Diyala Journal of Engineering Sciences

Journal homepage: https://djes.info/index.php/djes

ISSN: 1999-8716 (Print); 2616-6909 (Online)

Efficient Routing in VANETs Using MRRP Algorithm

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ARTICLE INFO

Article history:
Received May 28, 2023
Revised August 7, 2023,
Accepted August 30, 2023,
Available online September 1, 2023

Keywords:
Mobile Ad-hoc networks
Vehicular Ad-hoc networks
Multi Path Route Restoration Protocol

ABSTRACT

Designing a reliable routing protocol for Vehicular Ad hoc Network (VANET) poses considerable challenges due to certain unique challenges inherently present in Vehicular Ad hoc Network (VANET) topology. Some of them are needed for vehicles acting as nodes having to abide by traffic rules, uncertain inter-vehicular speed variations that may affect link stability etc. Designing a routing protocol capable of dealing with multiple limiting conditions such as long congestion periods, link failures and handoffs is a challenging task, where most of the existing multipath routing protocol shows poor performance. In this paper, the proposed Multipath Route Restoration Protocol (MRRP)is aimed at providing a robust communication channel in case of link failure between nodes. This is realized by focusing on better route maintenance for the protocol. In a wireless network, a routing protocol determines the particular ways in which routers connect. In a wireless network, as the number of hops in a wireless communication path increases, various signal factors such as interference and path loss degrade the network performance. however, sending data over a longer distance will reduce throughput. Furthermore, link stability is substantially impacted by the unpredictable movement of vehicles. Multipath routing is regarded as a potential solution to improve packet delivery and end-to-end delay in VANETs.

1. Introduction

The natural formation of a wireless network of mobile devices, which is a significant principle of mobile ad-hoc networks (MANETs) [1], is applied to the domain of vehicles to create Vehicular ad-hoc networks (VANETs) [2]. In the year 2001, VANETs made its entry as a part of a “car-to-car ad-hoc mobile communication and networking application that allowed the formation of networks to relay information from car to car. Important features like road safety, navigation, and other roadside services could be provided by installing vehicle-to-vehicle as well as vehicle-to-road communication architectures as integrated into AVANET. In the intelligent transportation systems (ITS) structure, VANETs play a major part. VANETs in some cases are known as ‘Intelligent Transportation Networks’.[3] VANETs during the first few years of the new millennium have outgrown their status beyond the simple application of MANET principles to a full-fledged research [4] area on its own. In the next decade, VANET attained a status almost interchangeable with inter-vehicle communication (IVC) despite the focal point being spontaneous networking and not on the application of Road Side Units (RSUs) or cellula.

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DOI: 10.24237/djes.2023.16311

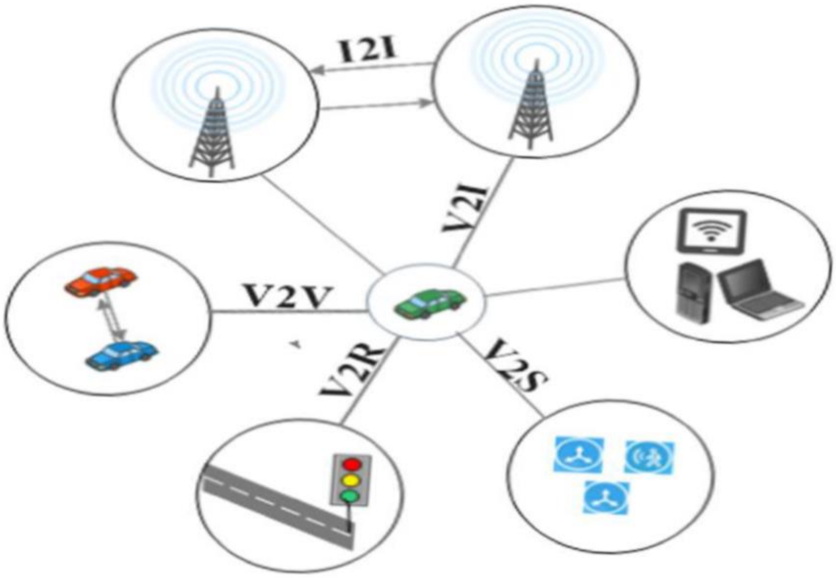

Figure 1. VANET Representation [26]

- **Ad-Hoc Routing Protocols**

The principal objective of these protocols is to create an optimal path that is dotted with the least possible intermediary nodes connecting the source to the destination, wherein there is less overhead in the route on the one hand and low bandwidth usage on the other hand for timely transmission of the message. Proactive routing protocols, reactive routing protocols and hybrid routing protocols have great applications in VANET. Due to the dynamic topology of VANET, single-path routing protocols like Ad hoc On-Demand Vector (AODV)protocol face problems since they frequently initiate a path discovery process every time there is a link failure and have been found to be unreliable. Multipath routing protocols have been found to address these issues and findings by various authors. Our proposed work works on the route finding and maintenance methods in the Ad Hoc On-Demand Multipath Distance Vector (AOMDV) [6] and Congestion Adaptive Multipath Protocol (CAMP) as they have been found to be suitable for route establishment. The important features of AOMDV and CAMP have been discussed in subsequent sections. The performance of existing mechanisms has been improved by a novel route restoration algorithm that adds more stability to the clusters.

- **AOMDV Protocol**

Ad Hoc On-Demand Multipath Distance Vector (AOMDV) [6] protocol improves performance at AODV [7] protocol during route discovery [8] stage. It overcomes the inherent drawback of AODV [7], in which a new route discovery is needed every time a link fails. In AOMDV, multiple redundant paths [9] are identified during the route discovery stage, which reduces the need for route discovery. The routing table can show alternate routes from its route list field. Route discovery may still be needed if no redundant path is available. This possibility may occur in sparse networks [10] with fewer neighbouring nodes within the sender's vicinity. The redundant paths are 36identified based on the information already available. Advertised hop counts [11] are used to prevent the formation of loops from source to destination. In AOMDV [6] protocol, we notice a couple of key components [12][13] like a route update rule and a distributed protocol. The former [14] links and ensures the maintenance of several loop-free paths at each node, whereas the latter helps in identifying link-disjoint paths. Anytime a node receives a route advertisement to a destination node from its neighbour, the route update rule is applied.

- **Congestion Adaptive Multipath Protocol**

Congestion Adaptive Multipath Protocol (CAMP), an adaptive link disjoint multipath routing protocol for congestion avoidance, proposes to introduce a congestion control mechanism in a routing protocol that helps in avoiding congestion by dynamically notifying the sender about congestion from intermediate nodes [15]. The hop count between source and destination is used as a metric to determine the shortest path. If congestion occurrence along the chosen path is indicated by congestion [16] notification, the sender switches to the next optimal path available in the routing table. Initially, the CAMP routing protocol creates node disjoint paths involving source and destination [17], while the destination node provides Link disjoint paths when a loose reply policy is followed. In this process, the reply is given to k number of packets that arrive from various neighbours [18], irrespective of the need to look at the first hop packet field. The calculation of average queue length is done on the basis of the Exponential Weighted Moving Average (EWMA) [19]. The performance of CAMP can be made more adaptive by continuously monitoring the multiple paths and restoring the previous path, once congestion subsides in it.

- **Related Work**

VANET makes use of multi hope communication [20], wherein data is sent by the source to the remotest nodes for linking them through the nodes found within them for better battery storage [21]. The MANET infrastructure primarily finds out a proper path to deliver the message with the assurance that makes it important to pick a path after ensuring trustworthiness and openness in all nodes. This is done to make sure we minimize the misbehaviour of certain nodes [22] for helping the network perform better.

However, the routing protocol can identify a path notwithstanding the presence of a selfish node. The protocol excludes such nodes having low energy and trust from the route between source and destination. An output file i.e. trace file [23] contains user inputs collected by the protocol as well as output. The suitability factor, average throughput and selfish node drop fraction [24] are some of the output parameters [25].

The authors introduced their paper on the study of assault that can be done on VANET; they introduced their examination of various assaults and give a relative report on the assaults and ways to deal with conquering those assaults. The authors said that in the last three or four years VANET draw a lot of consideration because of the benefit it gives over the network that many examinations are around its organization and to build its ability to utilize its benefit appropriately. Creators examined the cravings for safety in the organization which are expected to make the network secure. Further, they talk about the assaults on VANET exhaustively and give an ongoing just as rebuilt way to deal with conquering those assaults. They further classify these attacks into various classes and give a similar report on these assaults. Creators inferred that the assault on VANET is a basic issue since it influences the organization and its working. Sure, it enjoys benefits yet, these benefits and its ability can't be utilized as expected if this security penetration is not settled

2. Proposed system

The proposed MRRP protocol comprises phases viz., route discovery, route update and route restoration. The following sections elaborate on the working of these three phases.

- **MRPP Protocol**
- **Route Discovery**

In our proposed approach, we follow the route discovery mechanism as envisaged in AOMDV [6]. The main idea of AOMDV [6] lies in ensuring multiple paths that are loop-free and disjointed, which is made possible by using routing information found in the basic AODV [8] protocol. The initiation of the route discovery process takes place despite the routing data while it is sent to a destination node by a source node. During this phase, Route Request (RREQ) packets are sent to neighbours by MRRP with the input given below:

<source_addr, source_seq#, broadcast_id, dest_adr, dest_seq#, hop_cnt, first_hop>,

where source_addr and broadcast_idare used to identify each unique RREQ and discard redundant broadcasts. Each node maintains local broadcast_id, which is incremented every time a new RREQ is broadcasted. A node responds to the RREQ if it is the destination or if it has a route to the destination with sequence number at least dest_seq#. On the other hand, it rebroadcasts the RREQ after increasing the hop count.

The RREQ packet in MRRP includes a first hop field, similar to the CAMP [7] protocol, so as to distinguish between RREQ packets traversing through link disjoint paths and non-link disjoint paths. The transmission of packets through disjoint paths up to the duplicate RREQs receiving node is ensured by this field. While broadcasting RREQ packets, all forwarding nodes in the network save some information for establishing a reverse path utilized to forward the Route Reply (RREP) packets from destination to source represented as:<source_addr, dest_addr, source_seq#, broadcast_id, expirationtime of reversepath>.

Ourproposed protocol is able to gain information about multiple link disjoint paths by examining the path in which duplicate RREQ packets travel. However, the duplicate packets are not allowed to propagate, once identified.

- **Route Updating**

Multiple loop-free paths are established and maintained at each node by using a route update rule which is proposed in AOMDV as it involves maintaining a similar invariant. An invariant is a condition that is true at the beginning and end of every route update. The invariant is based on the concept of “advertised hop count” as proposed in AOMDV [6] (Marina & Das 2002) representing the maximum hop count for a node i to a destination d. This maximum hop count value is considered as a constant for the same destination sequence numbers and the route discovery process accepts alternate routes with lower hop count only. This invariance effectively guarantees a loop-free network.

- **Route Restoration**

The path with the least number of intermediate nodes is selected as the optimal path based on the route information gathered during the route updating stage. Due to the limited bandwidth allotted for communication among nodes, the link quality has to be consistently monitored for congestion. Congestion may occur due to a wide variety of factors such as excessive packet transmission, path breakage due to highly dynamic node movement etc.

Our proposed protocol continuously monitors the current path. The route maintenance process of MRRP is accomplished by two control packets, namely the Route Error (RERR) packet and the Route Streamline packet (RSP) packet. The RERR packet is generated by an intermediate node if it encounters a congestion situation along the optimal path. Congestion is a situation that can occur when a node is unable to route an arrived packet due to link failure. Congestion is detected based on the Exponential Weighted Moving Average (EWMA) value for each node and is calculated as follows:

$$Newavg((1-\alpha) * Oldavg)+(\alpha*cur\_q)$$

Where $0 \leq \alpha \geq 1$ and $\alpha = 0.9$

Newavg: new average queue size in packets Oldavg: old average queue size in packetsα: smoothing factor (back-of-queue) curr_q: current occupied queue size in packets. The smoothing factor α, also referred to as back-of-queue in road traffic theory has been taken as 0.9 as suggested by Akçelik (1980), based on practical observations for queue lengths at Queue-end (QE) under stationary and free traffic conditions.

The RSP packet provides information about the congestion occurring in all the possible paths between a source and a destination node. This information is used to select an alternate path, in case of congestion exceeds a threshold value or to restore the existing path as the main packet route, when congestion subsides.

The identification of a congested path is based on Queue length and is essential for timing the retransmission of packets along the originally selected optimal path after congestion is cleared. We adopt the technique followed in CAMP [7] (Raviteja et al 2012) for calculating the Exponential Weighted Moving Average (EWMA).

- **MRPP Algorithm**

The proposed MRRP algorithm consists of three modules namely, the Path weight ( ), Optimal path detection( ) and Queue Chk ( ). The function of the Path weight ( ) module is used to calculate the congestion value in each node and aggregate the node congestion value in each path by adding the individual node values. Optimal path detection ( ) module compares the path congestion value in each path with that of the existing current path and if the congestion is lower along any compared path, the new information is sent to the sender node, so that it can transmit along the less congested path. Queue Chk ( ) module is used to identify all possible paths separating a source from destination node. MRRP algorithm is shown in Table1.

Table 1: MRRP algorithm

```
Algorithm MRRP ( )
1. {
 // Total( )
// stores path congestion value
// CP→ congestion value
//S→Source node
// D→Destination node
// newavg →new average queue size in packets
// oldavg →old average queue size in packets
// α →smoothing factor (queue weight) 0≤α≤1 and α= 0.9
// cur_q →current occupied queue size
// RSP→Route Streamline
2. for each packet arrival
3. {
4. S←Packet.Source;
5. D←Packet.Destination;
6. if (RSP = TRUE)
7. {
8. Path Weight ( );
// congestion value of each path is calculated
9. oldavg =curr_q;
10. new_path = Optimal Path Detection ();
//Optimal path is 46 46 selected by comparing with congestion values
11. curr_q = new_path;
12.}
13.}
14. While (1) // to check whether new path needs to be found
15. {
16. If (newavg> threshold)
17. {
18. Path weight ( );
```

```
19. Optimal Path Detection ( );
20. }
21. else
22. Optimal Path Detection ( );
23. }
24. }
Path Weight ( )
1. {
2. if (Q is not empty)
3. {
4. for i= 1 to Q
// for each path
5. for j = 1 to m
 // node in each path
6. Queue[i][j] = newavg = ((1-α)*oldavg)+( α*cur-q);
//EWMA based congestion calculation
7. total[i] = total[i]+ Queue[i] [j];
8. }
9. }
QueueChk(S, D)
1. {
2. Q= Count (All possible paths between (S, D))
3. RETURN Q;
4. }
Optimal Path Detection ( )
// comparison of path congestion values
1. {
2. for (i=1 to Q)// no of paths
3. {
4. if (total[i]> total [i+1] )
5. CP= total [i+1];
6. }
7. RETURN CP;
8. }
```

- **Simulation Setup**

A closer look at the limitation of outdoor experiments highlights the relevance of VANET simulation. While making an evaluation of safety applications for a huge quantity of vehicles in real-time poses challenges, which is similarly challenging while analyzing how the protocol performs in highly distributed scenarios. The researchers find it tough to replicate the same situation while making comparisons between two protocols, thus making it necessary for a simulation tool to be employed for evaluating performance. There are two components viz., network model and mobility model in a simulation program, wherein the network model is almost identical to the MANET environment. It recognizes the communication stack consisting of a wireless channel [17] model, antenna model, MAC layer, network and application layers, whereas a mobility model is so different from a MANET as it is important to identify how a vehicle is moving in a structured road scenario. The classification of mobility models is done as microscopic and macroscopic models, wherein the macroscopic model has special applications in traffic-related logistics like roads, streets, crossroads [20] and lights. On the contrary, issues such as traffic density, traffic focus and initial distribution of vehicles are dealt with by microscopic models. However, accuracy and realistic topological maps, lane-changing models and inclusion of protocol features are usually expected in a realistic mobility model. In this work, MOVE (Mobility model generator for Vehicular networks) (Karnadi et al 2007) has been applied in order to create realistic mobility models by building it atop an open-source micro-traffic simulator known as “Simulation of Urban Mobility” (SUMO). In conjunction with Network Simulator-2 (NS2 2008), the output of MOVE is used as a trace file.The MRRP is applied to a lattice topology mirroring an urban setting, while the simulation parameters and the range of values are exhibited in Table 2.

Table 2: Simulation Parameters for MRRP Algorith

Parameter	Value/Type
Simulation tool	NS-2.34
Simulation time	1000 s
Routing Protocols	AOMDV, CAMP, MRRP
MAC protocol	IEEE 802.11p
Traffic	Constant Bit Rate (CBR)
Maximum vehicle nodes	80
Range of transmission	200 m
Packet Size	1024 bytes

- **Performance Metrics**

A comparative performance study between MRRP and AOMDV, CAMP and FROMR protocols has been attempted here with the following evaluation metrics:

- The standard time taken for the arrival of a data packet at the destination as calculated in milliseconds is known as the Average End-to-End delay.
- The ratio of packets found at the destination and the quantum of packets the source node sends is known as Packet Delivery Ratio.

3. Results and discussion

The end-to-end delay experienced by constant 80 nodes at varying speeds on an average is shown in Figure 2. The end-to-end delay observed over different nodes increases as the network tends to be more dynamic with an increase in the average speed of nodes. From Table 3, it is observed that the suggested MRRP protocol clocks 61% less than average delay than AOMDV and 27% less when compared with the CAMP protocol. This is due to the route restoration mechanism, which allows for better routing compared to the other approaches

Table 3: comparative End-to-End delay for variable speed between MRRP, CAMP and AOMDV

S/.NO	Average speed for nodes(m/s)	End –to- End Delay of MRP (proposed Approach) (ms)	End –to-End Delay of CAMP (ms)	End-to-End Delay of AOMDV (ms)	Reduction % in Average Delay for MRP w.r.to CAMP	Reduction % in Average Delay for MRP w.r.to AOMDV
1.	10	50	65	90	30	80
2.	20	60	80	110	33.33	83.33
3.	30	70	90	118	33.33	68.6
4.	40	78	100	120	28.21	53.85
5.	50	90	105	130	16.67	44.44
6.	60	100	120	140	20	40
Overall Reduction % in Average Delay for MRRP					27%	61.7%

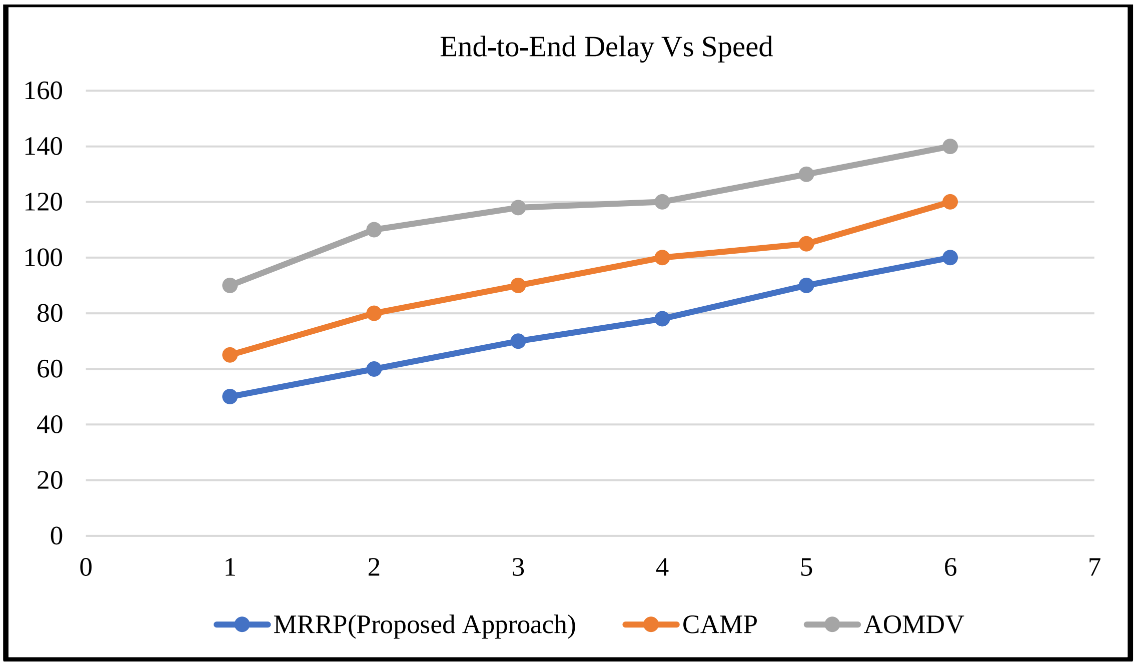

Figure 2. End-to-End Delay Vs Speed

Table 4: Simulation Results of Comparison between MRRP, CAMP and AOMDV in terms of End-to-End delay for variable number of vehicles

S.NO	No. of. Vehicles	End-to-End Delay of MRRP	End-to-End Delay of CAMP	End-to-End Delay of AOMDV	%Improvement in E-to-E Delay w.r.to CAMP	%Improvement in E-to-E Delay w.r.to AOMDV
1.	30	45	55	62	22.2	37.8
2.	40	52	61	75	17.3	44.2
3.	50	50	73	87	12.3	33.8
4.	60	60	90	95	9.6	15.9
5.	70	70	99	105	4.2	10.5
6.	80	80	110	113	4.7	7.6
Average % increase in PDR for the proposed MRRP protocol					11.72	24.9

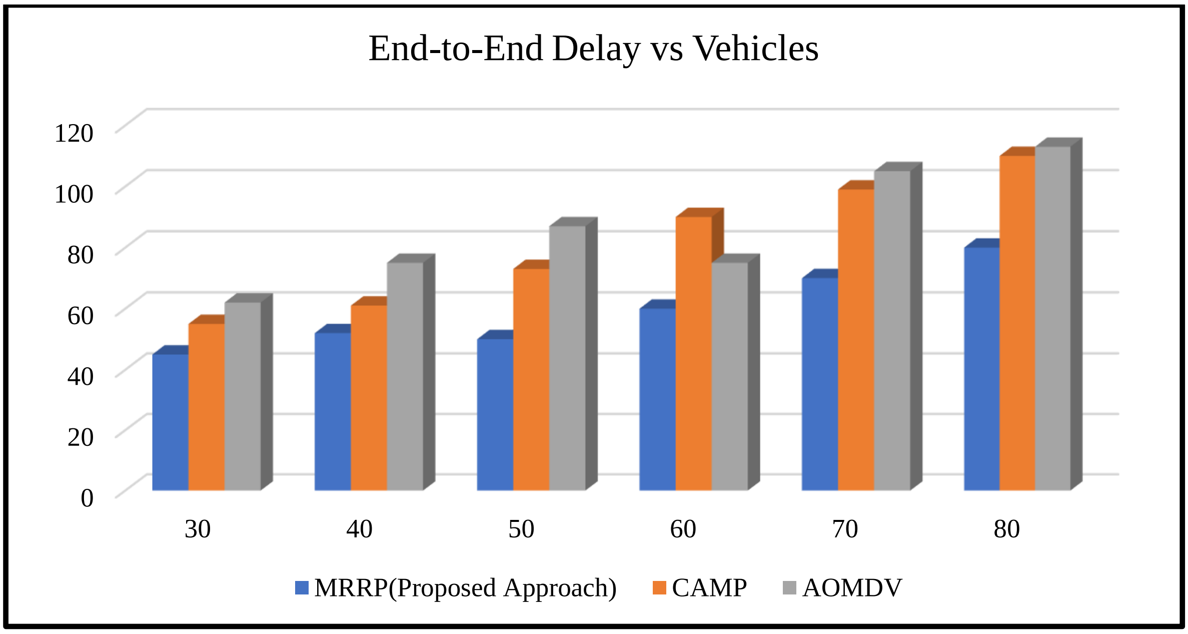

Figure 3. End-to-End Delay Vs Vehicles

Figure 3 as a flowchart for Table 4 shows the average delay in transmitting end-to-end packets experienced by vehicle nodes of different cluster sizes travelling at a constant average speed of 50 m/s. When the cluster size gets bigger, the delay in end-to-end transmission increases across all the protocols tested. However, the proposed MRRP protocol shows better performance at low to medium-density clusters. As the cluster size increases beyond a level, the performance of MRRP gradually declines and is similar to the other protocols compared. From the graph, it is observed that the delay experienced while using the MRRP protocol is lower than AOMDV and CAMP protocols at varying cluster sizes, thus showing marked performance improvement.

Table 5: Simulation Results of Comparison between MRRP, CAMP and AOMDV in terms of End-to-End delay for variable number of vehicles

S.NO	Avg. Vehicle Speed(m/s)	PDR of MRRP	PDR of CAMP	PDR of AOMDV	%Improvement in PDR w.r.to CAMP	%Improvement in PDR w.r.to AOMDV
1.	10	0.93	0.8	0.6	16.25	55.00
2.	20	0.87	0.7	0.56	24.29	55.36
3.	30	0.78	0.62	0.48	29.03	66.67
4.	40	0.72	0.54	0.41	33.33	75.61
5.	50	0.54	0.46	0.35	36.95	80
6.	60	0.49	0.33	0.24	48.48	104.1
Average % increase in PDR for the proposed MRRP protocol					31.39%	72.79%

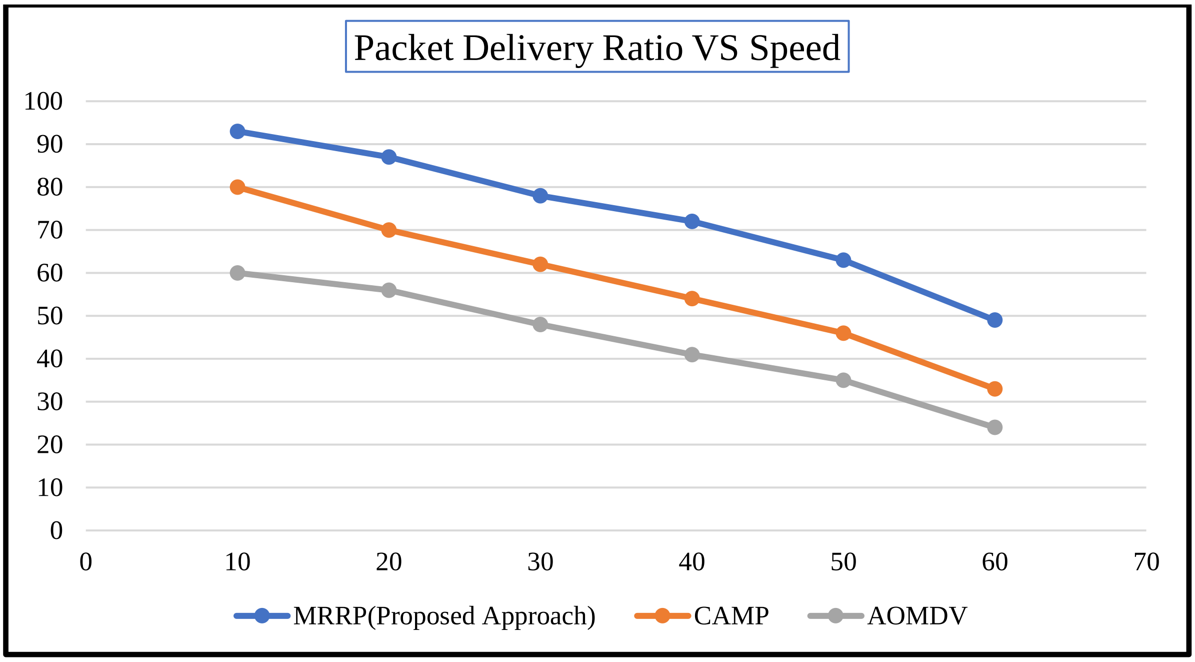

Figure 4. Packet Delivery Ratio (PDR) Vs Speed

The Packet Delivery Ratio (PDR) experienced by constant 80 nodes at varying speeds on average is shown in Figure 4 as a flowchart for Table 5. It is observed that the PDR of our proposed MRRP routing protocol performs better than AOMDV and CAMP. This is due to the transmission of more packets through the optimal path. Though, it is observed that as the average vehicle speed increases, the PDR declines for all the protocols compared. It is observed that at lower speeds, MRRP protocol performs approximately 31% better than CAMP and 72% better than AOMDV.

Table 6: Comparison of PDR at variable speed between MRRP, CAMP and AOMDV

S.NO	No. of Vehicles	PDR of MRRP	PDR of CAMP	PDR of AOMDV	%Improvement in PDR w.r.to CAMP	%Improvement in PDR w.r.to.AOMDV
1	30	0.48	0.31	0.22	54.84	118
2	40	0.56	0.38	0.27	47.37	76.32
3	50	0.63	0.46	0.35	37	80
4	60	0.69	0.51	0.43	35.3	60.04
5	70	0.74	0.58	0.49	27.6	51.02
6	80	0.82	0.65	0.56	26.2	46.43
Average %increase in PDR for the proposed MRRP Protocol					38.1%	72%

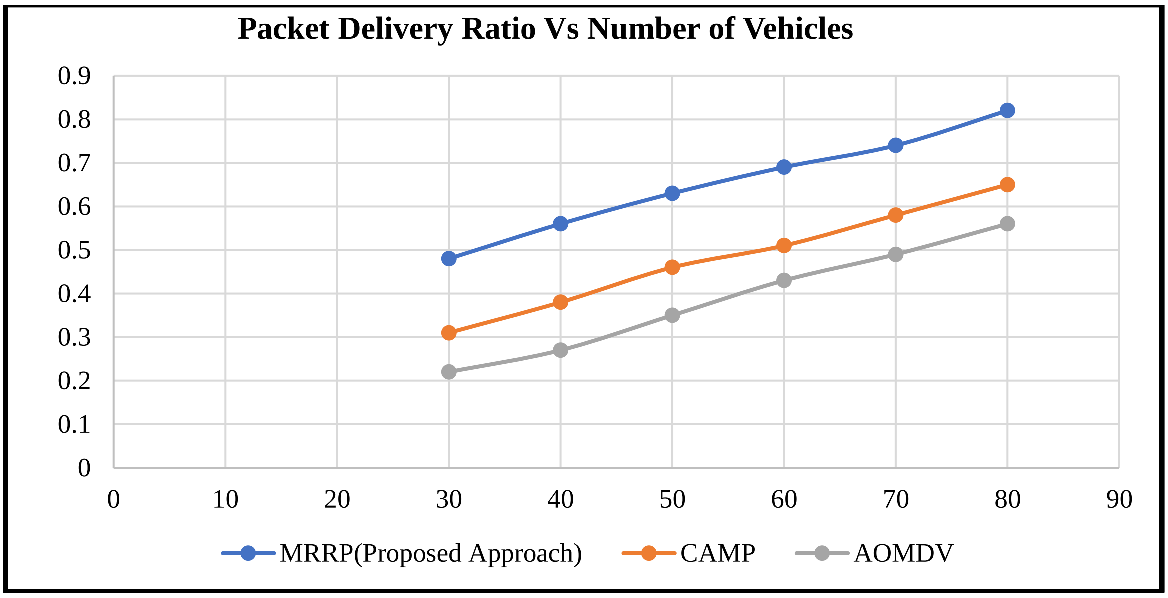

Figure 5. Packet Delivery Ratio (PDR) Vs Number of Vehicles

Packet Delivery Ratio (PDR) is shown in Figure 5 as a flowchart for Table 6. experienced by vehicular nodes of different cluster sizes travelling at a constant average speed of 50 m/s. The suggested MRRP routing protocol has better PDR performance than AOMDV and CAMP even for different cluster sizes. It can be observed that there is an overall increase in PDR of the proposed MRRP protocol when compared to that of the AOMDV and CAMP protocols.

4. Conclusion

A Multipath Route Restoration Protocol (MRRP) has been proposed to improve routing performance among nodes in VANET. It is compared with the existing AOMDV and CAMP protocols. The suggested approach displays marked betterment in end-to-end delay and PDR at varying vehicle speeds and cluster sizes when the simulation results are analyzed. In scenarios ranging between medium and dense traffic, the application of this approach offers the best possible capabilities in handling routing challenges like recurrent link breakdown, which can significantly transmit critical safety information across the ends.

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