RDVFF- Reliable Data Dissemination in Vehicular Ad Hoc Networks Based on Validation of Far to Farthest Zone

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Abstract

The rise of connected and autonomous vehicles has resulted in the development of vehicular ad hoc networks (VANETs) as a means of improving road safety, traffic efficiency, and passenger comfort. However, VANETs present challenges to achieving reliability and service quality in networks suffered highly by broadcast storms due to their mobility, scalability, and high node density. By addressing such challenges, this paper seeks to contribute to solving the problem of efficient information dissemination by diluting the broadcast storm and coverage issues by proposing a novel relay selection scheme based on the validation of the far-to-farthest zone technique. A flag control suppression mechanism is presented to overcome repeated information problems. RDVFF includes a separate algorithm for the optimization of participants for relay inclusion to address the latency issue during communication based on a multi-directional multiple-selection scheme. Compared with state-of-art protocols in terms of throughput, delivery ratio, collision, and latency experimental results show improvement of an average of 21.27%, 18.34%, 36.76%, and 38.04% respectively.

Keywords: Broadcast storm, Data dissemination, VANET, Quality of service, Relay selection

1 Introduction

Vehicular Ad-Hoc Networks (VANETs) are a kind of wireless network that allows interaction between automobiles and other entities on the road to facilitate the services by disseminating the information among themselves for ease of driving and handling real-time situations and now categorized in the vehicle to everything (V2E). In the past few years, the demand for vehicular ad hoc networks (VANET) increased to a very high extent, as this communication system can be used to provide multiple categories of services such as safety and traffic related to the end users. The data generated in VANETs is increasing at a rapid pace due to the increasing popularity of intelligent transportation systems even in regions where other communications via other techniques are difficult. This has resulted in a need for efficient and effective data dissemination techniques to ensure that data is transmitted quickly and reliably [1] as VANET has a very important role in making successful of Intelligent Transport systems and delay in same may affect the proper and efficient decision making [2]. Broadcasting of information causes repetition of similar information multiple times from many other nodes and thus there is a broadcast storm or congestion that affects dissemination reliability and quality of service [3] by introducing latency, and packet drop rate and this can increase the not required utilization of natural and man-made resources [4]. One of the promising solutions to this problem is the utilization of relay selection based techniques, which allow data to be disseminated through intermediate forwarder nodes that act as relays. Relay selection approaches have been used in VANET to reduce the broadcast storm problem. The proposed method is a sender-based multi-hop technique that applies a more restrictive approach to minimize the number of packet retransmissions. The selection of the relay nodes is carried out by a three-step screening process. In each step, filtering is done based on some guiding parameters and the corresponding threshold values. The design and implementation of a selection mechanism for multiple relay vehicles to disseminate information, which is validated through the application of the far-to-farthest technique. We are maintaining the core information through the flag control suppression mechanism in our work aiming to tackle two important issues: broadcast storm and coverage. By implementing this mechanism, we address the challenges associated with excessive broadcast traffic and ensure efficient coverage of the network.

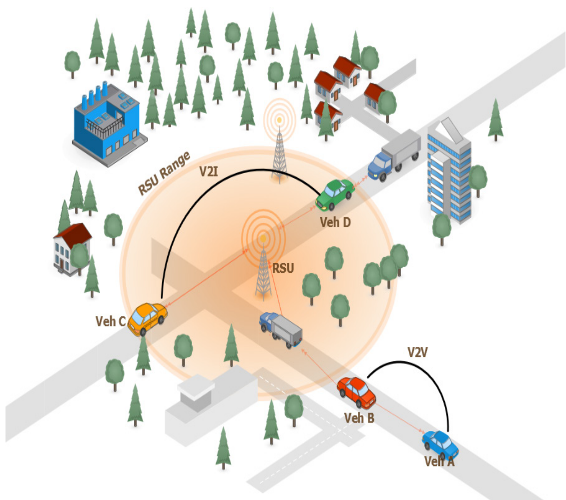

Figure 1. Vehicular communication scenario

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Our focus is on the development of an efficient relay selection algorithm that can be used to select the best possible set of relays for a given data transmission task in VANETs. We also investigate the impact of various factors such as the speed, direction, and density of the vehicles to measure the quality and performance of our proposed relay selection methodology. The goal of this research is to provide insights into the benefits and limitations of relay based selection approaches as a data dissemination technique in VANETs. Figure 1, indicates the basic scenario of a vehicular network. In many aspects, dissemination reflects the security in ad hoc networks from attacker nodes and improvement in this will improve the overall vehicular ad hoc communication system [5].

1.1 Contribution

The key contributions of the research article are:

- Design of mathematical model for RDVFF communication system including the expressions, lemmas, and proofs.
- Designing novel algorithms for the selection of multiple relays based on the RDVFF mechanism. This includes the selection of relays not in the source transmission range and this increased the coverage of information to vehicles in low latency.
- Development of an optimized approach based on vehicle mobility to reduce the relay candidates in selection algorithms.
- Comparison of RDVFF with the state-of-art protocols for performance evaluation
- The proposed research results in the improvement in terms of the average PDR, throughput, delay, collision, signaling cost, and coverage.

1.2 Organization

The remaining article is organized as follows. In section 2, we focus on providing a review of the related literature on data dissemination techniques and relay selection in VANETs. Section 3, includes the outline of the methodology used in our research. In section 4, we present our findings and discuss the results based on experiments, followed by a conclusion and discussion in section 5.

2 Related Work

Recent research in the field of relay-based data dissemination in Vehicular Ad Hoc Networks (VANETs) has proposed various schemes and protocols to improve the efficiency and reliability of message dissemination in VANETs. Al-Kharasani et al. [6], proposed the use of a relay node selection mechanism to ensure reliable and efficient data transmission while minimizing communication overhead and reducing the risk of malicious attacks in vehicular ad hoc networks. Moreover not considered the impact of failure on data dissemination efficiency. Rashid et al. [7] present a hybrid data dissemination scheme that combines the advantages of both flooding and controlled flooding to achieve efficient and reliable data dissemination in VANETs. Though, focuses on specific aspects of relay-based data dissemination, without considering the broader network context. Wang et al. [8] propose a dynamic road condition-aware data dissemination scheme that uses vehicle-to-vehicle communication to exchange information about road conditions and adapt the data dissemination process accordingly. However, not considers a wide range of factors that can impact data dissemination efficiency and reliability. Abbas et al. [9] introduce an efficient cooperative data dissemination scheme that uses a combination of vehicle-to-vehicle and vehicle-to-infrastructure communication to improve the reliability and efficiency of data dissemination in VANETs. Moreover, many more factors can consider reflecting dissemination efficiency and reliability. Liu et al. [10] propose an efficient content-based message dissemination scheme for VANETs, which uses a Bloom filter-based approach to disseminate messages only to the vehicles that are interested in receiving them. However not considered the latency and other issues are due to real-time variations in traffic-related scenarios. Busaileh et al. [11], proposed a relay selection algorithm for data dissemination in wireless sensor networks that takes into account the energy consumption and signal strength of nodes. However, their approach assumes that all nodes have uniform transmission power, and does not consider the impact of node mobility on relay selection. Duan et al. [12] proposed a joint relay selection and power allocation scheme for energy-efficient data dissemination in vehicular based ad hoc networks. However, their approach assumes that all nodes have perfect channel knowledge and does not consider the impact of node failures or network partitioning on data dissemination efficiency. Guidoni et al. [13], intend an optimized relay placement algorithm for data dissemination in wireless sensor networks. However, their approach assumes that all nodes have uniform energy consumption and does not consider the impact of packet loss or network congestion on dissemination efficiency. Jeevitha et al. [14], proposed a hierarchical data dissemination approach for multi-hop vehicular ad hoc networks using relay selection and power control. However, their approach assumes that all nodes have the same transmission power and does not consider the impact of node heterogeneity or mobility on data dissemination efficiency. Khan et al. [15] suggest a distributed beacon-based message dissemination protocol for VANETs, which utilizes a distributed message forwarding strategy to improve the efficiency and reliability of message dissemination. However, the approach not considered the factors affecting sparse networks. Singh et al. [16] proposed a new relay selection algorithm for VANETs that is both distributed and efficient. The algorithm is designed to reduce the overhead associated with relay-based data dissemination, while also improving the reliability and scalability of the network. However not considered the scalability and congestion issues due to random mobility. B. Ravi et al. [17], proposed a stochastic methodology for proper connectivity in both vehicle-to-infrastructure and vehicle-to-vehicle communication for efficient data dissemination using a queuing model. Meanwhile, the delay in emergency information needs to consider in the method. P. Spadaccino et al. [18], suggest a technique to reduce the load over the network during message dissemination by using an epidemic algorithm. The number of relay node participants is reduced based on the timer. However, the approach not taken V2I-based communication into account. D. Preethika et al. [19], proposed a methodology to reduce delay for emergency messages during broadcasting. A collision avoidance scheme for chain transmission is considered to decrease the message propagation time. At the same time, the approach increases the delay in dense communication. X. Fan et al. [20], proposed the replication-based efficient dissemination of information by considering the strongly connected Internet of Vehicles (IoV) with different values of basic parameters. However, the frequent network fragmentation problem does not consider by the approach for dissemination efficiency. S. Alani et al. [21], worked on energy-efficient routing protocols for mobile ad hoc networks and proposed an approach using optimization algorithms to make node and network energy efficient. However, the approach assumes that all nodes have uniform transmission power during mobility and does not consider its impact on routing. I. Turcanu et al. [22], named the information as floating car data which was produced at the time of communication between vehicles when they are connected. This huge amount of information can be used in the development of Intelligent Transport Systems (ITS). The approach is providing better solutions for the improvement and development of the existing transportation system. However, the approach needs to consider the ensuring of QoS of data due to the huge information. C. S. Evangeline et al. [23] discussed the safety-related dissemination of messages for assisting diver of vehicles. A message priority strategy had been proposed to deliver the information rapidly. Relay selection for this was based on the maximum distance from the source. However, the approach does not consider network scalability and dynamic fragmentation. Chahal et al. [24] cover the frequent network disconnection problem by proposing an efficient approach for continuous link provision for information transmission. A unique mechanism was suggested to address the issue of intermediate link breakage. Performance in packet delivery and throughput improved by greedy approach for transmission using reliable and shortest path selection during motion on the transmission links. Chahal et al. [25], address the key challenge of path optimality including the possibility of obstacles occurring during vehicular ad hoc communication through a discrete particle swarm optimization method. DPSO serves to improve the process of determining the best and optimal path to disseminate the information in comparison to PSO. Routing packets per data are well reduced. Chahal et al. [26] proposed Stackelberg game theory-based SDN-based communication to cover the bandwidth and coverage issues. The further layering of controller modules with the duration of links between units mechanism applied for dissemination of information during mobility. Balfaqih et al. [27] address the performance issues at anchor units in processing the information due to the groups of vehicles moving from one RSU to another by proposing the DMM based on the centralized mobility protocol CMM. To achieve the desired outcomes through DMM; for fast handovers to mobile users, many effective configurations were performed in the proxy mobile version of IP6 (PMIPV6) to FDMM. Balfaqih et al. [28] focus on research in particular performance on performing the deep analysis on handover strategies in mobility protocols based on IP for PMIPv6 and DMM domain in vehicular networks through MAGs and MAAR respectively. Once in PMIPv6, MAG received a PBA message from LBA; while in DMM, MAAR from CMD the handover of MU takes place.

Furthermore, data dissemination is a critical aspect of VANETs, as it allows vehicles to share information about traffic conditions, road hazards, and other relevant information. There are several open issues related to data dissemination in VANETs that have been the subject of ongoing research as the network needs to handle a large amount of data by more and more vehicles increasing day by day such as scalability, reliability security, privacy, service quality, and energy-efficient communications.

3 RDVFF Design and Implementation

This article suggests the selection of relay nodes for the V2V transmission system to minimize the dissemination process's latency and improve the quality of service by quicker accessibility of transmitted information. The proposed method is based on choosing the relay node that is next most distant from the current distant vehicle from the source and must not be inside its transmission range. Additionally, in later subsections, the method has been developed for selecting more than one relay node while taking moving vehicle directions into account to improve coverage with less latency.

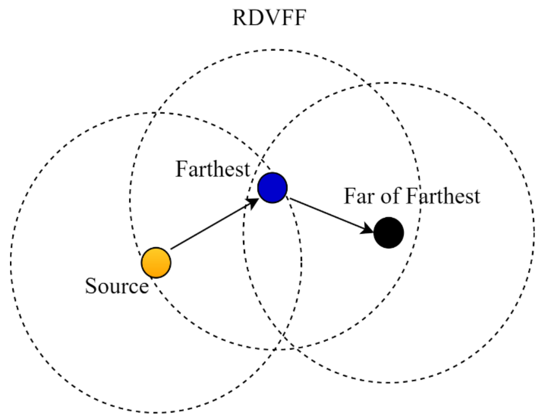

Figure 2. Proposed approach-RDVFF

Figure 2, presented the approach, and begins with the process of selection of the farthest node in its region (BLUE) from the source (ORANGE). This distant node further applies the procedure to get a new node (BLACK), the farthest from it, as a relay node, not within the range of the source one. By minimizing relay participation, the candidate relay nodes list is generated, and improving the overall system of information transmission and receiving during the vehicle moving by V2V communication. The flag has been assigned at the time of processing to optimize relay selection. As the network is highly dynamic therefore the link stability is required to maintain till the completion of dissemination of data even if the nodes leave the transmission range of the source. Flag value including acknowledgment from the receiver maintains the link stability during nodes leaving the existing or entering a new network. A particular region source's unique flag is set up on transmission using beacon signals and exchanged with another source while entering its range of transmission. RDVFF process for the selection of multiple relay vehicles is explained in the later section, while the working steps for selection are described in Figure 3.

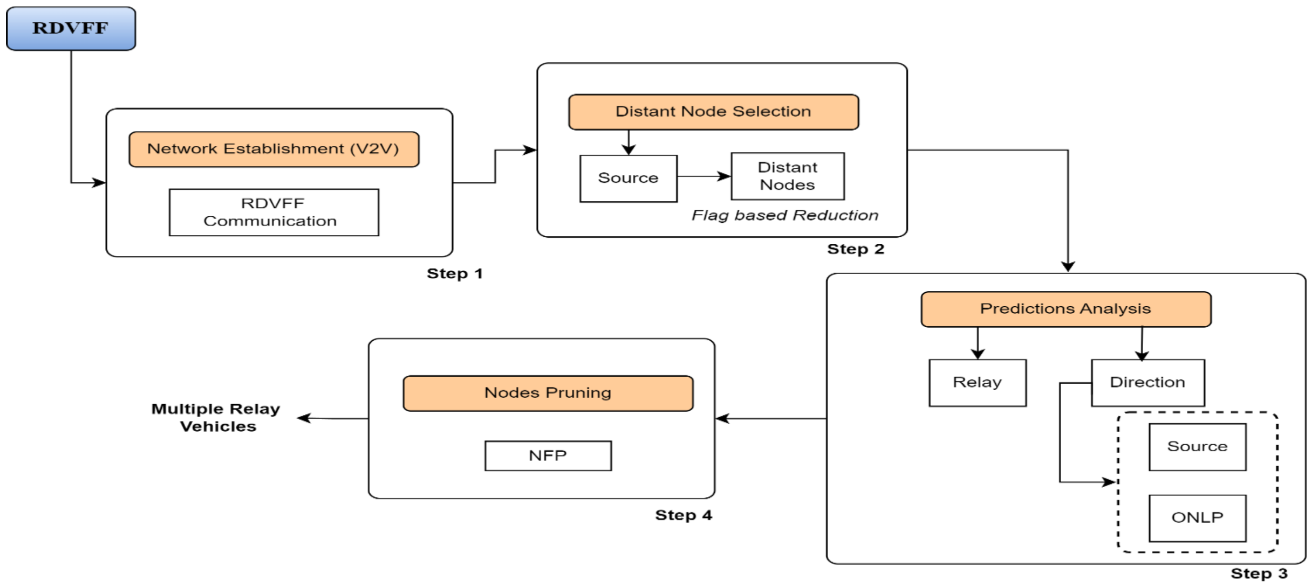

Figure 3. RDVFF working steps

3.1 Network Establishment

The establishment of the network consists of a set of vehicles V ranging N in number of vehicles and other supporting units in communication involving U roadside units R_U. In V2V communication when the vehicle is not able to set up the wireless ad hoc connection to the neighbor due to unavailability or not discovered then nearby RSU broadcast the identification of the vehicle to set up the connection with other vehicles. Vehicle discovering neighbors with transmission range is the coverage region T_S for messages M moving with speed S. Network establishment for this is shown in Figure 4. Primary factors, N_F related to the establishment of a communication network are defined in (1) vector.

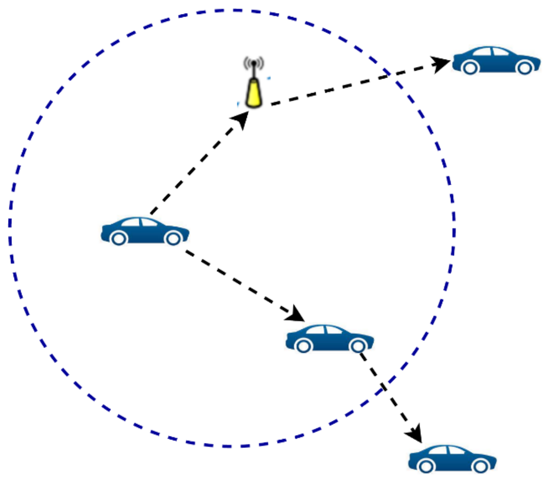

Figure 4. Vehicles link establishment

$$N_F = \left\{V[1,2,...,N], R[1,2,...,U], \left[\int_{V=1}^{N} T_V\right], \left[\int_{V=1}^{N} S_V\right]\right\}. \quad \textbf{(1)}$$

After link establishment between the nodes, message sending and receiving started. Also, the connection between nearby RSU and the sender is created by publishing a path discovering a message at regular intervals of time to enhance coverage outer of the region. Tracking of vehicle communication is maintained by regular monitoring by the sender to update the records of link establishment and termination for frequent delivery of the message. Figure 5, depicts the workflow for proposed strategy.

3.2 RDVFF Communication Model

In the real-time mobility of vehicles on road lanes, every vehicle is either moving in the left or right direction for each other. Road lanes are always bilateral in opposite directions. For the evaluation and development of the mathematical model for mobility in RDVFF; some basic conditions are considered including the total number of N vehicles with the distribution in terms of binomial coefficient C. As the approach is dedicated to a scenario on V2V communication at highway road lanes; the probability of turn in left or right or intersection is very low and let it is assumed to be $P(q)$ for all such vehicles. Therefore, the probability of moving in straight by the remaining vehicles is $P(1\text{-}3q)$. With the communication range R; the velocity of every moving vehicle is defined by the component's speed and direction. Vehicles are moving on the ground surface so the above-mentioned

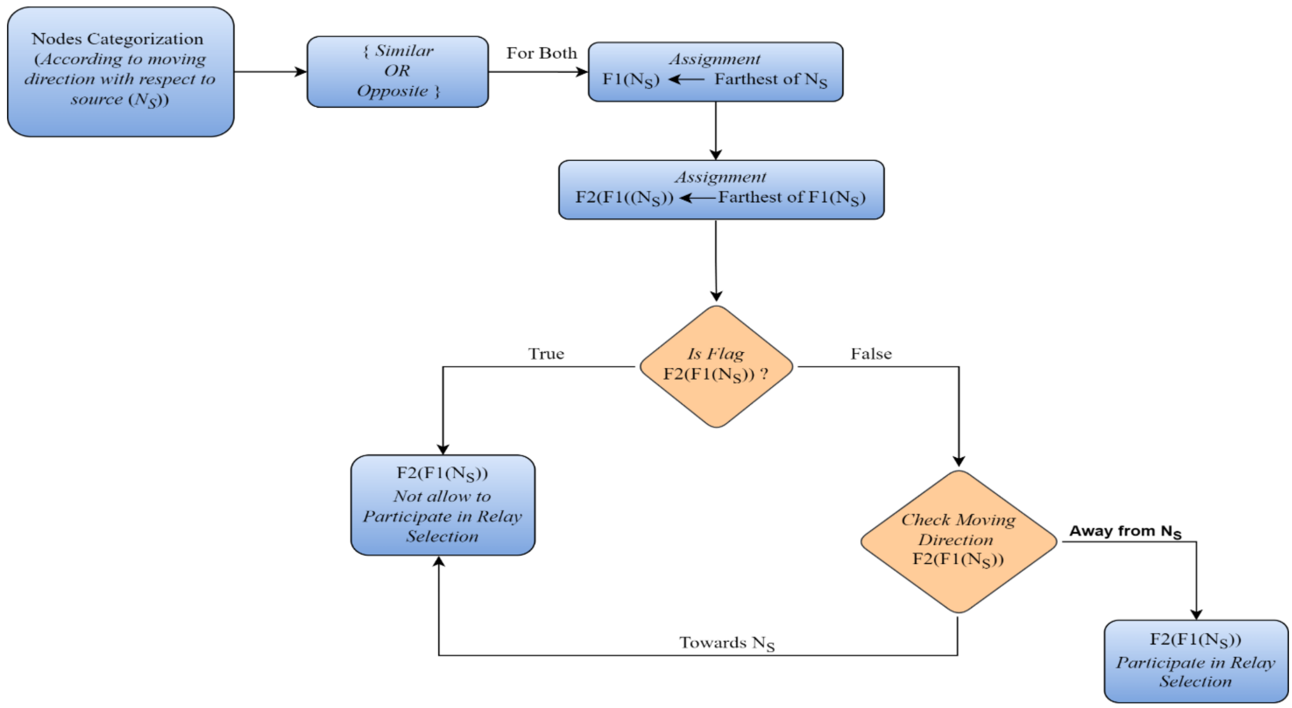

Figure 5. The flow of RDVFF processing

components can be represented in terms of unit vector (ˆi, ˆj) making an angle of ϕ as shown in Figure 5. Following lemmas are considered to evaluate RDVFF.

Lemma 1: *Time of communication between similar direction moving vehicles with relative speed* V_R.

Part A of lemma 1: *If the speed of the behind vehicle is greater than the vehicle ahead then communication time decreases.*

Proof: Let vehicles x and y are moving with velocities V_x and V_y where ($V_x < V_y$) in the range of communication with each other is at the angle of ϕ_1 *and* ϕ'_1 respectively to each other. The component of relative velocities is given below in (2).

$$V_R[i \pm j] = [V_x \cos(\varphi_1) - V_y \cos(\varphi_1^{'})]i \\ \pm [V_x \sin(\varphi_1) - V_y \sin(\varphi'_1)]j. \tag{2}$$

Net relative velocity is defined as in (3) of these vehicles.

$$V_R = \sqrt{V_x^2 + V_y^2 - 2V_xV_y \cos(\varphi_1 - \varphi_1^{'})}. \tag{3}$$

In the worst case when the distance between Vehicle x and Vehicle y is maximum and still in range of each other then the coverage for dissemination is maximum. *t* is the time taken between (*x*, *y*) to communicate at any instant; while *max_t* is the maximum time taken in the worst case. The covered region of such vehicles is given in (4) for computation in (5).

$$0 \le Coverage \le R_{Max}(x, y); \\ Max(Coverage) = (R_x + R_y). \tag{4}$$

In general;

$$Speed = \frac{Distance}{Time} \Rightarrow t = \frac{Coverage}{V_R} \\ \Rightarrow \left| \frac{(R_x + R_y)}{[(V_R)]_{\min}^{\max}} \right|. \tag{5}$$

The value of (ϕ_1 - ϕ'_1) is 0°; when (x and y) are moving in similar irrespective of their comparative velocities. Thus, *cos*(ϕ_1 - ϕ'_1) is 1 and accordingly through (3) gives the minimum value of relative velocities. Consequently through (5) it can be concluded that for minimum V_R the time *t* for communication is maximum that is *max_t*. Hence the conclusion of lemma 1 for the time of communication is as follows in (6).

$$V_\varphi \in \{0^\circ \text{ to } 180^\circ\} \ \ if(V_R): Minimum :: t : \max\_t \ . \tag{6}$$

Proof of Part A of Lemma 1;

For a maximum time in (7); Let vehicle x is behind vehicle y and $V_x > V_y$. In a such case with the increase in time, the coverage will decrease due to the difference in V_R for *t*.

$$For\ t = maximum;$$
$$t \propto \left[\frac{1}{(R_x + R_y)} \right] : \int [t]_1^{\max\_t} : decreasing\ . \quad \textbf{(7)}$$

Part B of lemma 1: *If the speed of the behind vehicle is less than the vehicle ahead then communication time increases.*

Proof of Part B of Lemma 1;

For a maximum time in (8); Let vehicle x is behind vehicle y and $V_x < V_y$. In a such case with the increase in time, the coverage will increase due to the difference in V_R for *t*.

$$For\ t = maximum;$$
$$t \propto \left[R_x + R_y \right] : \int \left[t \right]_1^{\max\_t} : increasing\ . \quad \textbf{(8)}$$

Lemma 2: *Time of communication between opposite direction moving vehicles with relative speed V_R is minimum.*

Part A & Part B of Lemma 2: For both conditions *Vx > Vy or Vx < Vy*; communication time increases.

Proof: The value of (ϕ_1 - ϕ'_1) is 180°; when (x and y) are moving in opposite irrespective of their comparative velocities. Thus, *cos*(ϕ_1 - ϕ'_1) is -1 and accordingly through (3) gives the maximum value of relative velocities. Consequently through (5) it can be concluded that for maximum V_R the time *t* for communication is minimum which is *min_t*. Hence the conclusion of lemma 2 for the time of communication is as given in (9).

$$\forall \varphi \in \{0^\circ \text{ to } 180^\circ\}\ if\,(V_R){:}\ Maximum :: t : \min\_t\ . \quad \textbf{(9)}$$

Proof of Part A of Lemma 2;

For a minimum time in (10); Let the velocity of vehicle x is more than the velocity of vehicle y; $V_x > V_y$. In a such case with the increase in time, the coverage will increase due to the difference in V_R for *t*.

$$For\ t = minimum;$$
$$t \propto \left[1/(R_x + R_y) \right] :\ \int [t]_1^{\min\_t} : increasing\ . \quad \textbf{(10)}$$

Proof of Part B of Lemma 2;

For a minimum time in (11); Let the velocity of vehicle x is less than the velocity of vehicle y; $V_x < V_y$. In a such case with the increase in time, the coverage will increase due to the difference in V_R for *t*.

$$For\ t = minimum;$$
$$t \propto \left[R_x + R_y \right] :\ \int [t]_1^{\min\_t} : increasing\ . \quad \textbf{(11)}$$

3.3 RDVFF V2V Linkage Probability

Variations in vehicle density at different locations will affect the RDVFF scheme, especially in the case of the non-availability of a V2V link. Therefore the issue of uncertainty in linkage during mobility needs to explore to provide the efficient outcome of the proposed in the low-density region. Let us suppose that the point of the vehicle is the origin of a Cartesian coordinate system to determine the value of relative speed (R_S). Points are represented in two dimensions by coordinates (*X*, *Y*) concerning the *X*- and *Y*-axes. Furthermore, the axes split the plane into four pieces, which are referred to as quadrants - one-fourth portion. Based on the position and mobility of the nodes, we must now evaluate the following various relevant situations. By ensuring the linkage estimation, RDVFF has a high probability of successful deployment and practical utility in real-world scenarios. The source *N*1 initiates sending the message in the range*T*_*N*1. Other vehicles are assumed to distribute in a random probability manner of Poisson with the degree *D*. Same can be shown in the *XY* region to process the link. Similarly, other quadrants may process linkage investigation. Distribution density of vehicles in an average is represented by η, and $D\eta$ is the inflow of vehicles.

Symbolizing and initialization at *t = 0* for the sender vehicle with Position (N1) ← (0, 0), the possibility of link availability can explore from (12) to (16).

$$\forall \left\{ x \in (2 \text{ to } n) \right\};\ \wedge \{p, q\} \equiv \{i, j\}; \quad \textbf{(12)}$$

$$N_x(X_p, Y_q) \leftarrow D(\eta) : [p, q] \in \begin{bmatrix} (X_i, Y_j) \\ (-X_i, Y_j) \\ (X_i, -Y_j) \\ (-X_i, -Y_j) \end{bmatrix}. \quad \textbf{(13)}$$

Considering $R_S \leftarrow (V1, Vx)$; Linkage probability *p*; between (*N*1, *Nx*) is:

$$p(x) \in [0 < p(x) \le 1];\ when\ (X_1 - X_x) \le T_{N1})\ . \quad \textbf{(14)}$$

For vehicles not in the source range; *p*(*x*) >1

Function *F*; represents the aggregated RDVFF linkage in the source region for random vehicle distribution.

$$F(x) = \int_2^x \left[{p_x}\big/{|n-1|} \right]. \quad \textbf{(15)}$$

$$if\ \ F(x) = \begin{cases} > 1, Disparity(R_S) \leftarrow V1 \\ \le 1, Link\ \ Viability \end{cases}. \quad \textbf{(16)}$$

3.4 Distant Node Selection (Source Zone)

This subsection outlines a method for discovering and selecting the node that is most far from the source. For each node in a source region, the residual distance from the periphery of source transmission has been evaluated. The node with the smallest residual distance will be taken into consideration for subsequent operations. Further, the work is enhanced for both opposite and similar directions in consonance with the source. The most distant two nodes from the source in the respective directions are identified using the processes described in later sub-sections.

$$Flag = \begin{cases} 1, & \textit{link stability validation} \\ 0, & \textit{otherwise} \end{cases}.$$

The method employed to determine the node's residual distance (DR) from the extremities of source transmission (T_S) for N such nodes at a particular time instant is depicted in Figure 6. The array comprises a list of each moving node in T_S at t. Beacon communications for consideration setting the *FLAG* value shown in (17).

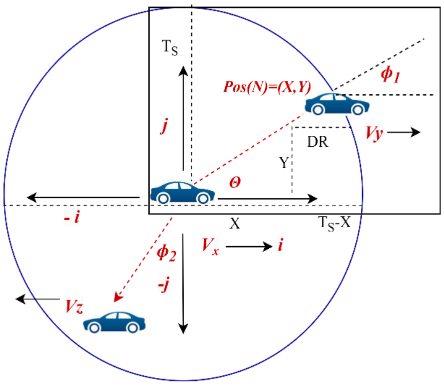

Figure 6. Residual distance evaluation

$$Flag[0,1] = \{'TRUE'\ if\,(Message\ Received)\ else\, 'FALSE'\}. \tag{17}$$

The position of the node at instant t is denoted by the coordinate's system value (X, Y). At that instant, a node is building an angle θ from the source location. Mathematical functionality is given in (18) to compute residual distance.

$$(T_S)^2 = \{(X^2 + Y^2) + (DR)^2 - 2 * [(DR)(\sqrt[2]{X^2 + Y^2}\cos(180^\circ - \theta)]\}. \tag{18}$$

Execution of algorithm 1 accomplishes the selection of the farthest node in the source zone for transmission. Preprocessing of broadcasting of the beacon to identify the nodes and related parameter values in its region is performed in the method and a corresponding list of active neighbors has been maintained. As an ad hoc network is highly dynamic for topology persistence; so a timer value provides the link stability.

Algorithm 1. Farthest_Node_Selection (N_S, T_S)

List_N_S[ ] ← ∀N ; such that {N ∈ T_S[t]}};
Broadcast(*Beacon*);
Start(*Timer*);
N_{ACK}[ ] ← ∀N ; {N_{STATUS} = ACK(*Received*)}
    // ***Computation of Residual Distance***;
For all N ∈ N_{ACK}[ ]
    Set N_{FLAG} == *TRUE*;
    {*Save node status for link stability*}
    $(T_S)^2 = \{\sqrt{(X^2+Y^2)}^2 + (DR)^2$
    $2\left[\sqrt{(X^2+Y^2)}(DR)\cos(180 - \Theta)\right]\}$
$F_1(N_S)$ ← Min{DR(N_S)[]}
Return $F_1(N_S)$;

3.5 Relay Predictions

Obtaining the relay node as stated by algorithm 2 is discussed in this subsection. The relay node will be the node that is distant to $F_1(N_S)$ and must not be in the source region, as suggested in earlier sections and given in (19).

Algorithm 2. Relay_Selection (N_S, F_1 (N_S))

List_ $F_1(N_S)$[ ] ← ∀N ;
    {such that {N ∈ T($F_1(N_S)$[t])}};
Label:
For all N ∈ List_ $F_1(N_S)$[ ]
    $F_2(F_1(N_S))$ ← **min** {DR ($F_1(N_S)$)[ ])};
    if {FLAG [$F_2(F_1(N_S))$} ≠ TRUE
        List_ $F_1(N_S)$[ ] ←
            { ($F_1(N_S)$[ ]) ∩ $F_2(F_1(N_S))$)};
        goto ***Label***;
    else
        R_N ← $F_2(F_1(N_S))$
Return R_N ;

$$R_N \in N : \{\{N \in (F_2(F_1(N_S)))\} \wedge \{N \in T(N_S)\}\}. \tag{19}$$

Some eventualities need to be taken into consideration before making the final decision for relay nodes. As follows, the same is shown.

Condition A: The node chosen for relay node consideration is a member of the source region.

Therefore;

[*Node_Selected*(*N*) ∈ *List*(N_S) *and* N_{FLAG} = *TRU E*;]

Condition B: The node chosen for relay node consideration is not a member of the source region.

Therefore;

[*Node_Selected*(*N*) ∈ *List*(N_S) *and* N_{FLAG} = *FALSE*;]

Outcome [***A, B***]= ***For***, { Condition A: ***Not Allowed***
Condition B: ***Allowed***

3.6 Directions Predictions

From the assigned highway lane numbers, the authors [29], explained to extract the traveling direction of nodes for vehicle-to-vehicle communication. Before obtaining the finalized relays, the node's direction of movement generates some potential situations that need to be examined. Case studies and their potential solutions will be put into consideration for optimization. The source node is presumed to be at position (0, 0), and any other nodes from its region that are moving in its direction or away from it are at position (X, Y) at any specified instant. The next subsections further demonstrate assumptions connected to the movement direction. The AI model Figure 7, conclude the driver behavior, and risk prediction and outlooks the scenario for ease of other vehicle heading to reach this zone from any direction. Figure 8, presented the possible situations involving the source changing direction. Road lanes are represented by the value of Y at node position (X, Y). As a result, any modifications related to Y won't modify the node's direction of motion though it validates learning the density or load on the section to analyze the system performance. Also, it develops the framework to provide support for the assessment and interpretation of intelligent behavior.

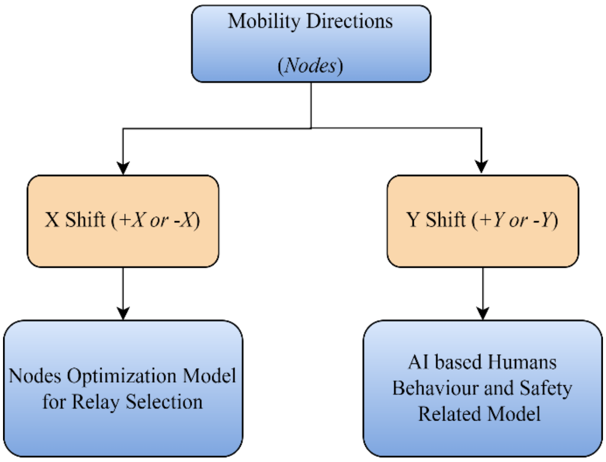

Figure 7. Vehicles directions variations

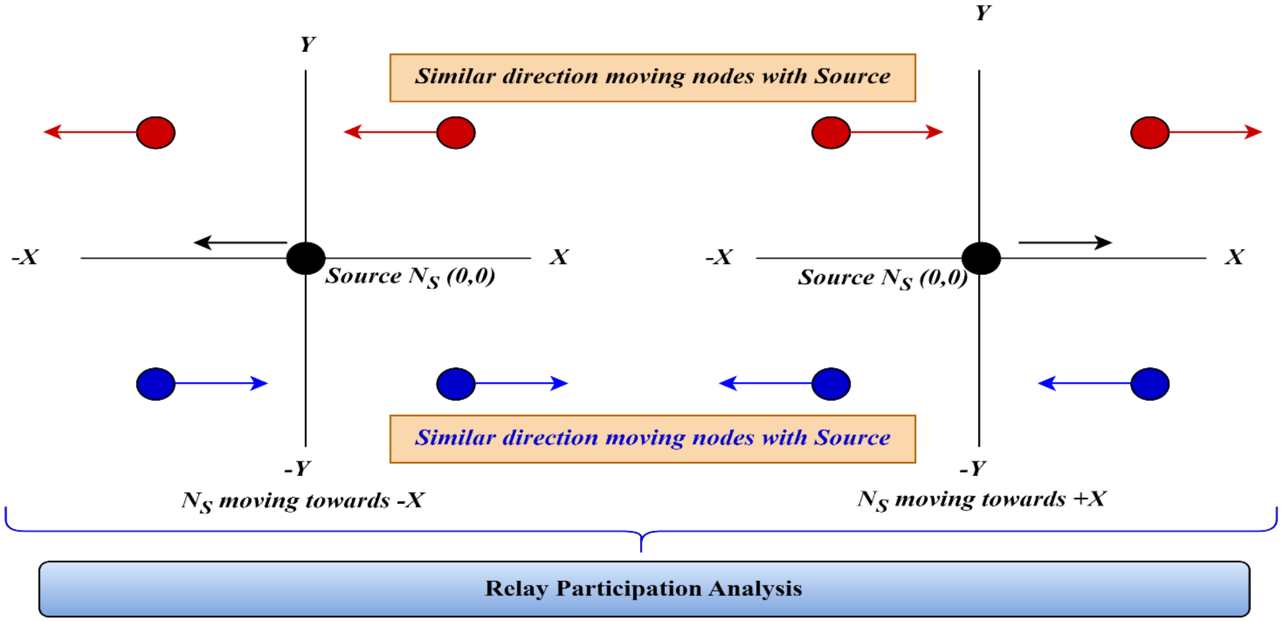

Figure 8. Mobility orientation

3.6.1 Source Directions (R_N Pattern)

Regarding the direction, in that, the source moving along the X-axis, Presumptions, and hypotheses are taken into consideration as presented in Figure 9, for other nodes in the source region in the form of various possible cases and sub-cases relative to each other. While moving toward the source a node yields cases for the either positive or negative axis of *X*. Similar for nodes that are heading away from the source. Each one leads towards the optimized solution by reducing the relay participation. Hence, overall limiting the system processing and minimizing the delay in information. Based on these the later subsections provide the categorization of nodes for inclusion or exclusion by filtration process at source for forwarder selection. Nodes mobility further consideration of link persistence during data transmission for each direction as per source heading. Any variation in *Y* indicates the changes in road lanes satisfying the possible conditions of either overtaking, change in node speed, arriving towards a road turn, or parking. This variation does not affect the execution of filtration handling and selection.

3.6.2 Relay Inclusion using ONLP

Table 1, represents the outcomes for all possible cases and sub-cases from the moving direction of the source and other nodes relative to other nodes. The conclusion is that, if the node is moving away from the source in either of these situations, it is included in the relay selection process and if it is moving toward the source, it is discarded from further processing to minimize the system processing and led towards the solution for broadcast storm and network congestion by reducing the number of retransmission of similar information as the node participation is now optimized and improving the quality of service to vehicle assistance. Method Node Reduction applies to reduce the node's engagement for disseminating the source message by returning an Optimized Node Participation List (*ONPL*).

Function: Node_Reduction ( )

1. ***For all*** $N \in List\_ F_1(N_S)[\ ]$
2. ***For*** (Dir (N_S) ← Heading {X or -X}
3. ***If*** (Dir(N) ≠ Dir(N_S)
4. ONPL[]←{List_ $F_1(N_S)[\ ] \cap N$}
5. ***Return*** ONLP;

3.7 Nodes Pruning

Based on the monitoring of vehicle communications, two relay nodes moving away from the source have been selected from each classification following the assumptions outlined in further sections to ensure the widest coverage and the rapidly reachable of the source information. The Node Filtration Process (*NFP*) and criteria for optimization during relay selection are shown in Figure 10.

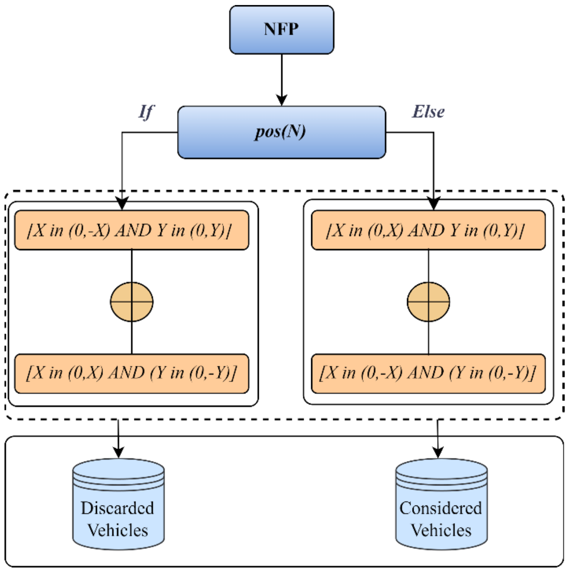

Figure 10. NFP execution

Table 1. Cases for mobility patterns

	Dir (N_S) towards (- X)		Dir (N_S) towards (+ X)	
Instance : Dir(N)	N away S_N : {Instance : SA}	N towards $S_{N:}$ {Instance : ST}	N away S_N : {Instance : SA}	N towards $S_{N:}$ {Instance : ST}
Association	SASS	STSS	SASS	STSS
Relay eligibility	Yes	No	Yes	No
Association	SAOS	STOS	SAOS	STOS
Relay eligibility	Yes	No	Yes	No

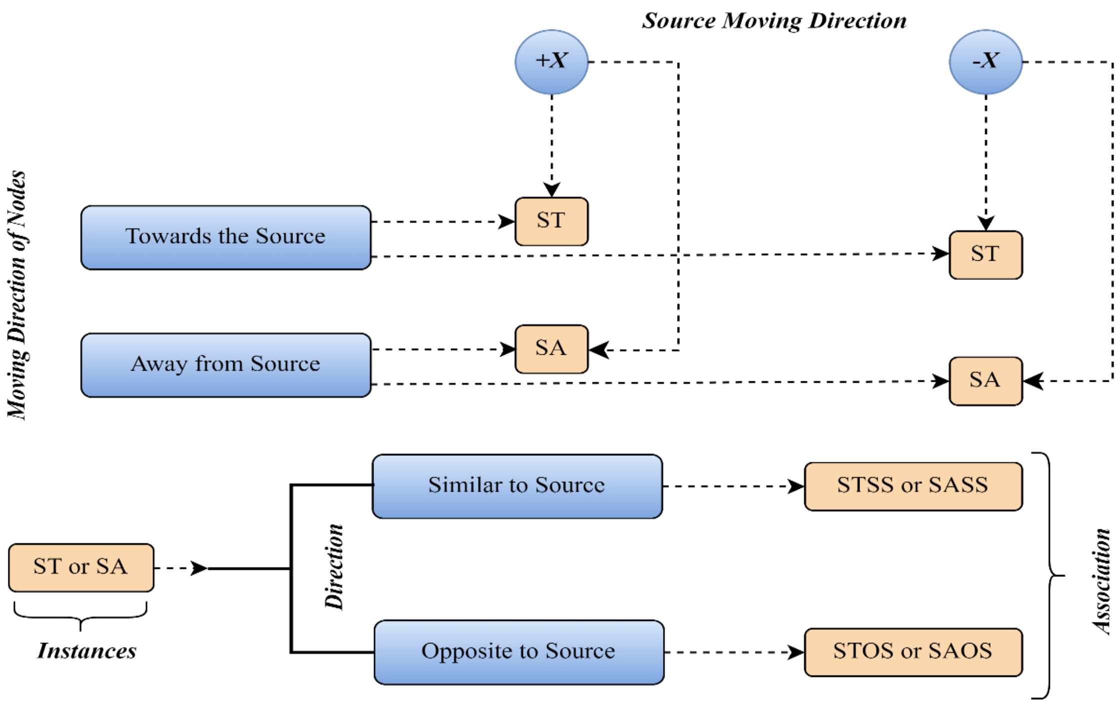

Figure 9. Nodes mobility

3.8 Algorithms Complexity

The complexity of the presented approach is assessed concerning both time and space complexity. For time complexity in algorithm 1, the loop at step 5 iterated N times, while all others with each by $O(1)$. Hence time complexity for algorithm 1 is $O(N)$. Similarly, $O(N)$ for algorithm 2 as step 3 is looped in N numbers. Therefore the total time complexity for the proposed approach is $[O(N) + O(N)]$ overall. Space complexity is the portion of memory used by both the algorithms in RDVFF that is linear and it is $O(N)$ as the maximum array size in algorithm 1 is at steps 1 and 4 is N and in algorithm 2, the N is maximum and linear for step 1 and 6.

Proof: We can examine the running time for some searching criteria c, with the β nodes involved in the computation of the relay. The developed searching problem for the mobile nodes with random distribution in ROI can be formulated for $\gamma = \beta - N_{Source}$; With the initialization of $\lambda_{max} = \gamma$, such that initial aspect $\beta[0]$ for the function of cycle $F(\gamma)$ with distant node computation. For every cycle to γ, when $\beta[0] >= \lambda_{max}$; update $F(\gamma)$ with $\lambda_{max} = \beta[i]$ only when $\beta[i] >= \lambda_{max}$. When each prerequisite is fulfilled by the generated illustration for RDVFF the running time $O(\gamma)$, of finding the farthest node is the function of $\sum(T_L)$, iterative (p) and non-iterative (q) statements where T_L is the duration it requires to process individual lines of code is defined as $O(\gamma) \leftarrow F(\sum(T_L), p, q)$: $L \leftarrow p+q$ and $\sum(T_L) \leftarrow \gamma * p + q$. Therefore; $O(\gamma)$ is linear time for input γ. The selected search for c establishes the model for the definition of the issue. Therefore $O(c) \sim O(\gamma)$. Hence RDVFF problem running time is the linear function of N.

3.9 Symbol Layout

An overview of the symbols used in this article or suggested technique is provided in Table 2.

Table 2. Symbols layout

Abbreviation's	Interpretation's
N_S	Source Node
T_S	Transmission Range (N_S)
(X, Y)	Node Position
Θ	Angle (*N and X axis*)
DR	Residual Distance
N_{ACK}	Node Acknowledgement
N_{FLAG}	Flag Value (N)
F_1	Node Farthest from N_S
F_2	Node Farthest from F_1
R_N	Relay Node

4 Performance Measurement

Performance reflecting the feasibility and effectiveness of the proposed scheme has been examined by simulation of diverse road traffic scenarios and other required conditions and is presented in subsequent subsections.

4.1 Simulation Organization

Traffic scenario developed for the road component for the Delhi-Noida Direct Flyway in a real-time environment. Considered section of road length is shown in Figure 11. Two sets of cases of simulations are performed in this structure to further classify the experiments on metrics for evaluating the performance of the suggested state-of-art, region of 3 km x 3 km selected from Delhi-Noida-Delhi Flyway through OpenStreetMap to SUMO for generating trace file for realistic mobility environment containing nodes information in terms of speed and location. This information is further used by NS2.35 as data set to evaluate performance. 2-Way roads are considered to consist of 8 lanes having 4 lanes in each direction. Variable node speeds ranging from 20 to 80 mph have been used to show the correlation between results. Comparative analysis on UDP transport with CBR traffic is performed for 400 vehicles such that 200 are traveling in the direction of the source in lanes 1 through 4 and the remaining are in the direction opposite to that of the source through lanes 5 to 8. Comparison outcomes of mentioned cases have been shown in Figure 11 to Figure 17.

Table 3. Parameters setup

Parameters	Values
Lanes on Road	8
Path Segment	3 km
Simulation Time	5 mins (300 secs)
Simulation (Numbers)	10
Node Speed	[20-80] mph
Transmission Range	300 meters
Message Size	2 KB
MAC Layer	802.11p
Flow Rate	[100-400] nodes/hour
Tools	Network Simulator (NS-2.35) Mobility (MOVE) Traffic (SUMO 0.32) Map (OpenStreetMap)

Case I: *Performance measurement with time while maintaining a constant node density of 400 vehicle*
Case II: *Performance measurement with variable node density ranging from 40 to 400 vehicles.*

An average of ten simulations for each statistic is taken into consideration. Table 3, lists the values that have been considered for the experimental procedure in this organization. Our experimental results afterward will show the sustainable growth in performance indicators in comparison to these. The subsequent section 4.2, contains metrics definitions, and the analysis of their comparison based on obtained results is given in section 4.3.

4.2 Performance Metrics

This section outlines the metrics applied to compare and measure the performance of the proposed system with other techniques for B transmitted bits in t time for n simulations.

Throughput (Th): It has been measured as the total volume of data bits efficiently sent across the network by the source node as given in (20) and (21).

$$Th = \sum_{k=1}^{t} \left(B / t\right)^{k}. \quad \textbf{(20)}$$

$$Avg(Th) = \left[\sum_{Sim=1}^{n} \left(Th\right)\right] / n. \quad \textbf{(21)}$$

Packet Delivery Ratio (*PDR*): The fraction of packets successfully delivered to destination nodes within range of the source to total packets being transmitted by it as shown in (22) and (23). More the PDR; high reliability of the network.

$$PDR = \left(\frac{\sum_{1}^{(n,t)} \left(Recv\_Packets\right)}{Total\_Packets\left(n,t\right)}\right). \quad \textbf{(22)}$$

$$Avg(PDR) = \sum_{1}^{t} \sum_{Sim=1}^{n} \left(PDR/n\right) \{t = 1,2,3.........n\}. \quad \textbf{(23)}$$

Delay (*D*): It is defined as the overall duration of time that any message takes from a source to reach every other node within the source's range. For total time *Recv_T*, by such nodes, the average delay for n simulation is presented in (24).

$$Avg(D) = \sum_{1}^{t} \sum_{Sim=1}^{n} \left(Recv\_T/n\right) \{t = 1\_to\_Sim = n\}. \quad \textbf{(24)}$$

Coverage Ratio (*CR*): This is the ratio of nodes that received a message from the source, including nodes beyond coverage, to all nodes that are available at that instant. *CR* for transmitting message *M* received by *Recv_N* nodes from *N* available nodes is given in (25) and an average of *n* such by (26).

$$CR = \sum_{1}^{t} \sum_{Sim=1}^{n} \left[\left(Recv\_N/N\right) * 100\right]_{t=1}^{n}. \quad \textbf{(25)}$$

$$Avg(CR) = \sum_{1}^{t} \sum_{Sim=1}^{n} \left(CR/n\right)_{t=1}^{n}. \quad \textbf{(26)}$$

Collision (*C*): Collision Ratio is the ratio of collided packets to nodes in the region of the source over a specific period. For, *CP* collided packets among *N* nodes; the collision ratio *CR* is given by (27) and (28).

$$C = \left\{ \left(\sum_{n=1}^{Sim} (CP)\right) / N \right\}. \quad \textbf{(27)}$$

$$Avg(C) = \sum_{1}^{t} \sum_{Sim=1}^{n} \left([C]_{t=1}^{Sim=n} / n \right) \{t = 1,2,3....n\}. \quad \textbf{(28)}$$

Signaling Cost (*SC*): The computation of the cost of signaling will be based on a count of messages exchanged for the handover management process. Though this involves the handover takeover mechanisms including the Mobile Access Gateways (MAG) and other APs. Here the works count of *SC* messages for N_H vehicles or users involves in this process at any *t* instant by exchanging M_H handover messages is given by (29).

$$SC = \left[\sum_{Sim=1}^{n} \left(\sum_{j=1}^{j=N_H} [M_H(N_{H(j)})]\right)\right]. \quad \textbf{(29)}$$

Figure 11. Road section (Delhi-Noida Direct Flyway, India)

4.3 Outcomes Assessments

The presented scheme's metrics performance is compared with that of the basic flooding in all directions, unidirectional and selective forwarding scheme by [29-31]. Gupta et al. [29] proposed a Multiple Relay Selection scheme based on a multi-directional selection approach for relay nodes based on highway traffic where the forwarding node is chosen for multiple directions of motion of nodes. Pradhan and De [30] proposed the LT selection method to select relay nodes based on leaving duration from the transmission range of the source. KB selection; a greedy approach based on knapsack was given by Farooq et al. [31] for relay selection to optimize the assignment problem through weight and ensuring the maximized profit in terms of dissemination. All these strategies expect nodes that escape the source's transmission range sooner will cover new nodes more quickly and deliver high coverage in a significantly short period. As simulation time elongates, networks become crowded with more flow of information, which reduces throughout. The same holds for node density. Performance of the packet delivery ratio parameter throughout the simulation while maintaining both constant and varying node densities is shown in Figure 12, which represents the throughput variation with node density and time. PDR performance throughout the simulation while maintaining both constant and varying node densities is shown in Figure 13. Furthermore, when such several nodes per hour reach the maximum or more than the stated values, then for both setups; the average PDR starts high, but as traffic grows and other factors come to appear, it starts to fall. Figure 14, illustrates that with time, the average delay values are lower but this latency will probably rise with the network's growing node density for all techniques and will cause more collisions and congestion. Likewise to this, even when node density was kept constant, the volume of messages for both previous and newly transmitted information grew over time, which raise the latency. In Figure 15, the coverage ratio has improved with the sampling interval and become more efficient in terms of providing the quality of service to end users of V2V networks for the proposed scheme, however as node number increases, it reduces as a consequence of increasing congestion. As there are more packet transmissions as the network's nodes or time grows, the possibility of collision also appears to be growing in the network as shown in Figure 16. The signaling cost for both models represents in Figure 17. The experimental results show improvement in throughput, PDR, collision, and latency on average by 21.27%, 18.34%, 36.76%, and 38.04% respectively.

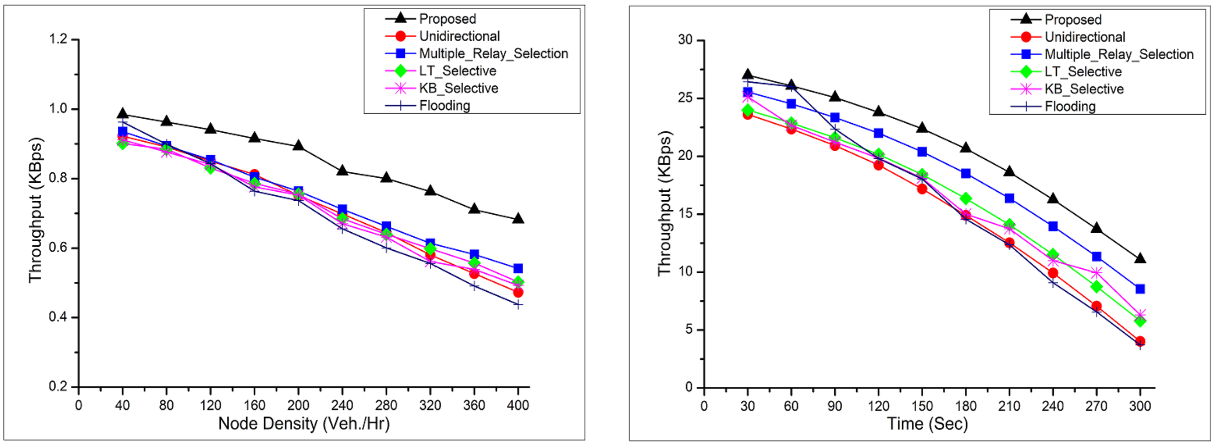

Figure 12. Throughput deviation

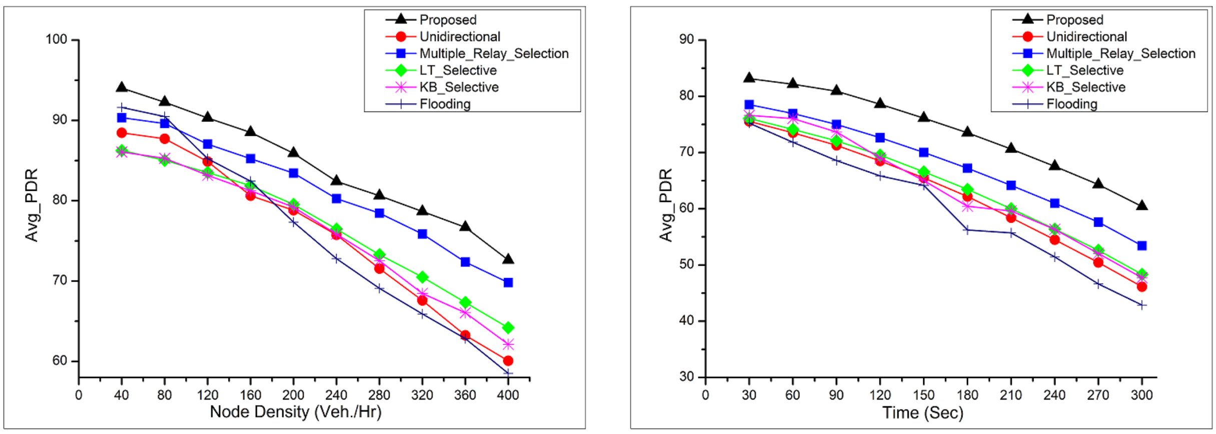

Figure 13. Packet delivery ratio

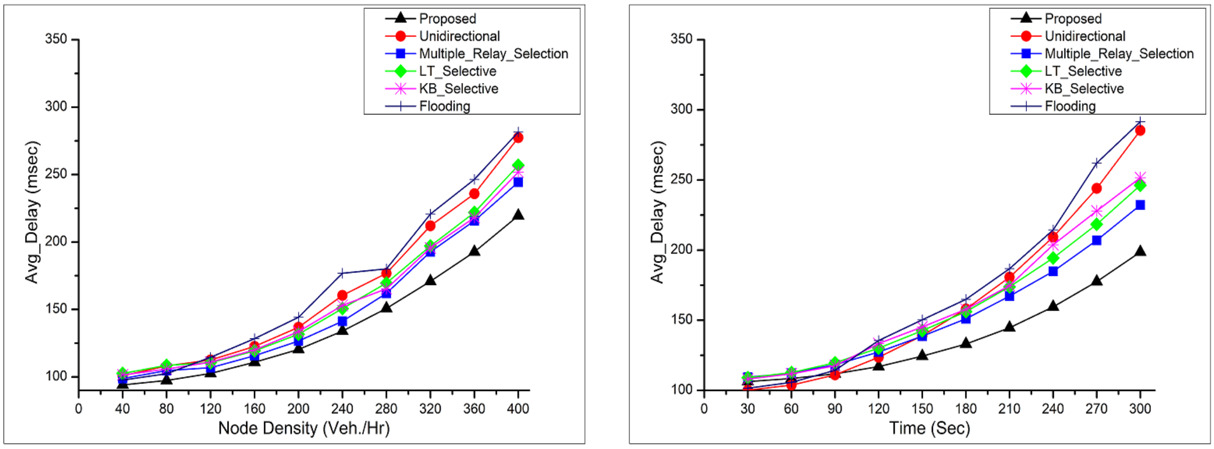

Figure 14. Variance in delay

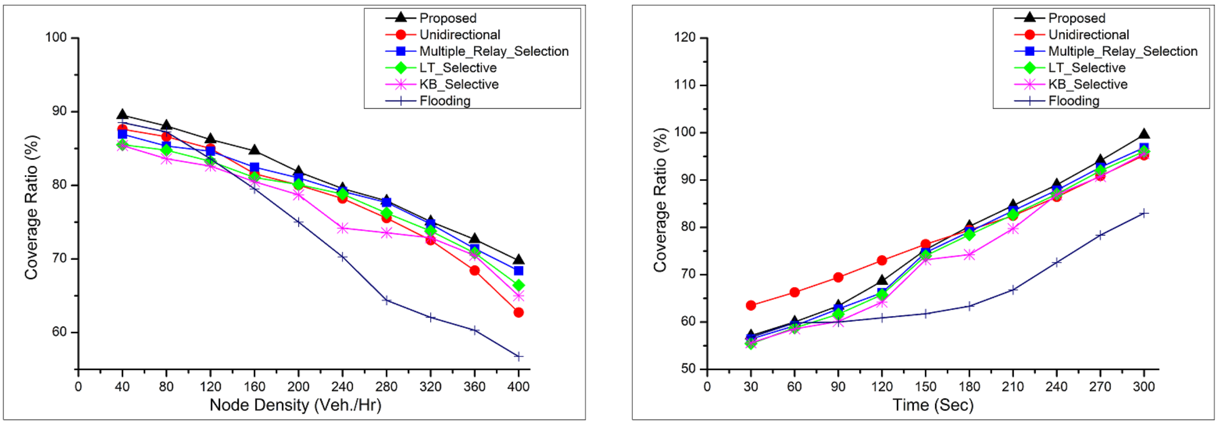

Figure 15. Network coverage

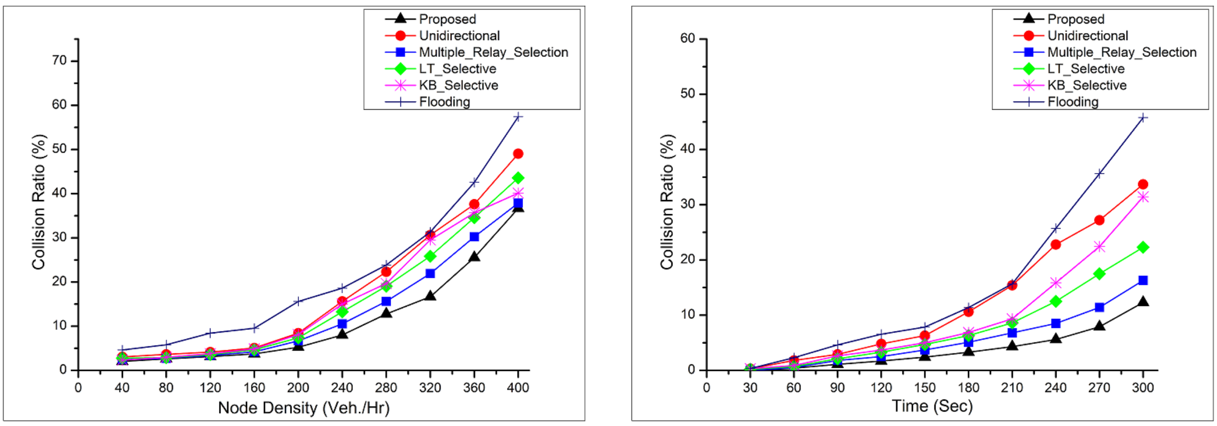

Figure 16. Collision deviation

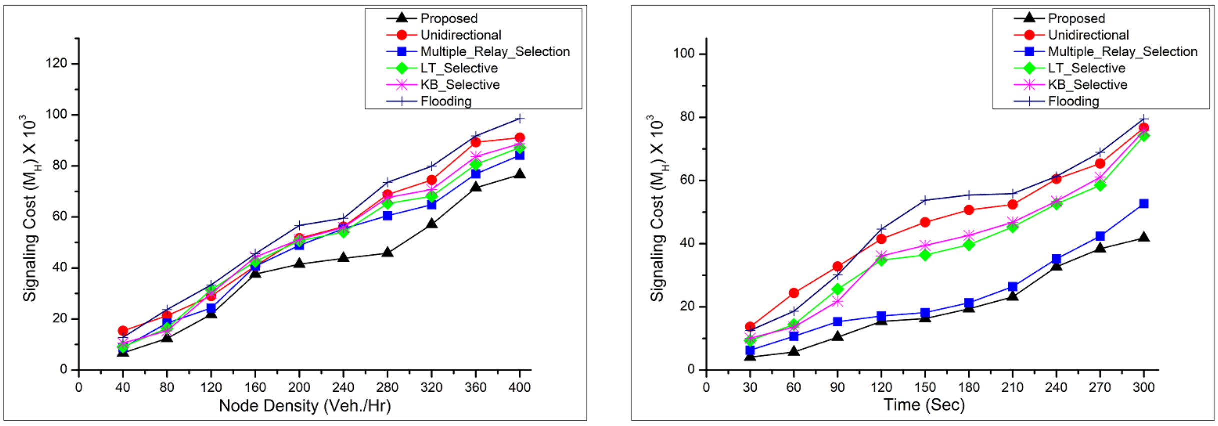

Figure 17. Signaling cost

Further, a comprehensive assessment was conducted to analyze both the likelihood of data collision and the reliability of transmission. This analysis was based on the anticipated impact of V2V link duration, vehicle frequency, and link probability. The outcomes of simulation-based experiments are presented in Figure 18. The simulations effectively modeled the V2V link duration by taking into account the vehicles' mobility patterns, including their position along the X and Y axes (R_S and axis coordinate). When the link duration was longer, it indicated that vehicles remained in close proximity for a considerable period, thereby escalating the probability of data collisions. Consequently, this resulted in reduced transmission reliability during mobility. Conversely, shorter link durations diminished the likelihood of collisions due to the decreased time intervals between data transmissions.

The collision probability was quantified by tallying the number of observed collisions throughout the simulation duration and comparing it against the total number of transmitted packets. Moreover, the efficiency of data transfer was examined by evaluating the number of successfully delivered packets with respect to the link probability. In scenarios characterized by higher vehicle frequencies, where a larger number of vehicles contended for the wireless medium, the probability of data collisions increased. The experiments observed both collision probability and transmission reliability in a dynamic model, considering vehicle density as a key factor, and provided insights into the correlation between the number of vehicles and collision incidents. The link probability was formulated by incorporating the Poisson distribution with the degree D, and the investigation was based on the distribution density of vehicles η, and the distributed vehicle rate D_η. The changes in the wireless channel's quality had a discernible impact on collision occurrences, which were observed in the figure below, illustrating the variation in link probability.

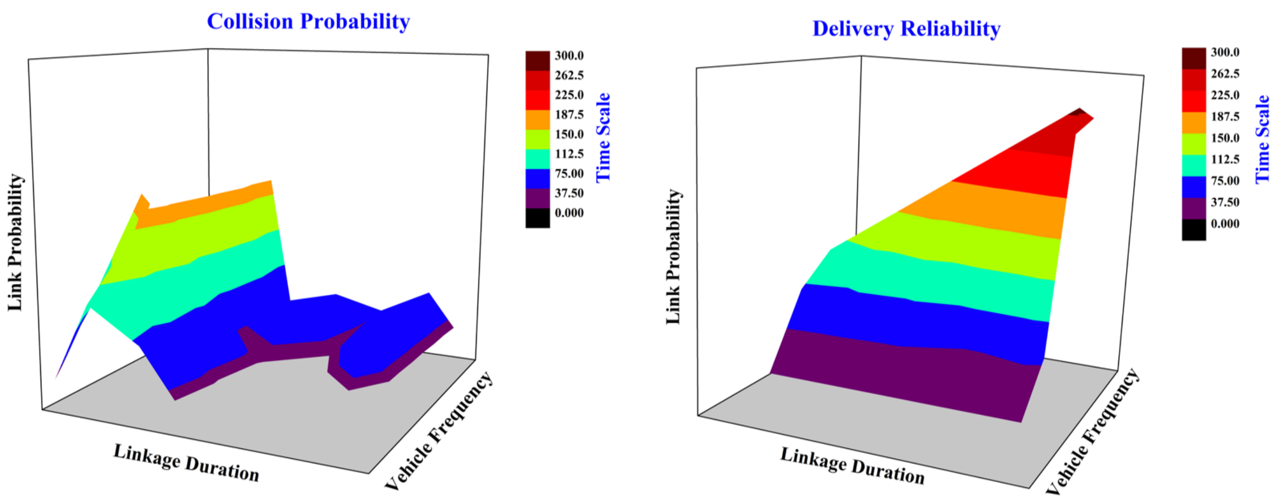

Figure 18. Data collison and reliability projection at linkage probability

Additionally, the efficiency of the proposed work RDVFF in terms of attainable estimation in time and defined node density within VANETs is visually depicted in Figure 19 providing insights into its effectiveness. The plot serves as a representation of the estimated time and the number of vehicles required for various processes or actions within the VANET. Spatial coordinates are assigned to the X and Y axes, while the Z-axis is utilized to illustrate the estimations of time and density. The distinct points on the plot indicate the decision-making process based on metric values and the estimated requirements for specific operations such as data transmission, routing, or decision-making processes. This spatial representation facilitates a comprehensive understanding of the proposed work's efficiency. Furthermore, by incorporating density information into the plot, regions characterized by high or low vehicle density can be visualized, thereby providing valuable insights into the proposed work's efficacy in adapting and managing different density scenarios. Researchers and designers can analyze how the RDVFF work performs under varying traffic conditions, enabling them to make informed decisions about system optimization. The efficacy of RDVFF, when contrasted with the prevailing state-of-the-art techniques in the practical implementation within the designated region, is demonstrated as follows.

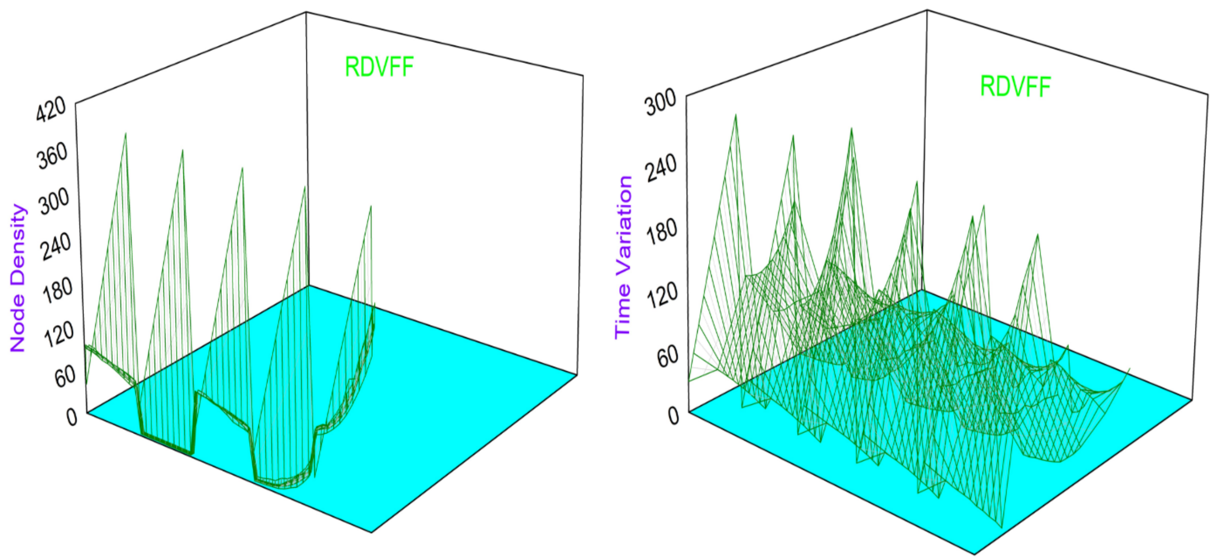

Figure 19. RDVFF Attainable estimation with time and density

4.4 Discussion

Here in this subsection, we present the analysis based on the summarization of key findings in support of the novelty of work and challenges involved in solving the RDVFF along with the comparative study of technologies. We examine the impact that different metrics have on transmission performance and based on their results it is feasible to make a statement that the broadcast storm problem has tremendously subsided and service quality to VANET users in terms of accuracy and timely information has enhanced through the proposed method. The solution to achieve reliability was quite challenging attributable to the variable speeds, frequent disconnection in sparse networks, and maintaining the link stability in dynamic topology. The novelty among these state-of-art represents through designing and implementation of the selection of multiple relay vehicles for information dissemination through the validation of the far-to-farthest zone technique. Further, a flag control suppression mechanism is presented to address broadcast storm and coverage issues. RDVFF includes separate optimization methods for significantly reducing the relay participants and for communication based on a multi-directional multiple-selection scheme to address the latency and link stability challenges in a dynamic and sparse network. We examine the impact that different metrics have on transmission performance and based on their results that shows sufficient improvement in throughput, PDR, collision, and latency on average based on their results it is feasible to make a statement that the broadcast storm problem has tremendously subsided and service quality to VANET users in terms of accuracy and timely information has enhanced through the proposed method. Other ways to improve the effectiveness of real-time vehicular communication systems those must the researcher community needs to be aware of includes task offloading through edge computing systems. Zhang et al. [32], proposed the reduction in delay and energy consumption for IOVs through OBUs by the optimal order scheme to schedule the vehicle tasks for execution or to offload based on directed acyclic graph theory using mobile edge computing. The problem of offloading computation is defined as a constrained multi-objective optimization problem (CMOP) solved by Non-dominated Sorting Genetic Strategy (NSGS). Chen et al. [33], worked on an energy-efficient scheme for IoT users through optimization of the population of quantum behavior particles to offload the perceptional task at intelligent devices and edge servers. Intelligent optimization scheme

NQPSOOM reduces the loss in energy and consumption time leaving from the local optimal outcome and enhancing the diversity in population based on PSO. Wei et al. [34], propose a privacy-aware MADRL approach that supports NE without leaking offloading preferences. PA-MADRL solves the problem despite non-convexity and centralization. This reduces system costs in VANET by optimizing offloading and transmitting power together, all while protecting privacy. Tian et al. [35] suggest using the KMM algorithm to improve user service quality by reducing task response time when task information is known. Selection of the offload server is done by using a two-time selection mechanism and then using the Kuhn Munkras algorithm to make the final decision. GMDC algorithm is applied to adjust the changing traffic dynamics, randomly assigning user vehicles and using a greedy algorithm to select the most appropriate server. Zhang et al. [36] introduce an innovative strategy to address the problem of incomplete data in the context of road network mobility by utilizing tensor mode to capture the speed information of the traffic system. Additionally, a fuzzy neural network is proposed as the learning model to estimate the missing data. The experimental results demonstrate that FNNTEL surpasses other methods in terms of Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD), and Root Mean Square Error (RMSE). Zhang et al. [37] have put forth an innovative solution to address the challenge of limited energy and communication capabilities in sensor nodes by introducing a novel routing approach called the Forward-Aware Factor Energy-Balanced Routing Method (FAF-EBRM). This approach focuses on achieving energy balance by considering the forward-aware factor, which incorporates link weight awareness and forward energy density. In FAF-EBRM, the selection of the next-hop node is guided by this awareness. Additionally, a mechanism for the spontaneous reconstruction of the local topology has been devised. The effectiveness of FAF-EBRM has been evaluated by comparing it to existing protocols such as LEACH and EEUC, using metrics such as Energy-Balanced Factor (EBF), Number of Last-Surviving Nodes (NLN), and Packet Reception Ratio (PRR).

5 Conclusion and Future Work

The method for selecting forwarder nodes in this article considering outside the transmission range of the source vehicle is enhancing reliability and quality of service for information dissemination in vehicle-to-vehicle (V2V) communication. Additionally, the system is selecting two such nodes, each of which is moving oppositely to the other, thereby expanding the coverage area, which is the fundamental requirement for all message classes. It is also deduced from the results, that the proposed method covers most of the applications for crash avoidance safety programs and others by minimizing delay, congestion, and collision. By allowing nodes to participate in relay selection in an optimized way, the approach presented is minimizing the selection overhead and system resource utilization. The simulation's output pattern at different points in time implies that the performance of VANET data dissemination has improved by approximately 18% to 40% for all metrics. This also indicates the improvement in trust, reliability, and quality of the V2V network. Even when the region of interest is dense or the message transmission rate is high, all of the decision factors taken into consideration are performing as expected. With the support of the interpretation of results as mentioned above, it is possible to conclude that the proposed method is quite reliable and robust in dynamic environments, and also more accurate in every way by reducing the broadcast storm. Future work can include greater or fewer highway lanes with a higher transmission range to examine the effectiveness and efficiency of the system with communication methods.

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