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Optimal Relay Selection Strategy for Efficient and Reliable Cluster based Cooperative Multi Hop Transmission in Vehicular Communication

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Abstract:

Routing is the key issue for Vehicular Networks since each node in the network has mobility. Dynamic nature of vehicular networks increases with the mobility and the consequence is reflected over control traffic overhead. As a result, the routing technique and the type of node mobility information are completely dependent on building dependable end-to-end communication links. To address these challenges, a Reliable Cluster based Multi Hop Cooperative Routing (RCCR) strategy was proposed by using velocity, distance and link quality parameters. This algorithm obtains the tradeoff between Quality of Service (QoS) and mobility constraints over link parameters. It improves routing scalability by electing cluster-heads and selecting Multi-Point Relays (MPRs) while considering mobility constraints and QoS needs. The proposed technique determines the link quality for every pair of nodes based on values of signal strength and distance parameters. The relay vehicles are chosen based on the highest possible QoS value, which is calculated to assure route stability, reliability, and durability. The heuristic limitations of the multi-point relay selection strategy are handled by considering the link quality, distance from source vehicle, and cluster-head coverage area to enhance the Packet Delivery Ratio (PDR) of multi-hop network with tolerable End-to-End transmission delay. Further, we optimize and obtained optimal number of cooperative vehicles in every hop with the objective to minimize the end-to-end energy consumption. Finally, simulation results demonstrate the effectiveness of proposed algorithm compared to other state of art algorithms.

Keywords: Optimal Relay Selection, Routing, Quality of Service, Energy Optimization, Cooperative Multi Point Relay.

1. Introduction

For future intelligent road transportation system (ITS) require reliable communication between vehicles, road side units (RSU) and infrastructure. Integrated with Inter of Things (IoT) in vehicular communication has steered to many user friendly applications like parking, accident response and traffic congestion [1]. Based on the aforementioned uses, the increase of present system capacity and incremental expansion of data rates are vitally significant, and are being investigated by third Generation Partnership Project (3GPP) as part of the fifth-generation (5G) standardization effort. Vehicle cooperative wireless [2] is one of the main topics to investigate under 5G, with the goal of reducing the effects of multipath fading and signal deprivation. Similarly, integration of cooperative relaying in vehicular networks (CVN) improve overall performance.

The development and expansion of ITS for future generation vehicular communications has brought few critical challenges with them. First, due to the signal degradation parameters and the key challenging properties of their channels is transmission power increases with propagation distance due to randomly time-varying nature, path-loss, signal fading, delay spread, and angular spread [3 - 4]. Second, during heavy traffic congestion and accidents latency plays a critical role in sending warning signals [5]. In fact, advance vehicular communication requisite high data rate transfers with minimal latency to provide better service to the end users

Furthermore, to enhance the coverage area, the collaboration mechanism between infrastructure and vehicles may be strengthened, resulting in greater road safety and network connection [6]. Implementing full duplex relaying to minimize end-to-end latency and also doubling spectral efficiency by eliminating the self-interference; is one of the primary answers to this demand [7]. However, owing to self-interference at the intermediate vehicles caused by simultaneous transmission and reception over the same channel, which cannot be completely prevented [8 - 9]. Meanwhile, because the intermediate vehicles send and receive in distinct time slots and over different frequency bands in half duplex relaying suffer a spectral efficiency loss. The self-interference mitigation in full-duplex cooperative vehicular communication is addressed in [44].

Most established vehicular communication relay selection and routing methods are based on MANETs which offers the traffic information through device-to-device (D2D), vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications [10-13]. The goal of Dedicated Short Range Communications (DSRC) [14] and multi-hop routing protocols [15] is to develop an effective transmission method for vehicles to exchange the information with one another. However, due to the frequent changes in network topology, packet transmission is challenging. During the routing process, most MANET routing protocols are unable to ensure network topology. For network designers, the increased processing cost of vehicles is essential which caused owing to the control message size utilized for path establishment. The highly dynamic scenario may result in incorrect route selection, shortening the network lifetime and causing connection failures [16-17].

Clustering approach is the most appealing strategies presented to overcome the scalability problem which examines a trade-off between mobility and quality of service constraints to improve network stability [18 - 19]. Optimized Link State Routing (OLSR) [20] is a well-known proactive routing technique that employs a Multi-Point Relays (MPRs) [21] strategy to reduce the number of relay nodes by reducing duplicate transmissions within the same zone. The primary idea behind OLSR is to elect a cluster-head for each set of neighbor vehicular nodes by beaconing control messages. However, in a high-dynamic environment like Vehicular Ad hoc Network (VANETS), this protocol fails to account for node mobility limits, resulting in repeated disconnections, network overhead, and a considerable reduction in network lifespan [22 - 23]. The added control overhead causes a network collision and hence the network resources are degenerative [24 - 25]. To address this issue, various researchers in [26 - 28] focused on QoS restrictions as critical component to improve the capabilities of routing strategies to reduce the effect of the VANET's high dynamic situation. To meet vehicular communication application needs, network resource information should also be evaluated [29 - 30]. Incorporating the capability of clustering in multi-point relay selection method to preserve the network connection and pick swift alternative paths in situations of link failures is a crucial challenge, rather than choosing the neighbor with a high link reachability degree.

OLSR protocol is developed especially for MANETs. It's a refinement of traditional protocols based on link quality to address the needs of wireless mobile users. The vehicles chosen by Multi-Point Relay (MPR) method generate link state information, which is a potential approach for reducing the control packet size. For this, each vehicle uses a simple Cluster Head (CH) to choose a collection of neighbor vehicle known as the multi point relay set. To minimize repeated transmissions within the same zone, each source vehicle broadcasts a control message and "**HELLO"**-Interval on a regular basis. Then the network is divided into clusters to obtain best multi point relay set, as shown in Figure 1. As a result, if an multi point relay scheme specifies symmetric links for their relay vehicles, OLSR delivers the shortest paths to all destinations. A routing table is updated on a regular basis to keep updated routes with a limited number of forwarding neighbor vehicles.

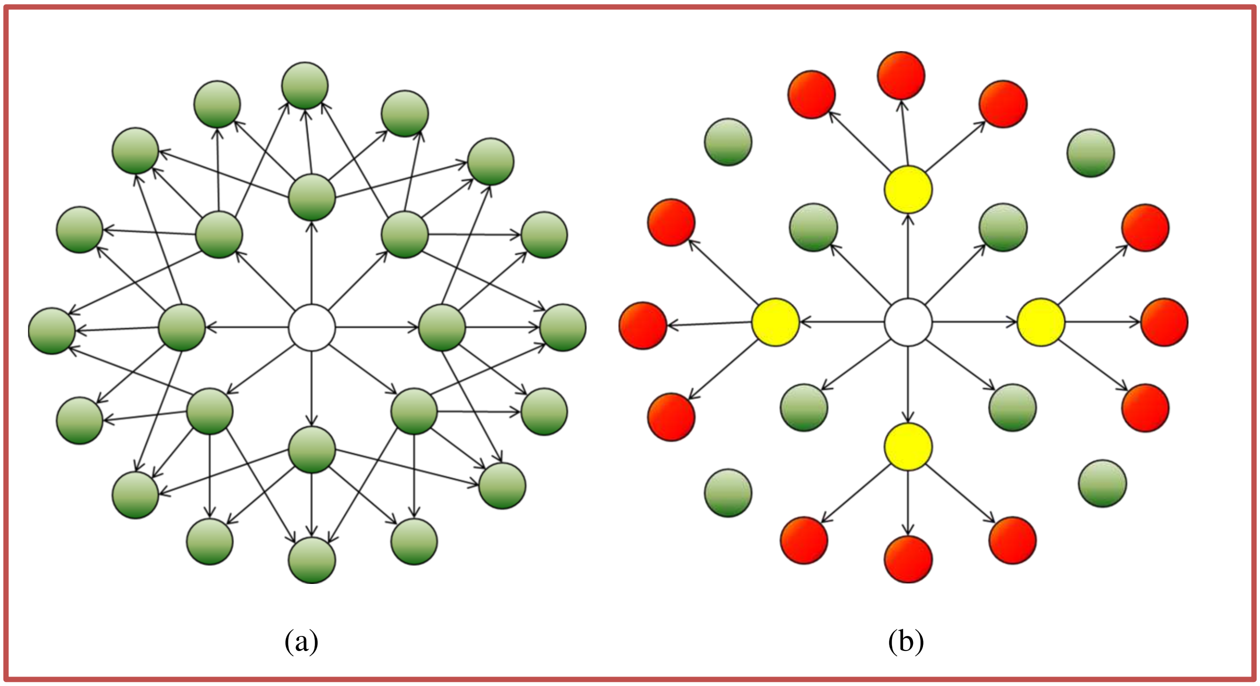

Figure 1: Flooding mechanism (a) without MPR (b) with MPR [31]

When a vehicle gets a "**HELLO"** message from one of its own first hop neighbors, based on link state information it begins to assess the link's quality. Simple information of mobility via one-hop and two-hop neighbors should be included in this data. From these control message vehicles must collect mobility and quality of link information in order to calculate the Candidate Relay (CR) set. In addition, each vehicle degree of willingness should be considered. This approach is used when the link is symmetric to its neighbor where they shelter maximum number of second hop neighbors with highest link reachability. The second-hop vehicles sheltered by MPR will not be taken in to consideration in next iteration. The MPR vehicles repeat this procedure till all the second hop neighbors is covered and thus reducing the number of multi point relay locally. This technique was developed to choose the route with the minimal number of multi point relay and the best connection quality.

Aside from its easy operation, Optimized Link State Routing (OLSR) functionality responds well to constant changes in topology. It creates a reasonable good latency for ad hoc networks with high dynamic environment. This protocol can be readily implemented into Vehicular Ad hoc Network systems due to OLSR characteristics [31-32]. Conversely, the vehicle's mobility and road impediments devise a significant influence on the Optimized Link State Routing operation's efficiency, causing in repeated link failures and a large control message overhead required for maintaining routes correctly. Due to their special form of neighbor location knowledge, the vehicular nodes are unable to swiftly calculate the next hops for data transfers. These constraints restrict the reliability of message delivery by lowering the information about mobility and route selection mechanisms. The goal of this project is to solve the route selection process in order to decrease needless broadcast overhead.

A novel Reliable Cluster-based Cooperative Routing Algorithm (RCCR) for vehicular network is projected in this paper. To improve the energy consumption of the network, we optimize the number of cooperative vehicles. In this method, most effective parameters are evaluated to obtain trade-off between mobility factor and reliable communication. The proposed algorithm improves the scalability of Optimized Link State Routing by considering capacity, link quality, distance and mobility metrics. This algorithm determines the link quality between each pair of nodes based on distance and signal strength. Cluster head and intermediate vehicles are chosen based on highest possible link quality, which is calculated to assure route stability, dependability, and durability. The heuristic constraints of the multi-point relay selection strategy are handled by concentrating on the link quality, distance from the source, and cluster-head coverage area to enhance the multi-hop PDR. Further, we optimize and attain optimal number of cooperative vehicles in each hop with the aim to reducing the end-to-end energy utilization.

The rest of the paper is organized as follows. The review of associated literature work is presented in section 2. Section 3 provides the description of the system model for the vehicular network and our reliable cooperative routing algorithm is presented in section 4. The optimization of energy consumption is described in section 5. The simulation results and analysis are presented in section 6 and finally we concluded our work in section 7.

2. Related Work

To deal with MANET networks, multi-hop relay selection procedures were frequently implemented. However, owing to the unique properties of a highly dynamic network, conventional methods of communication in MANETs cannot be straightforwardly applied to vehicular communication. The key issues are the network overhead, PDR and end-to-end latency. Clustering is one of the methods suggested to operational exploitation of network resources for routing problem in vehicular communication. It is one of the strategies proposed for handling the issue of scalability and quality of service.

The authors of [20] have been proposed Multi-Point Relay (MPR) for Optimized Link State Routing to improve routing scalability by lowering overhead of control topology. The basic notion of MPR operations is to elect cluster-head (CH) which separates each set of neighbor vehicles into clusters, which is based on the premise of an exploratory selection process. Each node generates and maintains a collection of its neighbors based on connection reachability metrics in every hop set in response to incoming control messages. These CHs then choose a group of MPR relay nodes, which are specialized relay nodes. By reducing duplicate transmissions, this technique decreases the overhead of regulating communications within the same zone. When dealing with a high mobility environment, this approach suffers from instability selection.

Authors in [33] reduced the number of intermediate vehicles locally, only after all second hop neighbor vehicles were covered to tackle the challenge of decreasing the number of innate clusters of Multi-Point Relay set. This technique performance is only visible in networks with high density. It also results in resource waste owing to poor selection. Accordingly, authors in [29] devised a Necessity First Algorithm (NFA) for handling relay selection problem, which enhances the Multi-Point Relay selection approach to a degree and introduces high performance. The calculation of the Multi-Point Relay set may take more time and greatly increase overhead. As a result, [25] presented the New Cooperative Algorithm (NCA) to decrease the overhead of control topology by lowering the number of Multi-Point Relay vehicles. This strategy has reduced the number of CHs in the local area by considering the degree of collaboration and connection reachability. To get the smallest set, it separates the nodes into master/slave roles. The Cooperative Communication, NFA, and NCA algorithms, were built for MANETs and only provided mediocre performance in VANETs.

In [34] to choose the best MPRs authors have been assigned weights to individual links. The average latency and bandwidth parameters were taken into consideration while selecting the best MPRs. With minimum control overhead, the performance of OLSR increases exponentially with QoS. This protocol, on the other hand, was created for MANET. In [35], the authors improved routing decisions based on QoS restrictions by proposing Link Defined OLSR (OLSR-LD), which incorporates link quality while selecting MPR sets. In-spite of showing better performance than the standard one, this metric failed in minimizing link failures and packet transmissions. In [36] authors have been described a strategy for lowering network overhead. To improve the relay selection mechanism authors have been considered the link quality, link stability, and vehicle mobility level, which improved routing scalability. The routes that have been identified take the advantage of most crucial information that is exchanged between nodes. The network performance was improved in terms of PDR When selecting relay vehicles, however, the QoS measure was ignored.

Gravitational Search Algorithm-Particle Swarm Optimization (GSA-PSO) was used to offer the capability of detecting signaling mechanisms in [37] to a specified set of nodes as appropriate member nodes. This methodology was used on the MPR-OLSR to decrease control topology overhead and make better use of available bandwidth. In terms of latency, packet losses, channel usage, PDR and throughput, this method has improved routing performance. However, the impact of vehicle mobility was not taken into consideration in their research. For crossroads in VANETs, a Cluster Head Electing in Advance Mechanism (CHEAM) was devised in [38]. In order to evaluate and maintain which vehicle is ideal for a CH, the cluster metric's capabilities were strengthened by considering the mobility and transmission power loss. The link quality was improved, resulting in a steady cluster with minimal overhead, particularly when the number of remote vehicles was reduced.

The authors of [39] introduced a Generalized Optimum Relay Selection (GORS) method for selecting the best relay while keeping the broadcast and cooperation phases secure. Then, using an incremental process, they offer an Adaptive Optimum Relay Selection (AORS) method that delivers and retains security in an adaptive manner. Due to their special form of neighbor location knowledge, the vehicles (nodes) are unable to swiftly calculate the following hops for data transfers. These constraints restrict the reliability of message delivery by lowering the route selection mechanisms and mobility information.

To preserve network stability during communication, the authors suggested Quality of Service Optimized Link State Routing (QoS - OLSR) in [16]. To avoid link failure, they evaluated QoS and mobility limitations. This approach keeps the network stable with lowering the transmission overhead and end-to-end delay. However, they did not taken the complexity of routing required to maintain the other route into consideration. The authors of [40] proposed the Chain -Branch - Leaf (CBL) clustering strategy for constructing a virtual backbone in a VANET. By restricting packet retransmission according to a preset approach, they were able to reduce the size of packet flooding. Over numerous scenarios, Simulation of Urban Mobility (SUMO) developed realistic traffic road layouts that assessed both multi point relay and Chain -Branch - Leaf. The Chain - Branch - Leaf can operate based on location and velocity data without taking into account any possible conjunctions at the CH, which is associated to conventional members. The control burden related to proactive method, especially in VANET circumstances, is the key disadvantage.

To improve the performance of multi-hop cluster vehicular network, best path from source vehicle to destination was obtained in [41] by using close-optimal and optimal intermediate vehicle selection strategy. In this work authors considered instantaneous Signal to Noise Ratio (SNR) for the selection of optimal relay. The optimal path obtained with this approach may not be reliable since nodes in the vehicular network are not stationary.

Authors in [31] have been proposed a Cluster-based ADEPT Cooperative Algorithm (CACA) based on quality of service. This method obtains the tradeoff between quality of service and mobility constraints by evaluating mobility factor and quality of link parameter, and it tries to improve routing scalability by choosing CHs and picking multi point relays while keeping QoS requirements and mobility constraints in mind. The proposed technique determines the link quality for every pair of nodes based on values of signal strength and distance parameters. The relay vehicles are chosen based on the highest possible QoS value

TABLE 1: Features and Challenges of Relay Selection Approaches Vehicular Communication

Paper	**Methodology**	**Features**	**Challenges**
A. Benabbou et all. [25]	NCA	• It reduces the control topology by reducing the number of multi point relay node. • It obtain the minimal set by splitting the nodes based on Master/Slave role.	• It is developed for Mobile Ad hoc Networks and gives moderate performance in vehicular communication.
Z. Li et all. [29]	NFA	• It improves the MPR relay selection schemes	• Computation of MPR set is high
Nori M et all. [31]	CACA	• It consider QoS and mobility factor for MPR relay selection	• Cooperative communication was not

			implemented
K. Yamada et all. [33]	MPR-OLSR	• It reduce topology control message. • Enhance scalability of routing. • Reduce the number of relays in MPR set	• Achieve better results in dense networks.
H. Badis et all. [34]	QOLSR	• It choose the optimal MPRs by assigning weights to individual links.	• It is developed for Mobile Ad hoc Networks and gives moderate performance in vehicular communication.
R. Jain et all. [35]	OLSR-LD	• It enhances routing decision based on QoS constraint	• QoS metric consideration failed in minimizing link failures in Vehicular communication.
S. Dahmane et all. [36]	P-GPSR	• It considers link stability and node mobility for relay selection mechanism.	• QoS was neglected.
SajadPoursajadi et all. [39]	GORS and AORS	• In GORS, optimal relay is selected based on privacy capacities. • Further they developed incremental version of GORS called as AORS with respect to existence of the direct link and the availability of CSI.	• It unable to swiftly calculate the next hops.
M. Z. Alam et all. [41]	Coop V2V	• It uses instantaneous signal to noise ratio for optimal relay selection.	• Effect of mobility was neglected.

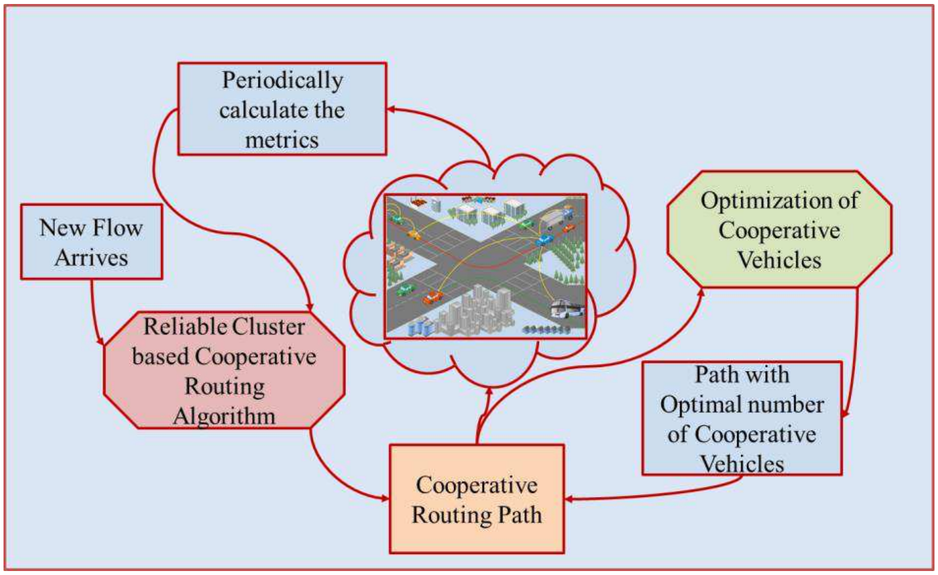

Figure 2: Solution Framework

Numerous clustering algorithms were developed to address the OLSR protocol's scalability to reduce routing cost in a dynamic network. The goal of our proposal is to apply a clustering technique to choose the best multipoint relay in terms of link quality. Further an optimization mechanism is incorporated in each hop to obtained optimal number of cooperative vehicles with an objective to reduce the end-to-end energy consumption.

The frame work of the proposed approach is illustrated in figure 2. The goal of our proposal is to minimize the cluster heads to further achieve minimum network overhead and maximum cluster heads in order to achieve the lowest network overhead and the maximum PDR possible. An optimization mechanism is implemented in each hop and optimal number of cooperative vehicles is obtained with an intention to reduce the end-to-end energy consumption.

3. System Model

The system model of the downlink cooperative vehicular network with NOMA is shown in Figure 3, where certain intermediary vehicular nodes are used in this context to enhance communications between source and destination vehicles by decoding the source messages and re-transmitting towards destination vehicle. Every node, including the source (v_s), K intermediate vehicles $(v_1, v_2, ... v_K)$, and destination (v_d), is equipped with single antenna. In full-duplex mode, each node simultaneously transmit and receive data to prevent spectral efficiency loss. Further, we assumed that the channel is accurately known, as the estimation technique is out of the scope of this research. Furthermore we assumed that the channel between each transmitter node $p \in \{v_s, v_k\}$ and receiver node $q \in \{v_k, v_d\}$, for $k = 1, 2, ..., K$, i.e., h_{pq}, is observed as the quasi-static flat fading with Rayleigh distribution of zero mean and variance σ_{pq}^2.

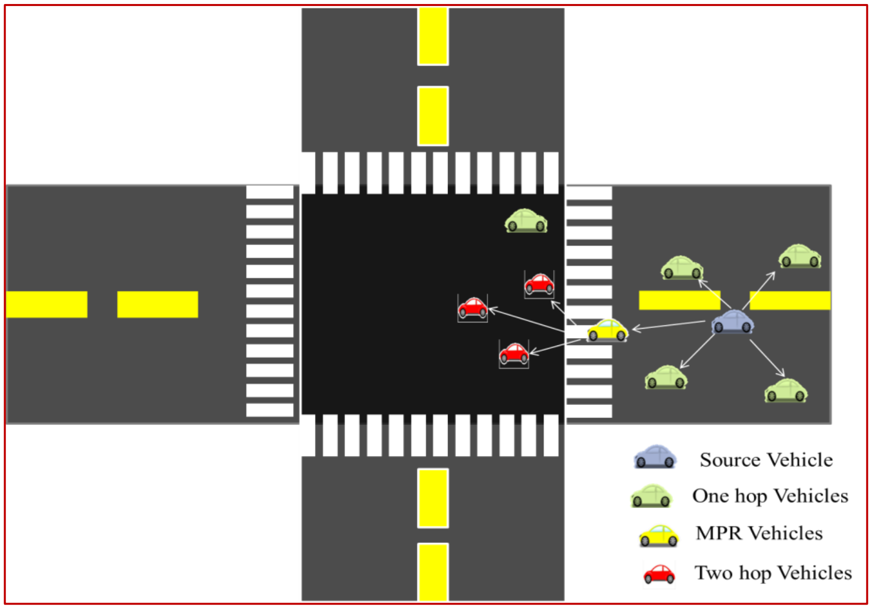

Figure 3: System model of Vehicular Networks

As per system model, NOMA is considered with two-way DF relaying protocol. It is assumed that *S*, *r*, and *D* uses similar transmit power (P). The signal received at Candidate Relay (*CR*) set nodes from source and destination vehicle is expressed as:

$$y_{v_d,v_s} = \sqrt{P} h_{v_s,v_d} \bar{x} + \eta_{v_d} \tag{1}$$

$$y_{v_k} = \sqrt{P} h_{v_s,v_k} \bar{x}_1 + \sqrt{P} h_{v_d,v_k} \bar{x}_2 + \eta_{v_k} \quad k = 1, 2, \ldots\ldots, K \tag{2}$$

In cooperative phase, the relay node broadcasts the signal $\bar{x}$ with transmission power P, the received signals at v_d can be depicted as

$$y_{v_d,v_k} = \sqrt{P} h_{v_k,v_d} \bar{x} + \eta'_{v_d} \tag{3}$$

At the destination node, Maximum Ratio Combining (MRC) strategy is used to combine the encoded information from various paths to obtain the information with minimal probability of error.

4. Reliable Cluster Based Cooperative Routing Algorithm

In this section, Reliable Cluster based Cooperative Routing (RCCR) algorithm for vehicular network is presented. This routing strategy improves the scalability of Optimized Link State Routing (OLSR) by considering capacity, link quality, distance and mobility metrics.

4.1 Cluster Formation and Cluster Head Selection

The shortest path method of the OLSR routing protocols used in [33], [29], and [25] are developed to decrease the number of multi point relay along with the control messages size. These heuristics don't always deliver the best option since they ignore other routes with the same hop path length and reachability of link. Those routes may be superior in terms of end-to-end latency, PDR, and network overhead in many circumstances. One of our goals is to prioritize the ideal path by selecting as many one-hop neighbors as possible.

To avoid repeated transmissions within the same zone, each source node emits a beacon signal and control messages on a regular basis. A routing table is updated on a regular basis to keep paths with a limited number of forwarding neighbor vehicles up to date. The quality of the path is analyzed when a vehicle receives a beacon message from its own one hop neighbor's vehicles, by taking into account metrics like bandwidth, connection, speed, and distance. The bandwidth parameter is taken into consideration to provide dependability, the connection factor is considered to ensure a larger coverage region; and speed and distance are taken into account to ensure route stability. Let v_s be a network source node and v_k be a two hop vehicle. The metric values are assigned to the link between $(v_s;v_k)$: dis_{v_s,v_k} is the distance between v_s and v_k, and WF_{v_s,v_k} is the cooperative weighting factor of both v_s and v_k. The capacity available between v_s and v_k is denoted by C_{v_s,v_k}. The link quality for v_s is $LQ(v_s)$, and the representation to the source vehicle neighbors is $N(v_s)$.

WF_{v_s,v_k} is proportional to the distance and inverse of mobility factor. The proportionality constant is the ratio between the *CR* of v_k to the total CR. WF_{v_s,v_k} can be given as shown in the equation below:

$$WF_{v_s,v_k} = \left(\frac{CR_{v_k}}{CR_v + CR_{v_k}} \right) \times \left(\frac{dis_{v,v_k}}{MF} \right) \tag{4}$$

The source node will compute WF_{v_s,v_k} using periodic beacon signals and the distance between two vehicles as indicated by Equ. (5) provided by [42].

$$dis_{v_s,v_k} = \lambda \left(\frac{\phi}{4\pi} - \frac{B}{2} \right) \tag{5}$$

Where, λ is a wavelength of the carrier. ϕ is a complete phase obtained from signals which are communicated with fixed carrier frequency and B is an integer.

In proposed work, low speed moving vehicles are best suited as CR vehicle to rebroadcasting the information. Equation (6) shows the mobility factor average value which depends on the speed of one's own vehicle(v). The computation of the following hop takes precedence in this equation.

$$MF_{v_s,v_k} = \frac{V_r - V_{\min}}{V_{\max} - V_{\min}} \tag{6}$$

where V_r depicts the speed of the receiver vehicle. $V_{\min}$ and $V_{\max}$ are the minimum and maximum speed of the vehicle, respectively.

The product of capacity and weighting factor $\left(WF_{v_s,v_k}\right)$ is used to determine the route quality. This is because, in the case of a high mobility factor, the MF_{v_s,v_k} will be low and resulting in a smaller value of LQ_{v_s,v_k}, as shown in Equation (7). If the denominator value MF_{v_s,v_k} is small, the WF_{v_s,v_k} produced by Equation 1 is large, resulting in a larger LQ_{v_s,v_k}.

$$LQ_{v_s,v_k} = C_{v_s,v_k} \times WF_{v_s,v_k} \tag{7}$$

In general, the new MPR selection algorithm prioritises vehicle nodes (v_k) with a greater number of multi point relay linkages to become an multi point relay of v. As a result, LQ_{v_s,v_k} selects the vehicle v_k with the highest multi point relay linkages while keeping the number of multi point relay in v_s low.

Our approach picks the source vehicle's CR set based on the LQ_{v,v_k} parameter; the algorithm selects the vehicles in v_k with the greatest LQ_{v,v_k} without repetition. Other vehicles in the CR set help the source vehicle to forward the information towards *MPR vehicle* which are called as *Candidate Relay* vehicle.

Algorithm Reliable Cluster Based Cooperative Routing

Input: A new flow request from source vehicle to destination
Output: Multi hop Cooperative routing path from source vehicle to destination
1: **While** $v_d \notin V_s(v)$ **do**
2: Find $V_s(s)$
3: Source vehicle v_s calculates the LQ_{v_s} of all the vehicles in $V_s(s)$
4: Forms the cluster based on LQ_{v_s}
5: selects the vehicle v_k with high LQ_{v_s} as CR
6: k^{th} hop CR vehicle will act as source vehicle for $(k+1)^{th}$ hop
7: **end**

5. Energy Consumption Analysis and Optimization

A cooperative Multi Input Single Output (MISO) transmission method with energy consumption model for a single hop is presented in this section. We calculated the ideal number of cooperative nodes using this approach. After obtaining the route information between source and destination vehicles, in each hop data will be transmitted in two phases i.e., broadcast phase and cooperative phase.

Broadcast Phase:

In first phase, data is disseminated to all n nodes in the cluster, where n can be obtained by

$$n = \frac{\pi r^2 V}{A} \mathbf{Pr}\left(LQ_{v_s}\right) \tag{8}$$

Where $\mathbf{Pr}\left(LQ_{v_s}\right)$ is the probability that the number of vehicles having Link quality LQ_{v_s,v_k} greater than the threshold and A is the considered road area.

For M-QAM modulation, the average energy use may be represented as [43]:

$$E_{ph1}=\frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\overline{E}_{avg,ph1}r^2+{\left(P_{Tx}+nP_{Rx}\right)}\Big/{b\cdot BW} \tag{9}$$

Where $\chi=3\frac{2^{b/2}-1}{2^{b/2}+1}$, b is the bitrate, BW is the Bandwidth, G_{Tx} and G_{Rx} are the transmitter and receiver gains respectively, M_l is the link margin, carrier wavelength is denoted by λ , N_f Noise figure, l path loss exponent, P_{Tx} , P_{Rx} are the transmitter and receiver circuit power respectively, $\overline{E}_{avg,ph1}$ is the average received energy per bit during broadcast phase.

Cooperative Phase:

In this phase, n nodes consist of $n-1$ intermediate vehicles and one source vehicle re-transmit the data to the candidate relay. The average energy consumption in cooperative phase can be obtained by

$$E_{ph2}=\frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\overline{E}_{avg,ph2}d_{\mathbf{max}}^2+{\left(nP_{Tx}+P_{Rx}\right)}\Big/{b\cdot BW} \tag{10}$$

The upper bound of $\overline{E}_{avg,ph2}$ can be obtained by applying the Chernoff bound (11), expressed as:

$$\overline{E}_{avg,ph2}\le\frac{2\left(2^b-1\right)N_0 n}{3b}\left(\frac{4}{bP_e}\right)^{1/n} \tag{11}$$

and $\overline{E}_{avg,ph1}$ can be obtained according to (11) by substituting $n=1$

The average energy consumption per bit for every hop $\left(E_{hop}\right)$ can be obtained by summing the average energy consumption in two phases i.e., $E_{hop}=E_{ph1}+E_{ph2}$

$$E_{hop}=\frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\overline{E}_{avg,ph1}r^2+{\left(P_{Tx}+nP_{Rx}\right)}\Big/{b\cdot BW}+\frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\overline{E}_{avg,ph2}r^2+{\left(nP_{Tx}+P_{Rx}\right)}\Big/{b\cdot BW} \tag{12}$$

By approximating the bound (11) as equality, analytical expression for the average energy consumption per bit for a hop can be expressed as:

$$=\frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\left[\frac{2\left(2^b-1\right)N_0}{3b}\left(\frac{4}{bP_e}\right)r^2+\frac{2\left(2^b-1\right)N_0 n}{3b}\left(\frac{4}{bP_e}\right)^{1/n}d_{\mathbf{max}}^2\right]+\left(\frac{P_{Tx}+P_{Rx}}{b\cdot BW}\right)(n+1) \tag{13}$$

$$=\frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\frac{2\left(2^b-1\right)N_0}{3b}\left[\left(\frac{4}{bP_e}\right)r^2+n\left(\frac{4}{bP_e}\right)^{1/n}d_{\mathbf{max}}^2\right]+\left(\frac{P_{Tx}+P_{Rx}}{b\cdot BW}\right)(n+1) \tag{14}$$

From equation (8), maximum distance from source vehicle to the cluster vehicles is $r^2 = \frac{An}{\pi V \,\mathbf{Pr}\left(LQ_{v_s}\right)}$. The energy consumption per bit can be written as

$$E_{hop} = \frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\frac{2\left(2^b-1\right)N_0}{3b}\left[\left(\frac{4}{bP_e}\right)\frac{An}{\pi V\,\mathbf{Pr}\left(LQ_{v_s}\right)} + n\left(\frac{4}{bP_e}\right)^{1/n} d_{\mathbf{max}}^2\right] + \left(\frac{P_{Tx}+P_{Rx}}{b\cdot BW}\right)(n+1) \qquad (15)$$

Therefore the analytical expression for energy consumption per bit for a hop is

$$E_{hop} = Q_0 n\left[Q_e\frac{A}{\pi V\,\mathbf{Pr}\left(LQ_{v_s}\right)} + \left(Q_e\right)^{1/n} d_{\mathbf{max}}^2\right] + \left(Q_p\right)(n+1) \qquad (16)$$

Where $Q_0 = \frac{\chi}{\eta}\frac{(4\pi)^l M_l N_f}{G_{Tx}G_{Rx}\lambda^2}\frac{2\left(2^b-1\right)N_0}{3b}$, $Q_e = \frac{4}{bP_e}$ and $Q_p = \frac{P_{Tx}+P_{Rx}}{b\cdot BW}$.

According to the proposed algorithm, CH should be in the transmission coverage region of source vehicle. Hence the distance among the two CHs $d_{\mathbf{max}} \le r$, so we have average number of nodes $n \le \frac{\pi d_{\mathbf{max}}^2 V}{A}\mathbf{Pr}\left(LQ_{v_s}\right)$. When $d_{\mathbf{max}}^2 \ge \frac{An}{\pi V\,\mathbf{Pr}\left(LQ_{v_s}\right)}$ we can evaluate optimal n for the optimization problem given in equation (17), otherwise $n=1$.

$$\min_n E_{hop}\; s.t. 2 \le n \le \frac{\pi d_{\max}^2 V}{A}\Pr\left(LQ_{v_s}\right) \qquad (17)$$

By performing the derivative for E_{hop} with respect to n, E_{hop} is a convex function with n when n is positive integer.

$$\left[\frac{Q_p}{Q_b} + \frac{Q_e A}{\pi V\Pr\left(LQ_{v_s}\right)}\right]n = d_{\max}^2\left(Q_e\right)^{1/n}\left(\log\left(Q_e\right)-n\right) \qquad (18)$$

Since the parameters in above equation (18) are all positive, n should be minor than $\log\left(Q_e\right)$. Let $Q_{\min} = \min\left(\log Q_p, \frac{\pi d_{\max}^2 V}{A}\Pr\left(LQ_{v_s}\right)\right)$ and n' be the real solution of (18). The approximate optimal number of intermediate vehicles can be obtained as

$$n_0 = \begin{cases} \lfloor n' \rfloor & 2 \le n' \le Q_{\mathbf{min}} \\ \lfloor Q_{\mathbf{min}} \rfloor & n' > Q_{\mathbf{min}} \\ 2 & n' < 2 \end{cases} \qquad (19)$$

6. Simulation Results:

This section compares and contrasts the experimental findings acquired with existing approaches to demonstrate the practicality of our proposed method. The parameters used in the simulation of proposed algorithm are listed in Table 1. For the simulation, 60 vehicles are distributed randomly and moving at a steady speed of 15 m/s in various directions. The data packets of 512 bytes with stable bit rate generated by a traffic generator are used to exchange information between vehicles.

TABLE 2: Simulation Parameters

Notation	Parameter	Quantity
	Area of the Network	1400m x 1200m
P	Transmit Power	1mW
BW	Band Width	22MHz
M_l	Link Margin	40dB
N_0	Noise power spectral density	-171dBm/Hz
N_f	Noise figure	10dB
G_{Tx}, G_{Rx}	Transmitter and receiver gain	5dB
P_{Tx}	Transmission circuit power consumption	97.8mW
P_{Rx}	Receiver circuit power consumption	119.8mW
	Combining Strategy	MRC
P_e	Target BER	10^{-3}
V_r	Vehicle speed	2.7 – 30m/s
	Transmission range	250m
	MAC protocol	IEEE 802.11

6.1 Impact of Traffic density

To investigate how the traffic density impacts the network performance, we differ the number of vehicles from 30 to 120 in the network. The number of possible vehicles for cooperative relay vehicles grows as the number of nodes increases. As a result, the aggregate throughput increases for all routing systems, as illustrated in Figure 4.

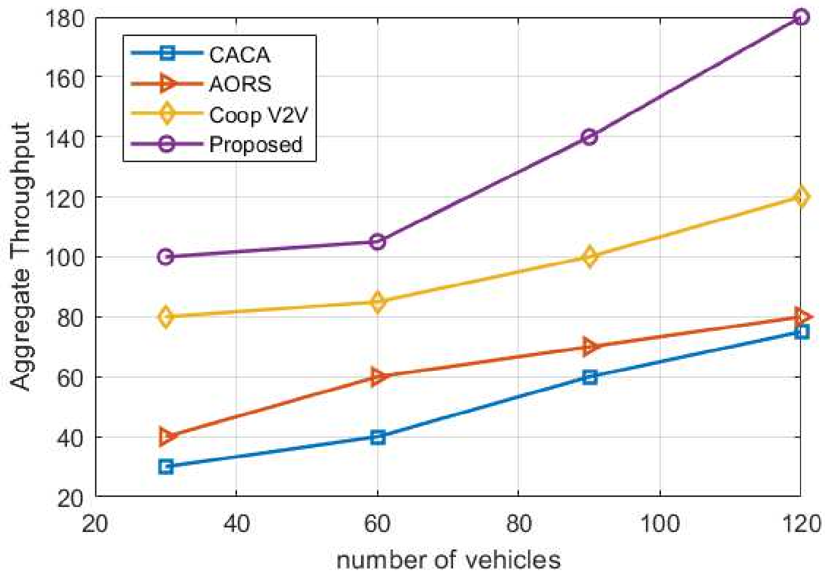

Figure 4: Impact of traffic density on Network throughput performance

Among all the routing algorithms, the aggregate throughput increases with number of vehicles under our proposed approach. With well-designed algorithm for path selection and relay selection, our approach can more effectively exploit the resources of cooperative vehicles to achieve high cooperative gain when the number of vehicles is large. At traffic density 120, compared with the CACA [31], AORS [39], and Coop V2V [41] approaches, our approach improves the aggregate throughput of the network by 240%, 225% and 150% respectively.

6.2 Impact of communication range

To analyze the influence of communication range on network performance, aggregate throughput of the network is evaluated by varying communication range from 250m to 450m by assuming other parameters as listed in table 2.

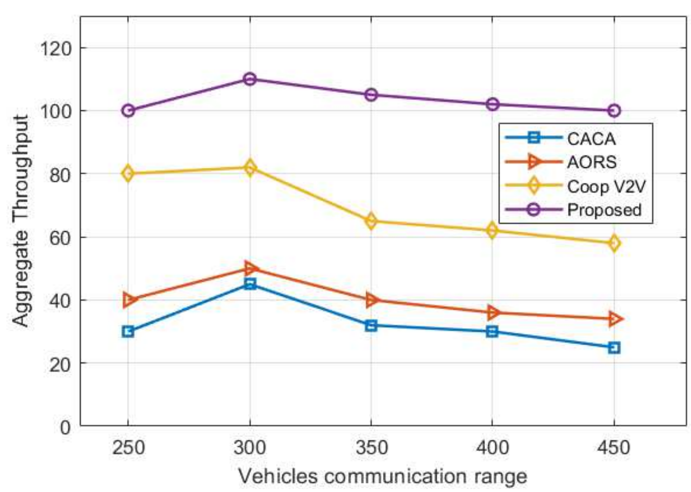

Figure 5: Impact of communication range on network throughput performance

As shown in Fig. 5, initially, the aggregate network throughput improves as the transmission range grows, but decreases as the node's transmission range increases further until it reaches a high value and remains the same until the transmission range reaches a large value. The reasons behind can be depicted as; on the one hand, increasing the communication range and therefore the number of network links allows for additional options in terms of higher capacity routes with better cooperative vehicles and MPR (CH) vehicle. The first boost in transmission range also aids network connection and the discovery of a better transmission channel. On the other side, it raises interference and, as a result, affects routing performance. As a result, using too much transition power is counterproductive. Extending the communication range for more relays comes at the expense of diminishing the interference range.

When the transmission range is more than 400m, all nodes are considered inside the transmission range and in the interference range of other nodes, since all 60 nodes are randomly positioned within the limited region of 1420m*1200m. As a result, when the transmission range is increased from 400 to 450, the performance of all routing systems remains the same. The impact of node density and vehicle communication range on aggregate throughput fig 4 and Fig 5 are tabulated in Table 3 and Table 4 respectively.

TABLE 3: Impact of traffic density on Network throughput performance

Node Density	**Aggregate Throughput**			
	CACA [31]	**AORS [39]**	**Coop V2V [41]**	**RCCR (proposed)**
30	30	40	80	100
60	40	60	85	105
90	60	70	100	140
120	75	80	120	180

TABLE 4: Impact of communication range on network throughput performance

Communication Range	**Aggregate Throughput**			
	CACA [31]	**AORS [39]**	**Coop V2V [41]**	**RCCR (proposed)**
250	30	40	80	100
300	45	50	82	110
350	32	40	65	105
400	30	36	62	102
450	25	34	58	100

Along with the effect of number of nodes and communication range, the throughput of the network is evaluated by varying the Signal to Noise Ratio (SNR). Fig 6 depicts the simulation result of the throughput with respect to the SNR. It can be depicted from the simulation results that, the proposed algorithm gives the better performance than CACA [31], AORS [39], and Coop V2V [41]. This is because; our technique can more effectively leverage the resources of cooperative vehicles in each hop to achieve significant cooperative gain when the number of vehicles are large.

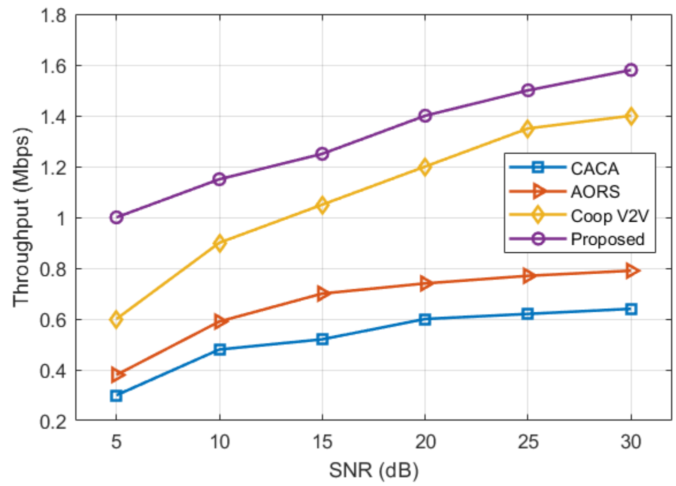

Figure 6: Throughput Vs SNR

Figure 7 depicts the network lifetime as a function of number of vehicles. If a larger number of nodes are put in the network region, the energy consumption of a specific vehicle is reduced, extending the network's lifetime. When compared to the CACA [31], AORS [39], and Coop V2V [41], the suggested RCCR achieves the highest network lifetime, as shown in the figure 7.

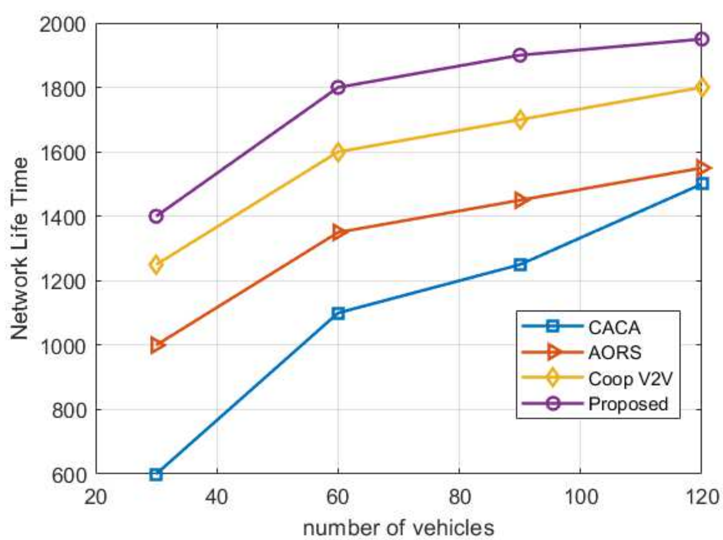

Figure 7: Network life time as a function number of vehicles

6.3 Packet Delivery Ratio (PDR)

When compared to the traditional CACA [31], AORS [39], and Coop V2V [41] protocols, Figure 8 reveals that the proposed algorithm (RCCR) has a superior PDR based on the link quality metric. Compared to clustering in cooperative methods, our algorithm's weighted link characteristics was utilized to pick the set of multi point relay with low collision probability, less mobility, and broad bandwidth path. This leads to the cluster head being selected as the best vehicle in its communication region and cooperative vehicles. MPRs are utilized as a link quality parameter to connect CHs to increase network connection and maximize network performance, specifically in high density scenarios. The effect of node density on network life time (Fig. 7) and Packet Delivery Ratio (Fig. 8) are tabulated in table 5.

TABLE 5: Impact of Node Density on Network Life Time and Packet Delivery Ratio

Communication Range	network life time				packet delivery ratio			
	CACA [31]	AORS [39]	Coop V2V [41]	RCCR (proposed)	CACA [31]	AORS [39]	Coop V2V [41]	RCCR (proposed)
30	600	1000	1250	1400	10	20	25	40
60	1100	1350	1600	1800	25	42	40	60
90	1250	1450	1700	1900	35	52	50	76
120	1500	1550	1800	1950	50	65	60	88

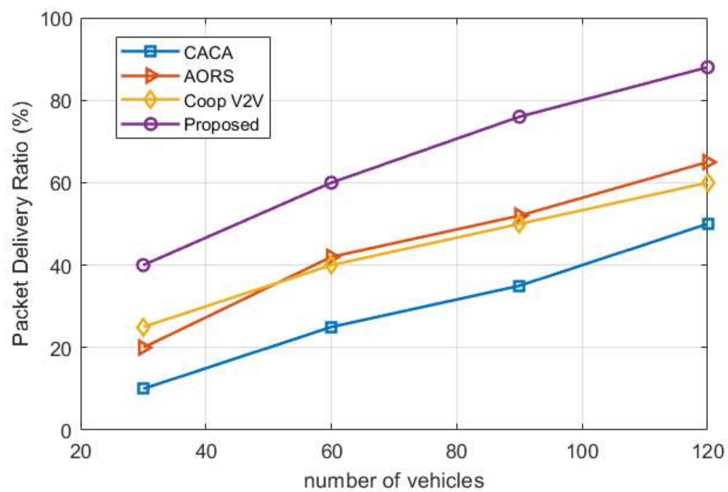

Figure 8: Packet Delivery Ratio (PDR) Vs Number of Vehicles

Figure 9 shows end-to-end energy usage for various routing systems for different number of vehicles and tabulated in table 6. The energy consumption of the route will decrease as we find the optimal number of cooperative nodes in each hop. With higher node density, our approach requires fewer hops, and energy consumption is reduced by 48.8% when compared to AORS routing techniques at vehicle density 120.

TABLE 6: Impact of traffic density on End-to-End Energy Consumption

Node Density	End-to-End Energy Consumption (J)				
	CACA [31]	AORS [39]	Coop V2V [41]	RCCR (proposed)	Optimized RCCR
30	20.5	20	18	11	11.1
60	22	24	22	15	14
90	28	35	25	19	17.5
120	35	42	30	23	20.5

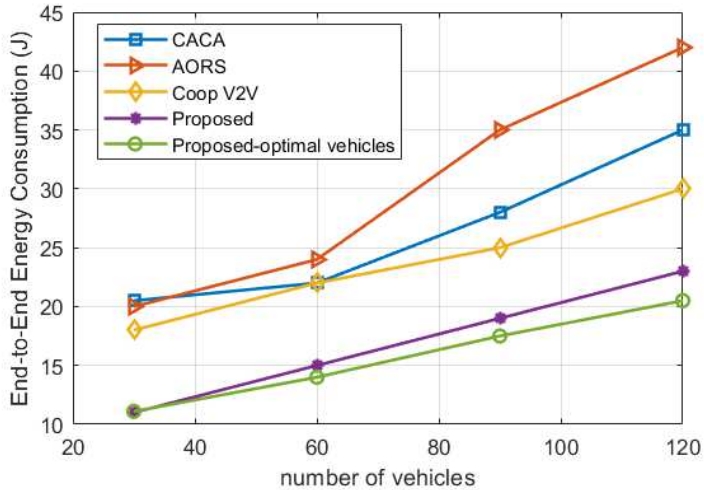

Figure 9: End-to-End Energy Consumption

7. Conclusion:

An efficient Reliable Cluster based Cooperative Routing (RCCR) algorithm was presented in this paper. This algorithm has been introduced to resolve a trade-off between mobility constraints and QoS requirements, and to improve routing scalability based on link quality metric which is used to select the cluster head and cooperative vehicles. For reliable communication, cluster head and cooperative vehicles are selected based on mobility factor and distance metrics. In each hop, optimization mechanisms are incorporated and obtained an optimal number of cooperative vehicles with the objective to reduce the end-to-end energy consumption. The simulation results validated the efficiency of our suggested method, particularly in terms of aggregate throughput, network life time, packet delivery and end-to-end energy consumption.

Appendix: On derivation of equation (18)

The analytical expression for energy consumption per bit for a hop is

$$E_{hop} = Q_0 n\left[Q_e \frac{A}{\pi V\,\mathbf{Pr}\left(LQ_{v_s}\right)} + \left(Q_e\right)^{1/n} d_{\mathbf{max}}^2\right] + \left(Q_p\right)(n+1)$$

To get the minimum/critical value of E_{hop}, differentiate above equation w.r.t. n and equate to zero.

$$\frac{dE_{hop}}{dx} = 0$$

$$\frac{Q_0 Q_e A}{\pi V\,\mathbf{Pr}\left(LQ_{v_s}\right)} + Q_0 d_{\mathbf{max}}^2\left[n\left(Q_e\right)^{1/n}\mathbf{log}\left(Q_e\right)\left(\frac{-1}{n^2}\right) + \left(Q_e\right)^{1/n}\right] + Q_p = 0$$

$$\frac{Q_0 Q_e A}{\pi V\,\mathbf{Pr}\left(LQ_{v_s}\right)} + Q_0 d_{\mathbf{max}}^2\left(Q_e\right)^{1/n}\left[1 - \frac{\mathbf{log}\left(Q_e\right)}{n}\right] + Q_p = 0$$

$$\left(\frac{Q_p}{Q_0}+\frac{Q_e A}{\pi V\,\mathbf{Pr}\left(LQ_{v_s}\right)}\right)n+d_{\mathbf{max}}^2\left(Q_e\right)^{1/n}\left[n-\mathbf{log}\left(Q_e\right)\right]=0$$

$$\left[\frac{Q_p}{Q_b}+\frac{Q_e A}{\pi V\,\mathrm{Pr}\left(LQ_{v_s}\right)}\right]n=d_{\max}^2\left(Q_e\right)^{1/n}\left(\log\left(Q_e\right)-n\right)$$

Declarations

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Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

Data Availability

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Code Availability

Software Code for the current study is available from the corresponding author on reasonable request.

Author Contributions

The paper conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing-original draft preparation, writing-review editing and visualization, have been done by **Sravani Potula**. The supervision and project administration have been done by **Sreenivasa Rao Ijjada**

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