): Communication between Fogs and Cloud or vice versa.

In our model, RSUs are located at the edges of roads to collect and process local information. They can transmit information about the infrastructure and road environment to vehicles. Fig. 2 shows that an RSU can send information directly to a neighboring RSU, and further, send it through the cloud to an RSU located two hops away.

In this mode, the cloud encompasses a collection of fogs, cooperating and coordinating to provide more computing and storage resources. This collection of fogs acts as a cloud-computing platform and delivers computational resources and processing services to vehicles. The cloud is capable of processing the user requests that require high computing resources. It can also store information for a long time.

At this level, the information sent by vehicles and processed by RSUs is stored in the cloud for further processing and analysis. Cloud services can provide vehicles with traffic information, optimized routing, and environmental information. Moreover, they can provide advanced features for data analysis, supporting intelligent decision-making, and improving smart city systems.

Collaboration between RSUs, Fogs, and Clouds can improve the efficiency and application of vehicle communication networks. Fogs play an important role in high-speed processing information and transmitting data from RSUs to vehicles. This hierarchical structure improves the performance and capabilities of vehicle communication networks, facilitating the development of IoT services and smart vehicles. As result, when stable and effective communication is needed between vehicles in a hierarchical structure of RSUs, Fogs, and Clouds, the quality of communication depends on the specific layer involved (for example, in Fog, Cloud, or Vehicle).

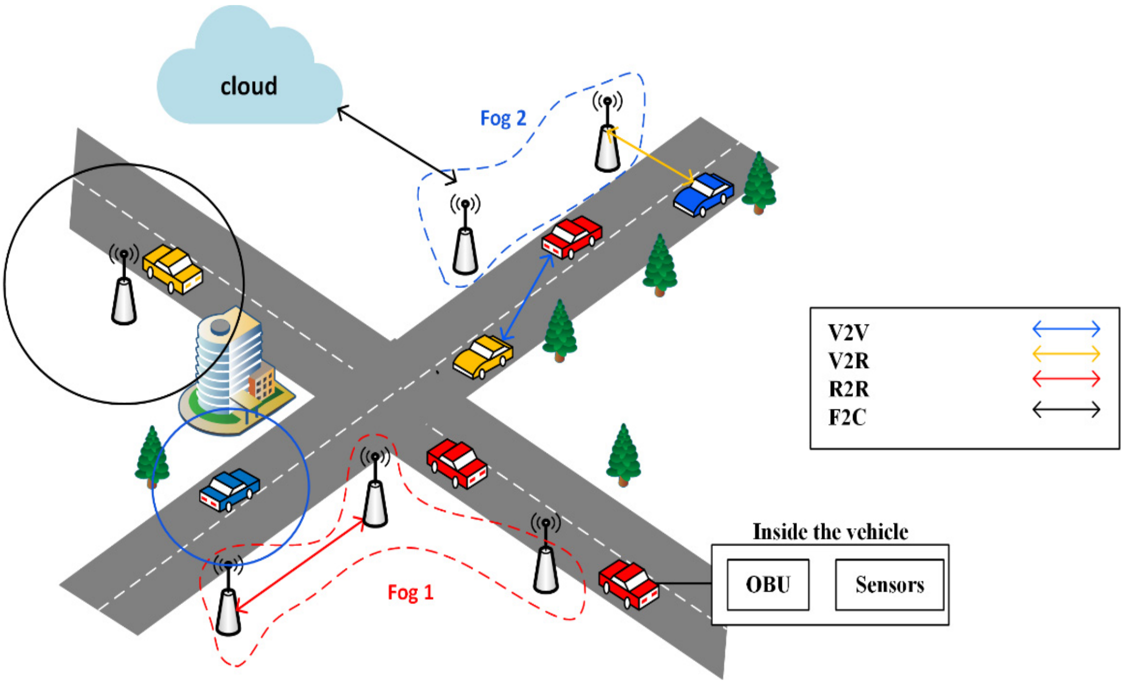

Fig. 1. Types of communications in VANETs

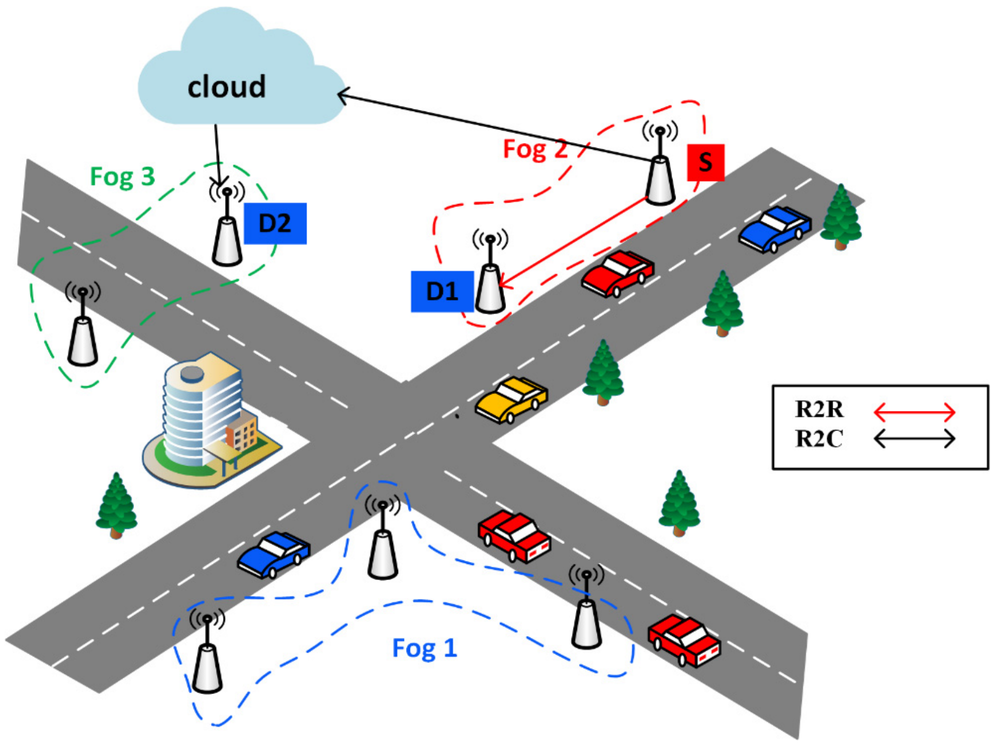

Fig. 2. Illustration of information transmission from an RSU(S) to a neighboring RSU(D1) and further through the cloud to an RSU(D2) located two hops away

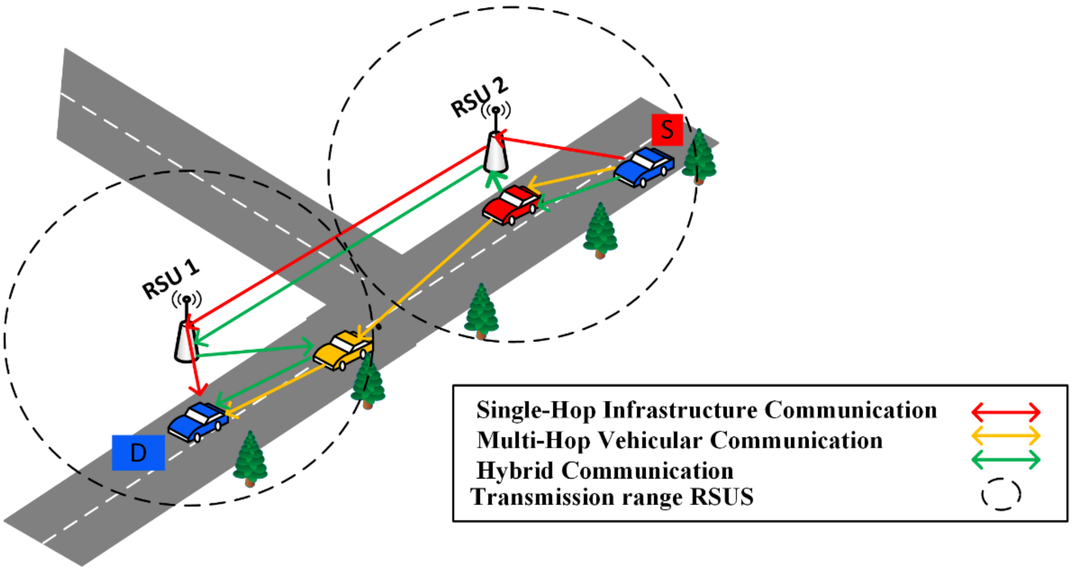

Fig. 3. Illustrates of Different Data Transmission Methods in the Network

IV. PROPOSED METHOD

In VANETs, mobility of vehicles causes frequent connections and disconnections. Some of these connections are stable and others are unstable.

A. DATA TRANSMISSION METHODS IN NETWORKS

We consider three data transmission methods for network: multi-hop vehicular communication, single-hop infrastructure communication, and hybrid.

1) Multi-Hop Vehicular Communication:

To establish communication between a source and a destination, vehicles within the same range can communicate through their OBU using a single-hop or multi-hop method. This enables the exchange of data on position, speed, acceleration, and other mobility parameters.

In this scenario, absence of RSUs along the communication route leads to minimizing load on RSUs and reducing corresponding costs. However, it incrases the end-to-end delay. In addition, connectivity challenges arise in this scenario, as vehicles are moving and may move out of the range over time.

2) Single-Hop Infrastructure Communication:

Vehicles within the transmission range of an RSU can connect to it and benefit from its processing and communication services. To establish communication between a source and a destination in

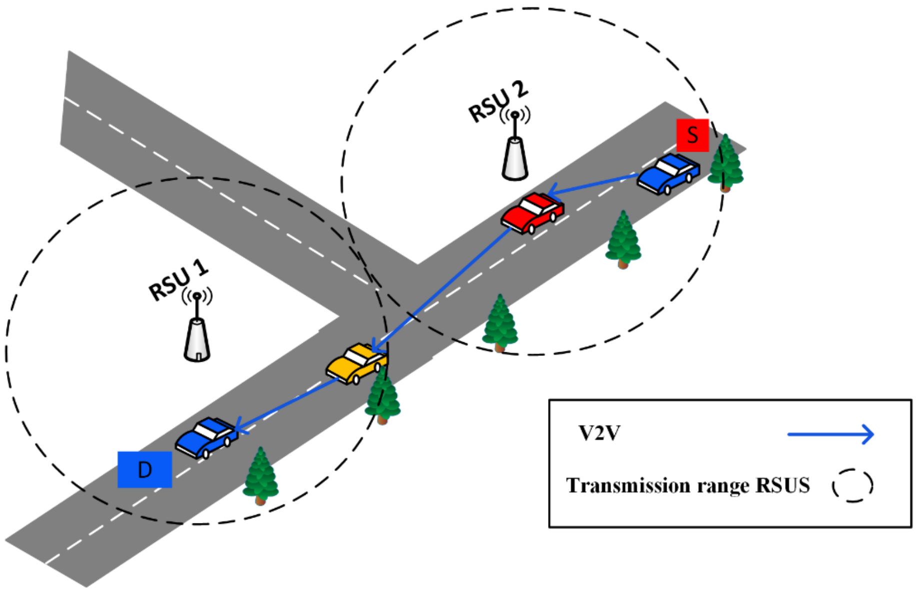

Fig. 4. Multi-Hop Vehicular Communication Between Source Vehicle (S) and Destination Vehicle (D)

this scenario, Fog computing can be used. As such, data is processed locally and near the vehicles.

This capability causes delay reduction, which is the main advantage of this method. However, as the load on Fog increases, processing resources may become restricted. It can lead to transfer of data processing task to other RSUs, and higher costs for system.

Increasing loads on RSUs will gradually lower system's efficiency and responsiveness, leading to higher latency and even disconnections. For instance, when the number of vehicles within the network, and at the same time, the volume of data is increased, the network infrastructure may become saturated rapidly and cannot respond to all requests.

The source RSU is a station connected to the source node in a single or multi-hop array. Similarly, the destination RSU is connected to the destination node in a single or multi-hop array. In this method, both the source and destination nodes are connected to the source and destination RSUs using a single- hop commutation, respectively.

3) Hybrid Communication:

This is a combination of two previously mentioned methods. In this method, each vehicle can connect to the source RSU either using single or multi-hop array. Similarly, from the destination RSU, it can connect to the destination vehicle either using single or multi-hop communication.

According to Fig. 6, to establish communication between the source vehicle (S) and the destination vehicle (D), at first, the source vehicle connects to the source RSU through a single-hop communication. Then, communication from the destination RSU to the destination vehicle is achieved using a multi-hop scenario.

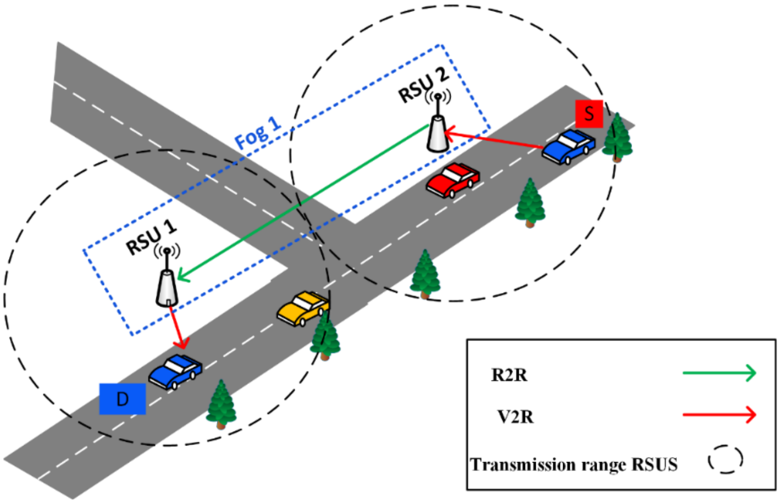

Fig. 5. Single-Hop Infrastructure Communication Between Source Vehicle (S) and Destination Vehicle (D)

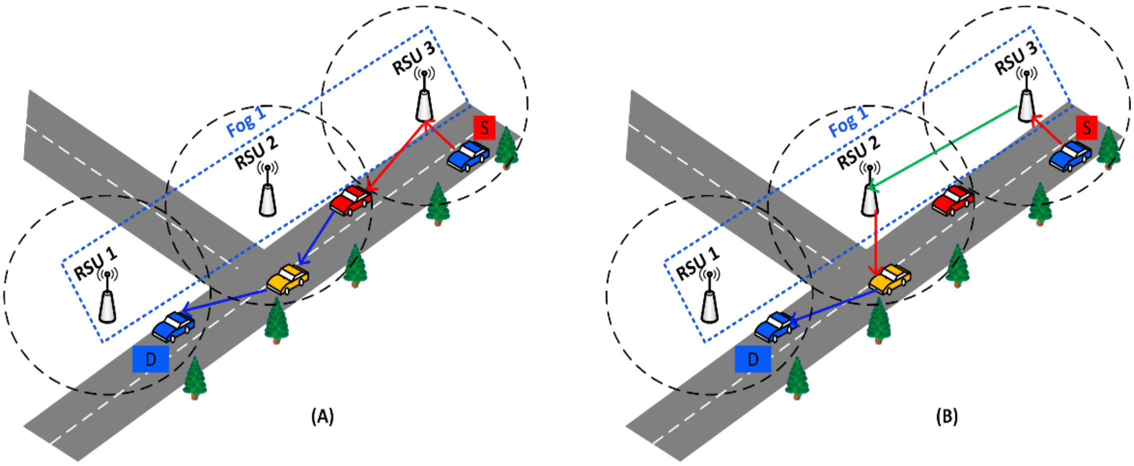

Fig. 6. hybrid Communication Between Source Vehicle (S) and Destination Vehicle (D)

Fig. 7 shows the communication from the source vehicle to the source RSU and from the destination RSU to the destination vehicle as a multi-hop communication mode.

In addition, as illustrated in Fig. 8, the connection between the source vehicle and the source RSU can be a multi-hop communication, while the connection between the destination RSU and the destination vehicle is a single-hop one.

Below, these three methods will be examined usig a hypothetical example.

Suppose that the V2V delay is 3 ms, the V2I delay= 2 ms, and the I2I delay= 1 ms. According to the above figures, the total route delay for each method is calculated as follows:

Multi-Hop Vehicular Communication: The total delay for this connection is equal to 9 ms (as shown in Fig. 4).

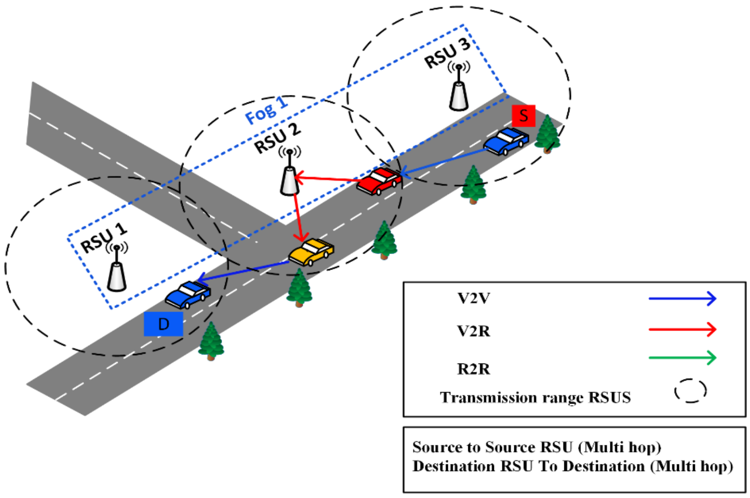

Fig.7. hybrid Communication Between Source Vehicle (S) and Destination Vehicle (D)

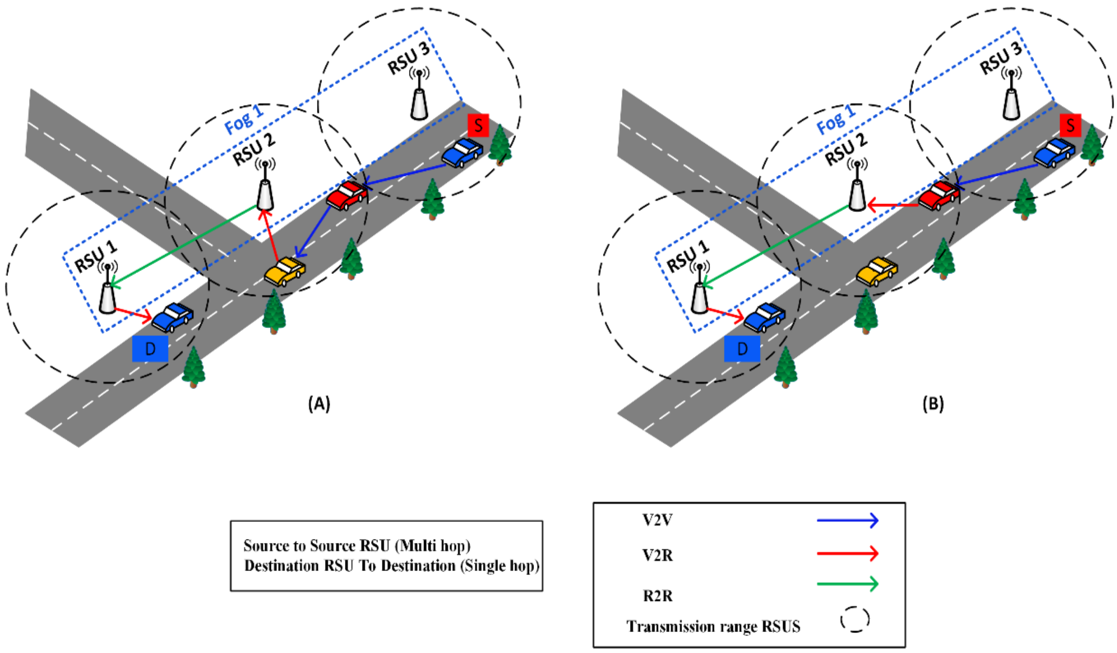

Fig. 8. hybrid Communication Between Source Vehicle (S) and Destination Vehicle (D)

Single-Hop Infrastructure Communication through fog: As shown in Fig. 5, the total path delay for this communication is 5 ms.

Hybrid Communication: In case where communication from a source to a source RSU is as single-hop, and communication from the destination RSU to destination is multi-hop, the total path delay in mode (A) is 10 ms and in mode (B) is 8 ms (As shown in Fig. 6).

If communication from the source to the source RSU and from the destination RSU to the destination is multi-hop, the total path delay is 10 ms (As shown in Fig. 7).

When communication from the source to the source RSU is as multi-hop, and communication from the destination RSU to destination is single-hop, the total path delay in mode (A) is 11 ms and in mode (B) is 8 ms (As shown in Fig. 8).

B. SELECTING COMMUNICATION TYPE

NHS factor is used to select the next node. It is defined as follows, using three parameters: the velocity of the current node, the RSU load, and the difference in the direction of the current node and the destination:

$$NHS = \propto \frac{v_v}{v_{max}} + \beta \frac{l_{rsu}}{l_{max}} + \gamma \frac{|\theta_v - \theta_d|}{180^\circ} \quad (1)$$

Where, v_v is the velocity of the current node, v_{max} the maximum velocity of a vehicle, l_{rsu} the RSU load, l_{max} the maximum load of an RSU, θ_v the direction of the current node, θ_d the direction of the destination node, and $\beta.\gamma.\alpha$ are the weight coefficients of each parameter.

To ensure normalization, the sum of all weight coefficients must equal 1, as shown in the Eq. 2. In this study, it is assumed that all weighting coefficients are equal, i.e. all three parameters -velocity, RSU load, angular difference- have the same significance in this scenario. This approach makes a balance between movement factors (i.e. velocity and direction) and infrastructure conditions (i.e. RSU load). Moreover, equality of coefficients simplifies the computations. Acordingly, as shown in Eq.3, the weight of each coefficient is set to $\frac{1}{3}$. Normalization further ensures that each component is placed within the [0, 1] interval, allowing their relative impact will fairly be considered in the NHS calculation.

$$\propto + \beta + \gamma = 1 \quad (2)$$

$$\propto = \beta = \gamma = \frac{1}{3} \quad (3)$$

Following the calculation of the NHS, the decision to select the next node is made as follows:

If the NHS value is greater than $\frac{1}{2}$, the RSU is selected as the next node. In this case, the data is sent to the destination via the RSU, without requiring any routing process. This is a proper approach for delay-sensitive data. However, if the NHS value is less than or equal to $\frac{1}{2}$, the vehicle is selected as the next node:

$$\begin{cases} NHS > \frac{1}{2} & RSU \\ NHS \leq \frac{1}{2} & Vehice \end{cases} \quad (4)$$

We chose $\frac{1}{2}$ as the baseline middle threshold to balance the decision-making between infrastructure-based and vehicle-based dispatch. However, this value is not fixed and can be adapted based on different network scenarios.

Table 1. Simulation Parameters

Parameter	Configured Value	Unit
simulation environment size	1000 × 1000	m^2
Simulation time	200	s
Transmission range	250	m
Speed range	1-20	m/s
Data packet size	512	byte
MAC protocol	IEEE 802.11P	-

The proposed method, which operates based on the NHS factor for selecting the next node in routing, has key differences from the GPSR and MMGPSR methods. In the GPSR method,

the next node selection criterion is purely geographical distance, which may have limited performance due to the lack of consideration of the dynamics of vehicular networks, such as the variable velocity of nodes or traffic load. In the MMGPSR method, the next node is selected based on the cumulative communication duration. While the proposed method uses the NHS factor, which is a combination of three dynamic parameters including the velocity of the current node, the RSU load, and the difference in the direction. This multi-criteria approach, by considering the dynamics of vehicular networks, improves the next node selection and provides better performance than single-criteria methods such as GPSR or MMGPSR.

V. PERFORMANCE EVALUATION OF THE PROPOSED METHOD

In this section, the results of simulations conducted to evaluate the performance of routing protocols are reviewed. These results are obtained using various metrics such as end-to-end delay, Packet Delivery Ratio(PDR) and control overhead. The purpose of analyzing these metrics is to compare the performance of the proposed protocol with existing methods and to examine the impact of added feature on improving the quality of service in VANETs. In the following, the simulation results are presented and analyzed separately for each metric and in different network conditions. The simulation uses a single-channel Two-Ray Ground Reflection propagation model for wireless communication.

The network simulation parameters are summarized in the table 1. These parameters include the size of the simulation environment, the speed range of nodes, and other settings related to the mobility model and the simulation platform. These parameters were selected with the aim of providing more realistic conditions of the VANET environment and accurate evaluation of the MHOP, RSU, Hybrid, GPSR, and MM-GPSR routing protocols.

A. END-TO-END DELAY

Fig. 9 shows the end-to-end delay comparison between GPSR, MM-GPSR, MHOP, RSU and Hybrid protocols with different numbers of nodes. Fig. 9 shows, when the number of nodes is low, the number of neighboring nodes for each node is less and the neighbor relationship is unstable and unreliable. In the GPSR protocol, only the distance of the node to the destination is considered as a criterion for route selection; but in the MM-GPSR protocol, in addition to the distance of the node to the destination, the cumulative communication duration is also considered as effective factors in route selection, which reduces the delay compared to GPSR.

In the proposed method, in addition to the distance of the node to the destination, other factors such as the RSU load, the direction of the vehicle movement and the node speed are also used in the route selection process. This approach provides better performance than the previous two methods and results in less delay in data transmission.

B. PACKET DELIVERY RATE

Packet Delivery Rate (PDR) is one of the main metrics for evaluating quality of service, especially in delay-sensitive applications. PDR indicates the reliability and stability of communications in the network. The higher the PDR, the more reliable the network is for data delivery.

Fig. 10 shows the comparison of packet delivery rates among GPSR, MM-GPSR, MHOP, RSU, and Hybrid protocols with different numbers of nodes. From Fig. 10, it can be seen that when the number of nodes is large, the number of neighboring nodes for each node increases, and the neighbor relationship is more stable and reliable, resulting in an increase in packet delivery rate.

A. CONTROL OVERHEAD

Control overhead refers to the total number of control packets exchanged in the network for route discovery, maintenance, and management. It directly impacts the efficiency and scalability of routing protocols, especially in highly dynamic environments such as vehicular networks.

Fig. 11 illustrates the comparison of control overhead for GPSR, MM-GPSR, MHOP, RSU-based, and Hybrid routing protocols across different node densities. As shown in the figure, the GPSR protocol has a higher control overhead compared to MM-GPSR due to frequent route failures and re-discovery processes caused by mobility and link instability. MM-GPSR improves this by incorporating the direction factor, which makes the route selection more stable, thus slightly reducing the overhead.

In the RSU-based and Hybrid protocols, the control overhead is significantly lower. This is because RSUs serve as fixed infrastructure nodes with broader transmission ranges and more

Algorithm 1: Route

```
Note:
SID: Source node identifier.
DID: Destination node identifier.
C: Current node.
NH: Next Hop.
NHS: Next Hop Selection score, calculated( from Eq.1)

Input: S (Source node), D (Destination node)
Output: path (Path from source to destination)

Begin
C←S
Route←False
path ← Empty
S Creates rreq(SID, DID)
while (Route==False) do
    if C receives rreq(SID,DID) then
        if C.id == DID then
            Create rrep(DID,SID)
            Send rrep(DID,SID) to S
            Add (C) to path
            Route←True
        End if
        else
            Calculate NHS for C using Eq. (1)
            if NHS > 0.5 then
                NH← Select next node from neighbor RSU
                Add (C,NH,D) to path
                Route←True
            End if
            else
                NH← Select next node from neighbor vehicles
                Add (C) to path
                C←NH
                Send rreq(SID,DID) to C
            End else
        End else
    End if
End while
Return path
```

Algorithm 1. Proposed Routing

stable connectivity, reducing the frequency of route discoveries.

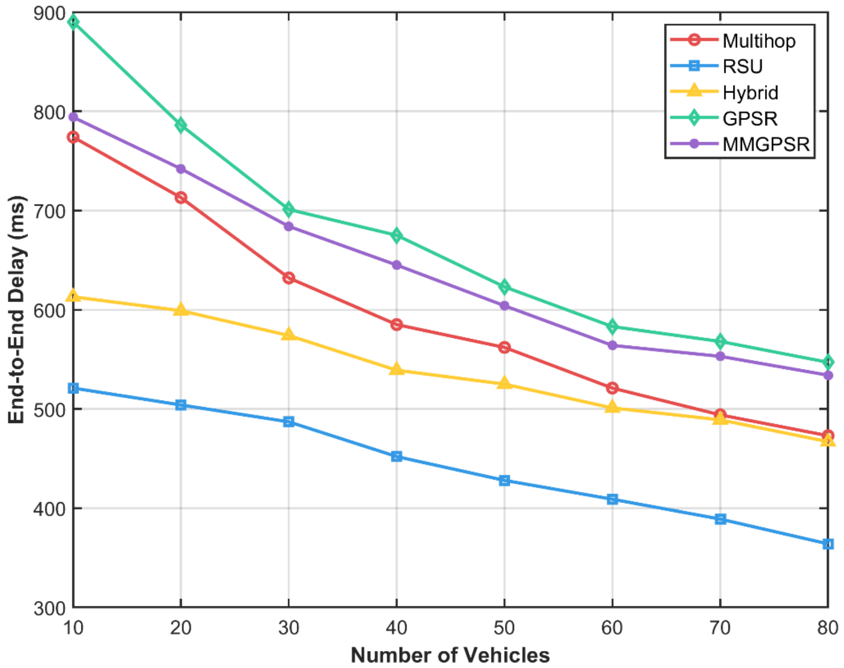

Fig. 9. End-to-End Delay(ms) vs. Number of Vehicles

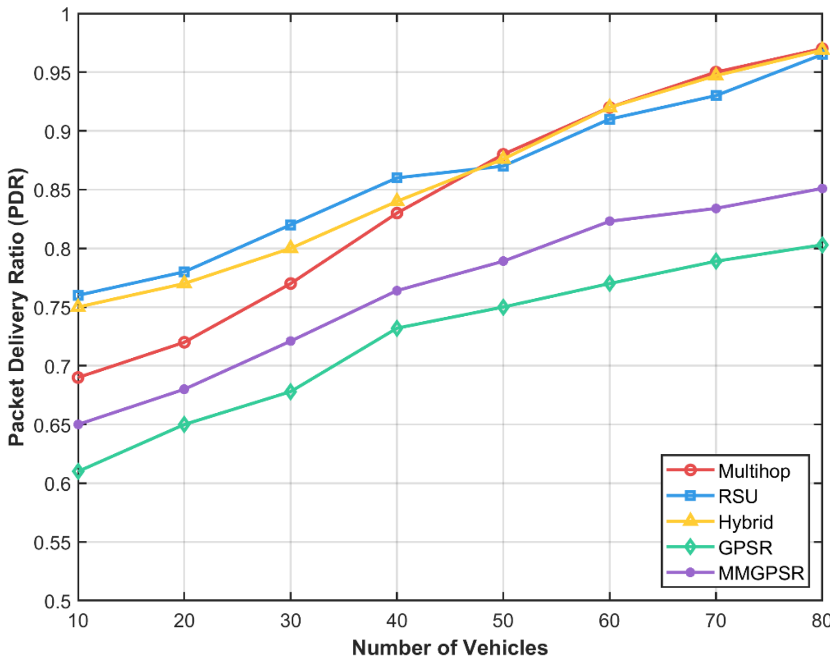

Fig. 10. Packet Delivery Rate (PDR) vs. Number of Vehicles

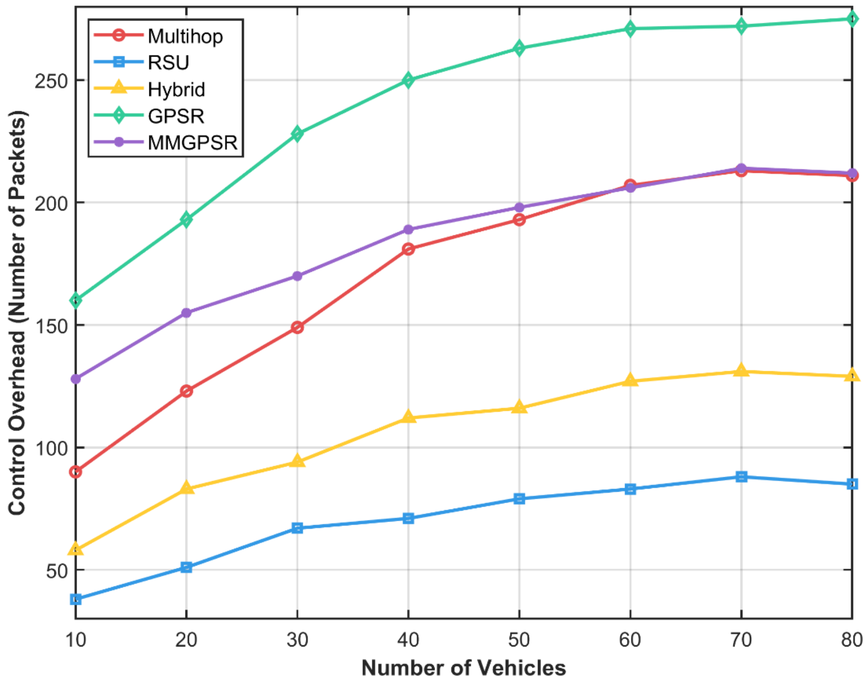

Fig. 11. Control Overhead (Number of Packets) vs. Number of Vehicles

Table 1. Routing Protocols Performance Metrics Comparison

Nodes	Control overhead					PDR					Dealy				
	Multihop	RSU	Hybrid	GPSR	MMGPSR	Multihop	RSU	Hybrid	GPSR	MMGPSR	Multihop	RSU	Hybrid	GPSR	MMGPSR
10	90	38	58	160	128	0.69	0.76	0.75	0.61	0.65	774	521	613	890	794
20	123	51	83	193	155	0.72	0.78	0.77	0.65	0.68	713	504	599	786	742
30	149	67	94	228	170	0.77	0.82	0.8	0.67	0.72	632	487	574	701	684
40	181	71	112	250	189	0.83	0.86	0.84	0.73	0.76	585	452	539	675	645
50	193	79	116	263	198	0.88	0.87	0.876	0.75	0.78	562	428	525	623	604
60	207	83	127	271	206	0.92	0.91	0.92	0.77	0.82	521	409	501	583	564
70	213	88	131	272	214	0.95	0.93	0.947	0.78	0.83	494	389	489	568	553
80	211	85	129	275	212	0.97	0.965	0.9688	0.803	0.85	473	364	467	547	534

VI. CONCLUSION

VANETs is recognized as one of the fundamental technologies in intelligent transportation systems. With the rapid growth of the number of vehicles, these networks requires stable and low delay communications. One of the main challenges in these networks is to ensure stable communication and reduce end-to-end delay for delay-sensitive applications. In this study, an adaptive routing method is presented that uses speed, direction, and network load parameters to find the most stable route. The proposed method is compared with the GPSR geographic routing protocol and an improved version of it, and the end-to-end delay and PDR metrics are compared.

These results indicate the improvement of the proposed method in terms of delay and PDR. In future research, the threshold value can be changed according to different network conditions and scenarios or the weight of each parameter (speed, RSU load, and angular deviation) can be adjusted. This allows the relative impact of each parameter on the NHS criterion to be examined more precisely and the algorithm's performance to be optimized under different conditions such as high density, variable speed, or heavy load on RSUs.

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