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Clustering-based reliable low-latency routing scheme using ACO method for vehicular networks

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ABSTRACT

In vehicular ad hoc networks (VANETs), communication links break frequently due to the high velocity vehicles. In this paper, based on the existing ad hoc on-demand multipath distance vector (AOMDV) routing scheme, a new clustering-based reliable low-latency multipath routing (CRLLR) scheme is proposed by employing Ant Colony Optimization (ACO) technique. Herein the link reliability is used as criteria for Cluster Head (CH) selection. In a given cluster, a vehicle will be selected as CH if it has maximum link reliability. Moreover, the ACO technique is employed to efficiently compute the optimal routes among the communicating vehicles for VANETs in terms of four QoS metrics, reliability, end-to-end latency, throughput and energy consumption. Simulation results demonstrate that the proposed scheme outperforms the AQRV and T-AOMDV in term of overall latency and reliability at the expenses of slightly higher energy consumption.

1. Introduction

VEHICULAR ad hoc networks (VANETs) objective to disseminate safety information between vehicles to advance road safety and prevent accidents. VANETs are a distinct form of mobile ad hoc networks (MANETs), where vehicles are equipped with wireless communication facility on-board-unit (OBU) to provide ad hoc connectivity [1]. It has many different types such as vehicle-to-sensor, vehicle-to-Internet, vehicle-to-vehicle and vehicle-to-road infrastructure [2]. Communication is a significant research theme in VANETs. The main purpose of VANETs technology to support safety and non-safety related applications by using vehicle-to-everything (V2X), vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) between vehicles.

VANETs have many challenges due to its dynamic structure. In order to cope with dynamic structure of VANETs, an efficient and reliable routing protocol is required for data distribution. Without distinct and efficient reliable multipath routing schemes, vehicles might be ineffective to share essential communications and take the advantages of the modern technologies presented by VANETs. In literature, many VANETs routing protocols have been proposed to deal with dynamic structure of VANETs. The existing protocols are generally divided into four main categories, namely position-based protocols [3], [4] broadcasting protocol [5], [6] clustering-based protocol [7] and infrastructure based protocol [8], [9]. All above mentioned protocols have limitations in their realistic use. The broadcasting and position-based protocol disseminate large amount of messages at the expenses of high end-to-end latency in VANETs. The position based protocols may not be suitable in real time scenario, where message delivery is strictly related to time. The position-based routing protocol have the same problem as that of broadcast-based protocol, where all the vehicles need to keep their neighbors updated information by frequent messages at the expenses of high communication overhead.

The cluster-based protocols aim to reduce the number of control messages by integrating vehicles into manageable groups led by a superior vehicle called cluster head (CH). A cluster is formed for intra-cluster data transmission among cluster members (CMs)) as well as inter-clusters through road side unit (RSU) [10], [11]. In both cases, CH performs the responsibility of data transmission as well as cluster formation. In intra-cluster, CH handles traffic control, media access and QoS provision. While in case of wide VANETs, CH forms a dynamic virtual backbone to handle fundamental functions such as routing and channel allocation. The transferring of an ongoing vehicle data session from one RSU to another is called handover [19], [20], [29]. The handover of fast moving vehicles group is an open challenge. The performance will be worst, if all the vehicles individually transfer their data session from connected base station to another. Signaling overhead will be too much between the vehicles. The adaptation of clustering will significantly reduce the signaling overhead by converting many hand-overs to one from CH to RSU. Among all types of

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schemes, any colony optimization (ACO) based clustering scheme seems to be the best optimistic one as they try to take the mobility of vehicles in a natural way and give quite established groups for communication.The major contributions of this paper can be summarized as follows.

- The existing AOMDV protocol is extended to clustering based reliable low-latency routing (CRLLR) scheme by employing ACO method in VANETs to choose an optimal and reliable route to reduce the overall latency under the high mobility scenarios.
- The proposed CRLLR uses link reliability and ACO optimization technique as selection criteria for cluster heads (CHs) and optimal route selection for vehicular environment.
- A heuristic technique is adopted in CRLLR to find the optimal and reliable route that is faster than existing scheme because it benefits from the initializing the pheromone values.
- The significance of CRLLR is evaluated by comparing the simulation results with AQRV and T-AOMDV.

The paper is sectioned as follows. The related work of the paper is in Section 2, Section 3 Proposed framework, section 4 Proposed CRLLR Scheme, Section 5 simulation results and discussions and finally VI concludes the paper.

2. Related work

The challenges of routing schemes in dynamic scenarios have been attracting more and more research efforts [21], and many types of multipath routing schemes and QoS routing using ACO technique have been proposed to achieve reliable data transmission and support adverse applications for VANETs [22], [23], [24], [28].

As a part of multipath distance vector routing scheme, there are two main methods to compute multipath routes, link-disjoint and node-disjoint. In the node-disjoint method, ad hoc on-demand distance vector multipath (AODVM) [25], every node is permitted to join in only one route, no joint nodes are allowed among any two conventional routes other than the source and the destination nodes. Furthermore, in the link disjoint method, AOMDV [17], [26] every link is allowed to cooperate in only one route, no shared links are allowed between any two established routes. As described in [27], the route established using the link disjoint method is only 20%–30% stable than the route stability established by the node disjoint method, and the average hop count is slightly different. The key objective to use AOMDV is, it permits intermediate nodes to reply to RREQs messages, while still selecting disjoint routes.

2.1. Representative schemes for comparison

To evaluate the significance of our proposed clustering-based reliable low-latency routing (CRLLR) scheme, we consider following representative schemes for comparison.

Guangyu Li et al. [12], proposed an adaptive QoS routing scheme (AQRV) for VANETs. AQRV calculates the optimal route between two terminal intersections based on the ACO technique, which is an adjacent intersection with the source and target vehicles. There are some limitations of this approach. Firstly, AQRV evaluates the discovered routes by combining only two metrics, connectivity probabilities and communication latency. When forwarding among two adjacent intersections, the data packet utilizes the greedy carry forwarding method and the data packet is dynamically delivered to the resulting node based on the determined global pheromone at the intersection that increases end-to-end latency. Secondly, when the terminal nodes of the source and destination modify, a new routing search process is originated at the source node to exchange the unacceptable routes which increase the time complexity and latency.

D. Wei et al. [13], [14] proposed a trust-based Ad hoc on-demand multipath distance vector (T-AOMDV) scheme by extending AOMDV protocol. In the proposed scheme nodes calculate trusted values based on multiple events by considering historical connections, exchange situation factors and behavior of neighbor nodes. There are two major limitations of this approach. Firstly, T-AOMDV selects trusted route based on neighbor nodes behavior and recommended trusted values to compute information packets which increases latency. Secondly, it integrates nodes trusted values into response route in route discovery process which increases end-to-end latency and complexity of RREQ messages.

The authors in [18] extended link reliability to an existing ad-hoc on demand distance vector (AODV) as a best route selection metric and improve its reliability by introducing R-AODV (Reliable-ad-hoc on demand distance vector). R-AODV selects single reliable route to destination, which improve the performance as compare to AODV. But the number of control messages are increased in route discovery of R-AODV. There are two major limitations of this approach. Firstly, R-AODV selects one path between source and destination for data transmission, hence in case of high payload transmission, the performance of R-AODV will be degraded due to frequently link breakages and data lost. To cope with frequent link breakage, R-AODV iteratively discover route which increases routing overhead significantly. Secondly, R-AODV has no load-balancing scheme due single path selection.

In summary, the current clustering methods in existing V2V and V2I environments do not take into account the use of clustering based reliable low-latency routing schemes to overcome transmission overhead, enhance efficiency and reliability. Although the existing cluster based algorithms has relatively one of the subsequent limitations: (i) the formation of clusters based on road network distribution rather than object movement, which reduces the time period of the cluster; (ii) the clustering procedure needs that each vehicle intermittently broadcast messages; (iii) Clustering requires assistance from road-side-units (RSU) that could not be accessible in several cases; (iv) Clustering focuses on small-scale situations. Our proposed scheme will overcome these limitations.

In this paper, the previous schemes [12], [13], [17] are extended to clustering-based reliable low-latency multipath routing (CRLLR) scheme by employing ACO technique in VANETs to choose an optimal and reliable route to reduce the overall latency under the high mobility scenarios. In literature, different protocols use different selection criteria for cluster head selection such as ID, range, propagation latency, travel time, relative velocity and number of vehicles etc. The proposed CRLLR in this paper uses link reliability and ACO optimization technique as selection criteria for cluster heads (CHs) and optimal route selection. A heuristic technique is adopted in CRLLR to find the optimal and reliable route that is faster than existing scheme because it benefits from the initializing the pheromone values in any VANETs scenario. In CRLLR scheme the vehicle having maximum reliability is selected as CH. The significance of CRLLR is evaluated by comparing the simulation results with AQRV and T-AOMDV.

3. Proposed framework

Consider a multilane highway having N total number of vehicles on the road follow normal distribution with respect to their relative speed v and location. We divide the moving vehicles to several clusters, and then select one vehicle as a cluster head (CH) in every cluster to store the information status of the all vehicles as well as message dissemination. During data transmission, the source transmits the message to the CH of its own cluster, then the CH forwards the message to the CH which is in the same clus-

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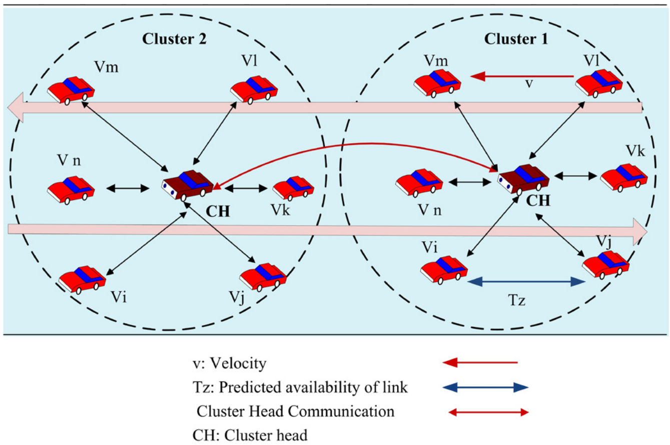

Fig. 1. System model.

ter with the destination as shown in Fig. 1. The vehicles/nodes in the same cluster can communicate directly with CH, while the vehicles of two different clusters can communicate through Cluster heads (CHs) of every cluster. The objective is to find the reliable and optimal link during the routing discovery process of moving vehicles in dynamic environment.

3.1. Link reliability

The discovery of a reliable route in VANETs is a complicated task due to high relative velocity of vehicles. The routing performance is influenced by many parameters such as vehicles traffic distribution and mobility patterns. For an efficient vehicles reliability model, it is necessary to understand mobility model and traffic characteristics. In transportation two broad techniques are used to describe the dissemination of vehicles traffic flow such as macroscopic and microscopic [7]. The macroscopic technique describes, the physical flow of traffic in a given road segment with respect to macroscopic quantities such as traffic flow, density and relative velocity. The vehicle clustering is defined as follows:

$$N = \{V_i, V_j, V_k, \ldots\ldots\ldots V_n\} \tag{1}$$

CRLLR aim is to find the optimal route in highly dynamic environments with better QoS based reliable route in terms of reliability, latency, energy consumption and throughput, while satisfying the latency constraints. In order to compute the link reliability $r_t(l)$ we utilized the vehicles relative velocity coordinates. Suppose velocity v of a vehicle follows normal distribution $N(\mu, \sigma^2)$ and T_z is the continual availability of a particular link $l(V_i, V_j)$ among any two vehicles with time period t, the link reliability value $r_t(l)$ for a link is determined as follows:

$$r_t(l) = \int_t^{t+T_z} f(T)dt \text{ if } T_z > 0 \tag{2}$$

$f(T)$ shows the probability density function (pdf) of communication time period T is calculated as follows:

$$f(T) = \frac{L_{V_iV_j}}{\sigma_{\Delta v_{ij}}.\sqrt{2\pi}} \frac{1}{T^2} e^{-\frac{(\frac{L_{V_iV_j}}{T} - \mu_{\Delta v_{ij}})^2}{2\sigma^2_{\Delta v_{ij}}}} \tag{3}$$

where $\mu \Delta v_{ij} = |\mu v_{ij1} - \mu v_{ij2}|$ and $\sigma^2 \Delta v_{ij} = \sigma^2 v_i + \sigma^2 v_j$ represents the mean and variance of relative velocity Δv_{ij} among communicating vehicles, correspondingly, $L_{v_i v_j}$ shows the wireless communication range and T_z is calculated as follows:

$$T_z = \frac{L_{V_iV_j} - \theta\sqrt{(y_i - y_j)^2 + (x_i - x_j)^2}}{|v_i - \vartheta v_j|} \tag{4}$$

where $\vartheta = 1$ and $\theta = -1$ when vehicle V_j cross vehicle V_i, $\vartheta = 1$ and $\theta = 1$ when vehicle V_i goes forward against vehicle V_j, $\theta = -1$ and $\vartheta = -1$ when vehicle V_i and V_j are moving towards each other. For all specified route $K(s_r, d_s)$ among source s_r and destination d_s, show the number of links as $n : l_1 = (s_r, V_1), l_2 = (V_1, V_2)$............$l_n = (V_n, d_s)$. For each link $l_n (n = 1, 2, 3, \ldots .n)$, denote by $r_t(l_i)$ the value of its link reliability as computed using (1).

3.2. Route reliability

The multipath route reliability for any route K, represented with $R(K(s_r, d_s))$ is defined as follows:

$$R(K(s_r, d_s)) = \prod_{i=1}^{n} r_t(l_i) \text{ where } 0 \leq R(K(s_r, d_s)) \leq 1 \tag{5}$$

The route reliability value is the product of the link reliability values of the links that form this route.

3.3. Ant colony optimization

Ant colony optimization (ACO) is an optimization technique that specifically supports to find the optimal route among vehicles during the route discovery process from source to destination vehicle. The objective to employ the ACO is to find the optimal route based on maximum reliability because it is superior in terms of good adaptability, robustness, decentralization, and satisfies the requirements of solving dynamic routing optimization problems [4]. The link reliability is defined by the value among two vehicles. Meanwhile the ACO rules have been formulated to introduce in a vehicles network situation and that is dynamic for ants to traverse the routes that are most reliable as compared to others. In such a way, ants prevent traversing weak routes that are extremely inclined to breakage. As T-AOMDV and AOMDV uses dijkstra and hop-by-hop method to select optimal route. Therefore, they could be improved using ACO technique to choose optimal route in term of reliability, latency and throughput.

3.3.1. State transition rule in ACO

Though seeking for reliable routes, ants choose subsequent hop when they reach at intermediary nodes depending on a stochastic method termed as state transition rule. Assume Ant A_m reaches at an intermediary node V_i. If nodes pheromone table RT^j don't have routing information about the destination node d_s, at that time ant A_m will be broadcasted. Else, selects V_j in RT^j as its next hop to d_s as stated in (5) if $\mu_i \leq \mu_i$ where μ_i is the random number continuously disseminated in [0, 1], and μ_j is a constant number elected among 0 and 1.

$$\arg max_{V_j \epsilon M(s_r^d)} \{[\tau_{mn}(t)]^\alpha [T_z(t)]^\beta\} \tag{6}$$

where $\tau_{mn}(t)$ is the pheromone rank connected by the link $l(V_i, Vj)$, α and β are the coordinates that manage relative rank of the pheromone rank against the expected link time period and $M(s_r^d)$ is the set of adjacent nodes of V_i still have to visit by A_m over which a route to d_s is known.

3.3.2. Pheromone deposit rule

In general, the pheromone level on a communicating link among vehicles contemplates the superiority of that link relative to the reliability-based QoS requirements considered. Thus, every ant A_m carries the traffic level detector. When moving from a node V_i to a node V_j the specified amount of pheromone, represented by $\tau_{mn}^{A_m}$ is deposited on the link $l(V_i, V_j)$ by ant A_m where $\tau_{mn}^{A_m}$ is computed as follows:

$$\tau_{mn}^{A_m}(t) = a(r_t(l)) + b\left(\sum_{n=1}^{m}(\frac{L_k}{W_k(l)})\right) \tag{7}$$

where $a > b$, $b > 0$, $(a+b) = 1.L_k$ represents a reliability based QoS requirements and $r_t(l)$ represents the reliability value for a link l.

3.3.3. Pheromone evaporation rule

The CRLLR scheme provides a way to handle the evaporation of pheromone paths traversed on the traversal link. In this technique, evaporation procedure minimizes the effects of previous routes and assists to prevent stagnation. As stated in the link reliability definition, the expected link duration T_z^e for a link $l(V_i, V_j)$ can be computed as follows:

$$T_z^e = r_t(l)T_z \tag{8}$$

each t^{eq} seconds, the pheromone level is reduced to all its links by subsequent formula:

$$\tau_{mn}(t + t^{eq}) = (1 - r)\tau_{mn}(t) \tag{9}$$

After η period of time relating (10), where r is the ratio of evaporation $0 < r < 1$, considering the preliminary pheromone level is τ_u for every route where $\tau_u > 0$, (10) can be written as follows:

$$\tau_u \approx (1 - r)^{\eta}\tau_{mn} \text{where } \eta = \frac{T_z^e}{t^{eq}} \tag{10}$$

Therefore, the evaporation ratio can be computed as follows:

$$r = 1 - \eta\sqrt{\frac{\tau_u}{\tau_{mn}}} \tag{11}$$

4. Proposed CRLLR scheme

4.1. Cluster head selection algorithm

The use of clustering in a reliable multipath routing allows the VANETs node to reject data in specific areas. Thus rather than each node On-Board-Unit (OBU) will transfer with his data, it will just transmits his data to nearby authentication OBUs, which will increase reliability, latency and also less chance of link failure. A reliable cluster head (CH) is one which can keep the information status of all vehicles as well as message dissemination for long time. A reliable cluster head selection algorithm is proposed to determine the reliable CH. The pseudocode in Algorithm 1 shows the procedure for reliable CH selection.

4.2. Routing discovery procedure

Once the cluster head (CH) gets a request for a route from its source to the destination, it first checks that it has a cluster node with information about all nodes associated with its cluster. It first checks its own routing table, if the destination does not belong to the cluster. In this situation, it sends a routing request (RREQ) message to every gateway node listed in the gateway. The requested gateway node sends a RREQ to the contiguous gateway nodes. The gateway adjacent nodes then requests the RREQ to send it to its

Algorithm 1: Reliable (R) cluster head selection.

Result: Return vehicle having maximum average reliability (R)
Send A matrix C[x][y] represenatation of cluster
for $V_k \longleftarrow 1$ *to N Intermediate vehicle* V_k*, among* V_j,V_i **do**
  for *each vehicle* V_i **do**
    for *each neighbor vehicle* V_j *of* V_i **do**
      if $R[V_i][V_j] < R[V_i][V_k] + R[V_k][V_i]$ *based on (5)* **then**
        $R[V_i][V_j] \longleftarrow R[V_i][V_k] + R[V_k][V_j]$
      else
      end
    end
  end
  $CH \longleftarrow max_{avg}R$
end

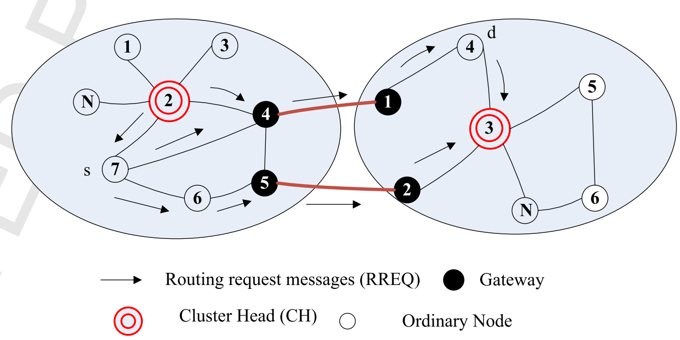

Fig. 2. RREQ and RREP messages.

CH, as shown in Fig. 2, which confirms the existence of the destination node in its own cluster.

The node sends a request RREQ to its CH node. CH will query the broadcast to all gateway nodes. Every gateway node sends a query to its neighboring gateway nodes. Thus, the gateway nodes receive the requests and send them to their corresponding CH nodes. The path sequence is presented in the request RREQ and is updated at every intermediate node. The solution guarantees loop free routing, and when the node identifier is included in the routing parameters requested by the RREQ, the RREQ request is simply deleted by the node.

Reverse path

When the CH node finds the destination node in its own cluster, the routing section finishes the routing sequence from the gateway node to the destination node and delivers the routing reply (RREP) packet to the sender gateway node. The return route used by RREP packets is not certainly the same as the route employed by RREQ. RREP packets use CH to display the reverse route, which is definitely better than the RREQ request traversal route. The CH node discovers the destination node in its own cluster and sends the RREP packet to the gateway node. These nodes transmit reply packets to their neighboring gateway nodes. The RREP packet follows the intermediate node sequence shown in the path sequence field to the source node. The CH node does not return the RREQ request to the gateway node because they are the sender's RREQ request. Though, the source node could not receive any RREP messages; in this case, after a certain waiting time, the source node initiates the path discovery process and repeats the search process until a reliable route is found. By adding reliability and Clustering to AOMDV,

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Reversed	RREQ ID	X-Pos	Y-Pos	Speed	Direction	Cluster Head	Link Reliability	Source	Destination	Hop count	Last Hop

(a) CRLLR RREQ Contents

ACK	RREP ID	CH Selection	Link Reliability	Source	Destination	Hop count	Last Hop	Life time

(b) CRLLR RREP Contents

Route List	Destination	Seq No	Advertised Hop count	Route timer	CH selection	Link Reliability

(c) CRLLR Routing Contents

Next Hop-1	Last Hop-1	Hop Count-1	CH selection-1	Link Reliability-1	Route timer-1
Next Hop-2	Last Hop-2	Hop Count-2	CH selection-2	Link Reliability-2	Route timer-2

Fig. 3. Route structure of CRLLR. (a) CRLLR RREQ contents, (b) CRLLR RREP contents, (c) CRLLR routing contents.

it extended to clustering based reliable low-latency routing (CRLLR) scheme. The updated tabular structure of RREQ, RREP and routing table with cluster head and link reliability is shown in table 1, 2 and 3 respectively.

The updated tabular contents of RREQ, RREP and routing contents with link reliability is shown in Fig. 3. RREQs messages are extended by adding new contents to its network as illustrated in Fig. 3a.

- $Xpos$, $Ypos$ contains the coordinates of the vehicles that proceeds RREQ.
- Velocity includes the current vehicles relative velocity that proceeds RREQ.
- Direction includes the vehicle movements that proceeds RREQ.
- Route_reliability includes the parameters of the link reliability among the sending and the receiving node of that RREQ.

The RREPs messages are extended by including a new contents to its network, as illustrated in Fig. 3b.

- ACK holds the acknowledgment of all circulated broadcasted messages.
- RREP ID holds the ID's of all routing reply messages (RREP).
- The routing reliability includes the last value of complete route reliability among the source node and destination nodes. The source node uses this value to determine which route will be selected when multiple potential routes exists among source and the destination nodes.

Routing contents are extended by including new data packets to their contents, as illustrated in Fig. 3c.

- The routing list keeps records of all different routes.
- Routing_reliability includes the parameters of the route reliability of that route entry. So the value is maintained each time with best reliability value is originated for the similar destination.

4.3. *ACO-based clustering algorithm*

ACO evolutionary capabilities enable CRLLR scheme to optimize the number of clusters in the network. In ACO based technique one solution called an ant and set of ants make a swarm which looks for optimal route [29]. These methods work effectively and apply to continuous and discrete variable problems. These features mean that ACO-based techniques are very effective for clustering in VANETs. The algorithm initially finds the optimal route and then finds the neighborhood of the CH. The labels of vertices represents the IDs of vehicles. These vertices are related with pheromone level and computed based on equation (9), (10).

5. Simulation results and discussion

The main purpose of performance estimation is to analyze the effectiveness of CRLLR in different simulation environments. All the simulation experiments are performed using MATLAB (R2015b) and Network Simulator NS3 (NS-3.25). MATLAB is used for statistically analysis and implementation of probability distributions such as Link reliability and route reliability. Following are the simulation environment and parameters employed in the experiments.

5.1. *Simulation environment*

The simulation is carried over a three-lane traffic scenario of 5000-m highway in two directions, where the average velocity of every vehicle is considered in the range of 20 to 100 km/h respectively. The traffic simulation parameters are shown in Table 1. We consider different scenarios of simulation by varying the number of vehicles simultaneously on the road among 20 to 100 vehicles. Two different simulation experiments are performed to evaluate the performance of proposed CRLLR.

Experiment A: The impact of different relative velocity from 40 to 120 km/h over the performance of CRLLR.

Experiment B: The impact of different vehicles on the road from 30 to 100 vehicles to measure the significance of CRLLR scheme, where the average velocity of vehicle is 60 km/h.

We considered the following performance QoS metrics to evaluate the performance of proposed CRLLR scheme:

- Reliability: It refers to the probability that a link among two vehicles will exist over a particular period of time.
- *Average end-to-end (E2E) latency*: Average Throughput: The amount of data efficiently transfered from source to destination in given time period.
- *Average end-to-end (E2E) latency*: It presents the time taken for a packet to be sent on communication media from source to destination vehicle.
- *Number of beacons messages*: It refers to the total number of routing requests (RREQ) messages that is required for the discovery of destination before sending packets.
- Average energy consumption: It refers to the sum of energy consumed by all transmitting and receiving nodes in the vehicular network.

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Algorithm 2: ACO algorithm to find optimal route from source to destination vehicle.

Result: Find the optimal route for Cluster Head Selection
while *Iteration== total iterations* **do**
  for $AntA_m = 1$ *to swarm extent* **do**
    $AntA_m.tour == empty, value == infinity$
    Vertices ⟵ *available for clustering=(All Vehicles)*
    while *(Accessible nodes for clustering = empty)* **do**
    end
    $AntA_m.value$= *evaluation*($AntA_m.tour$) based on (7)
    if ($AntA_m.value \le BestAnt.value$) **then**
      $BestAnt = AntA_m$
      $AntA_m{+}{+}$
    else
      Iteration=0
    end
  end
  for $AntA_m = 1$ *to swarm extent* **do**
    Update τ_u(*Ant* A_m*.tour,Ant* A_m*.value*) based on (10)
    if (*Best.value ==last iteration Best.value*) **then**
      $Iteration{+}{+}$
    else
      Iteration=0
    end
  end
end
CH=BestAnt.tour

Table 1
Network simulation parameters.

Parameter	Value
MAC Protocol	802.11p
Road Length L	1 km × 5 km
Mobility Model	Highway
Connection type	UDP
Communication range	200 m–1000 m
CBR rate	128 kb/s
Mobility trace duration	300 s
Vehicle's speed	Normally distributed

5.2. Simulation results and discussions

5.2.1. Effect of different relative velocities on routing performance

The Fig. 4 shows that proposed cluster-based reliable low-latency multipath routing (CRLLR) scheme achieves best reliability as compare to existing schemes AQRV and T-AOMDV. CRLLR outperforms due to adaption of clustering and ACO technique, as proposed scheme maintains reliability by adjusting optimal number of clusters though relative velocity will not affect the performance. The increase in relative velocity causes high variations in VANETs, but due to the beauty of spectral clustering and ACO technique that provides optimal routes to destination which may not affect the performance. In CRLLR every reliable route passing by CH whose selection based on ACO optimization technique.

It can be observed from Fig. 5 CRLLR is more stable as compare to AQRV and T-AOMDV in the case of throughput. The proposed

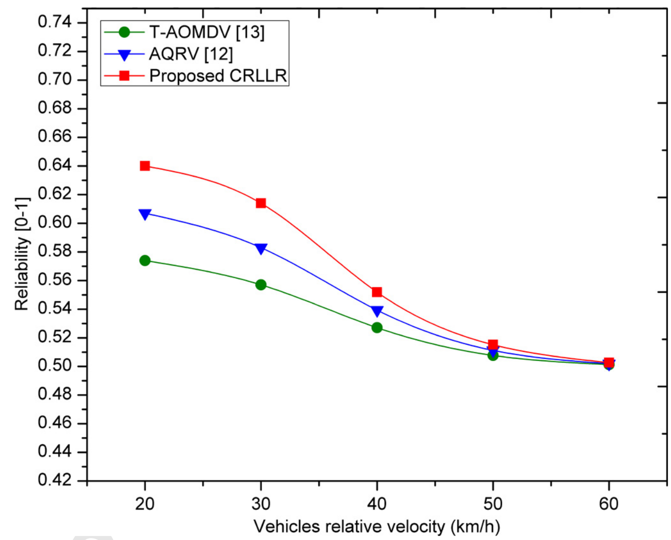

Fig. 4. Impact of different relative velocities on reliability (Number of vehicles 50, R 1000 m, t 10 sec).

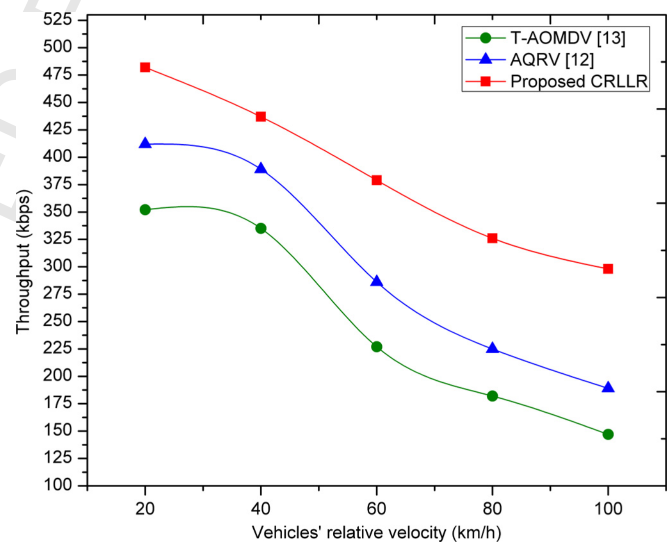

Fig. 5. Impact of different relative velocities on Average throughput (Number of vehicles 50, R 1000 m, t 10 sec).

scheme shows good performance with different relative velocity. As CRLLR classifies vehicles into optimal group on the basis of reliability, hence most reliable route will be selected from source to destination. The highest throughput mean the rate at which data packet transmitted or received at destination successfully. Due to the high reliability and efficiency the route will be stable and the throughput will not be effected.

From Fig. 6, it can be determined that CRLLR has the lowest end-to-end latency under different vehicles relative velocity as compared to existing schemes. The integration of clustering and ACO technique in AOMDV has very good impact on the timely packet delivery ratio. The variations in the velocity are not affecting the delivery time to destination in CRLLR. As shown in Fig. 7, the impact of relative velocity on the number of beacons messages are less in CRLLR scheme as compared to existing schemes. Whereas the network is divided into clusters, hence the message broadcast boundary will not be too much as that of existing schemes. Sometime even in highly dynamic environment, the number of beacon messages are less as shown in Fig. 7 at relative velocity 60 km/h. At that moment, the network is divided

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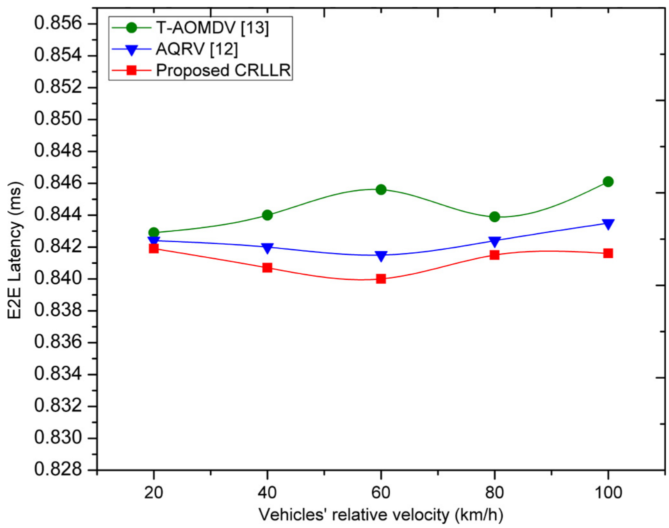

Fig. 6. Impact of different relative velocities on Average E2E Latency (Number of vehicles 50, R 1000 m, t 10 sec).

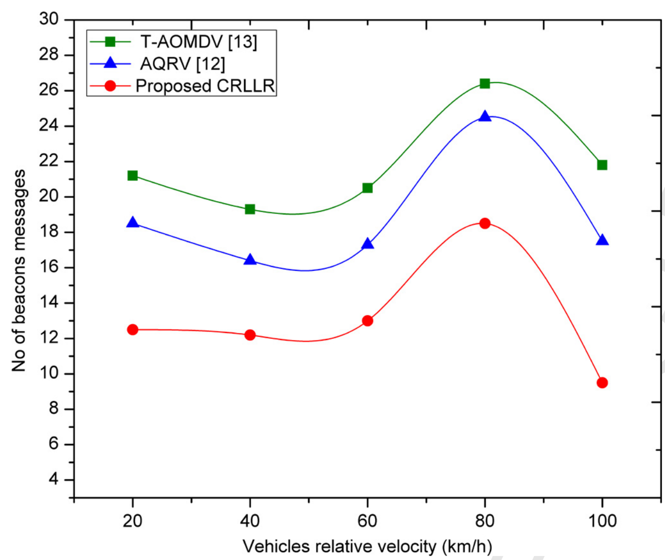

Fig. 7. Impact of different relative velocities on number of beacons messages (Number of vehicles 50, R 1000 m, t 10 sec).

into many small groups, where route discovery will not require too many messages.

Fig. 8 shows the average energy consumed under different relative velocities in CRLLR is slightly higher as compared to T-AOMDV and AQRV. The higher energy consumption with different number of velocities in CRLLR is due to formation of clustering and ACO technique as compared to existing schemes.

5.2.2. Effect of different vehicles on routing performance

The purpose of experiment B is to analyze the effect of different number of vehicles on performance metrics. In Fig. 9 it is shown that, the proposed CRLLR always achieves good performance under different number of vehicles as compared to the existing schemes. The evolution of antenna coverage area increases the size of cluster, which increase the link reliability of every vehicle in VANETs. The link reliability of each link increases the reliability of whole VANETs.

Fig. 10 shows that the increase in the number of vehicles has positive effect on end-to-end latency. The proposed CRLLR always achieves lower latency in comparison to existing schemes. The employment of ACO technique avails many reliable routes from source

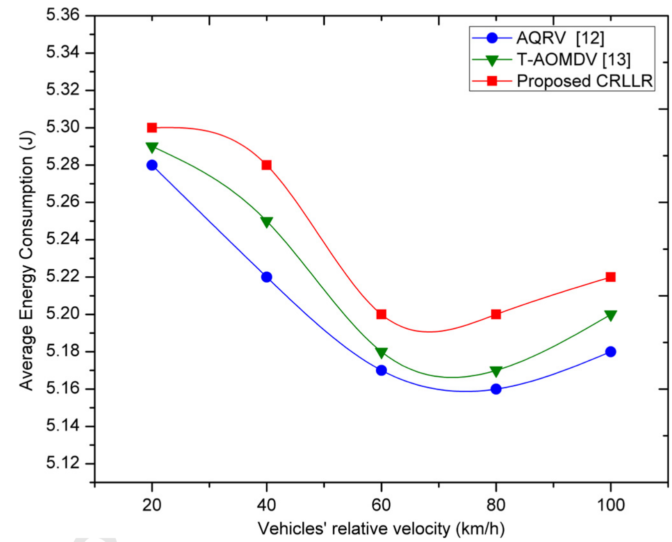

Fig. 8. Impact of different relative velocities on energy consumption (Number of vehicles 50, R 1000 m, t 10 sec).

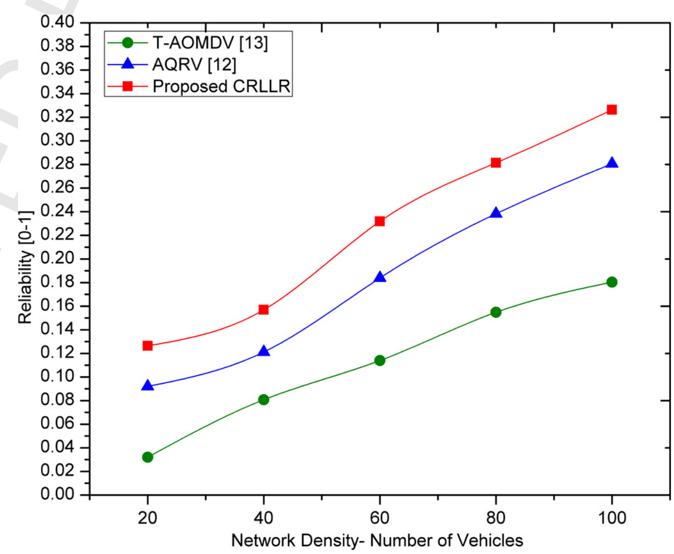

Fig. 9. Impact of different number of vehicles on reliability (Average velocity 60 km/h, R 1000 m, t 10 sec).

to destination, which improves the performance such as lower E2E latency and higher throughput. The improved throughput is also shown in Fig. 11, where CRLLR performs better than other existing schemes over different number of vehicles.

The number of beacons messages are slightly affected over different number of vehicles as shown in Fig. 12. As the number of vehicles increases, the discovery of reliable route will require more number of beacons messages due to the more number of vehicles, but still the proposed CRLLR scheme perform better than other existing schemes as shown in Fig. 12. The number of beacons messages also increases in T-AOMDV and AQRV. But in CRLLR the density of link is not increases too much because of clustering and ACO technique. Due to adoption of clustering proposed CRLLR scheme performance is better than T-AOMDV and AQRV.

Fig. 13 shows the average energy consumption with different number of vehicles in CRLLR is slightly higher as compared to T-AOMDV and AQRV. The higher energy consumption in CRLLR is due to formation of clustering and ACO technique as compared to existing schemes.

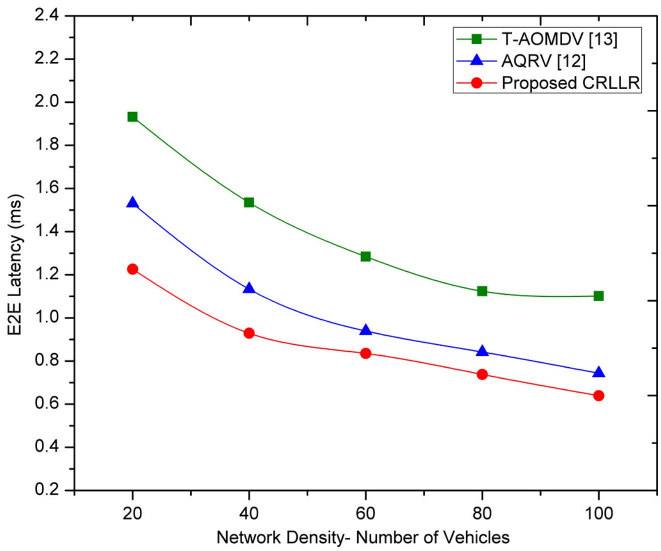

Fig. 10. Impact of different number of vehicles on E2E Latency (Average velocity 60 km/h, R 1000 m, t 10 sec).

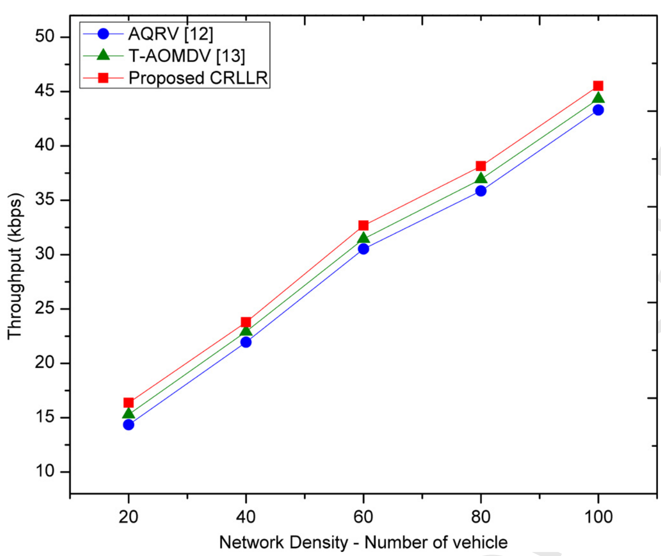

Fig. 11. Impact of different number of vehicles on Throughput (Average velocity 60 km/h, R 1000 m, t 10 sec).

6. Conclusions

In this paper, we have proposed a new clustering-based reliable low-latency multipath routing (CRLLR) scheme by employing ACO technique for vehicular communication. The proposed CRLLR scheme significantly reduces the end-to-end latency and enhance the reliability by eliminating excessive RREQ messages. The performance of CRLLR has been compared with existing schemes using extensive simulations under different relative velocities and number of vehicles. The results showed that the proposed scheme has higher reliability, lower end-to-end latency and higher throughput compared to existing schemes at the expenses of slightly increased energy consumption.

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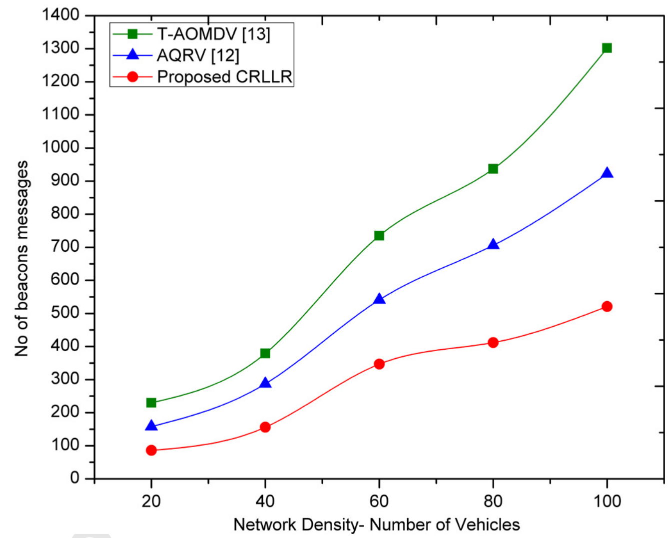

Fig. 12. Impact of different number of vehicles on number of beacons messages (Average velocity 60 km/h, R 1000 m, t 10 sec).

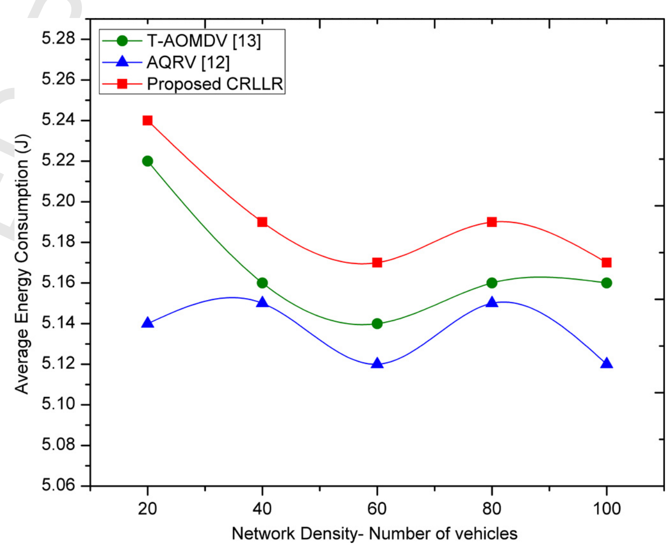

Fig. 13. Impact of different number of vehicles on Energy consumption (Average velocity 60 km/h, R 1000 m, t 10 sec).

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