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Ant Colony Optimization Based Qos Routing Protocol (ACORP) for Vanets

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Abstract : Vehicular Ad Hoc Network (VANET) is a special type of communication network that promises wide applications ranging from road safety to driving comfort. The rich applications enhance the safety and comfort of travelers by establishing a cooperative communication among the vehicles. To increase communication efficiency this work proposes an Ant Colony Optimization based Quality of Service Routing protocol(ACORP) for VANETs that aims to enhance the road safety and travel convenience in VANETs.

***Key words**: ACORP, Intelligent Transportation System (ITS),* **Quality of Service (QoS),** *Road Side Unit (RSU), VANET.*

I. INTRODUCTION

In recent years, the development of Vehicular Ad Hoc Network (VANET) has received more attention in Intelligent Transportation System (ITS), as it has the potential to provide safety and travel comfortably to the drivers and passengers facilitating communication among vehicles and Road Side Units (RSUs). The vehicles are equipped with on-board units (OBUs) to establish communication with other vehicles and RSUs[1][2]. The preliminary intention of VANET communication is to provide safety to the VANET users. The safety enhancement applications aim to assist drivers in handling unpredictable events or hazardous situations by broadcasting the safety messages such as an accident or collision warning, and weather conditions such as icy and foggy roads [3]. In a safety environment, a vehicle rapidly broadcasts safety information to other vehicles in the dangerous zone using dedicated RSUs.

The geographic routing protocols, especially greedy routing protocols are the most desirable for VANET, as they allow the vehicles to select optimized next hop routers based on geographic information . Due to the environmental factors such as obstacles and road intersections, it is a daunting task to provide reliable and timely communication in the realistic VANET environment. The performance of VANET routing protocols drastically depends on the link availability and quality between the vehicles that communicate with each other. The link availability is a measure that assists in selecting the links that have a long lifetime to route the packets [4]. In the real time VANET environment, several factors such as vehicle speed, direction, and driver decision affect the link availability.

The link quality guarantees to deliver the packets with high reliability by considering some Quality of Service (QoS) parameters. Most of the current works select reliable links based on distance measurement techniques such as Euclidean distance and signal strength.

Euclidean distance leads the VANET to miscalculate the greedy nodes as closer nodes to sender node due to the restricted road topology, whereas signal based distance measure is likely to select the greedy nodes wrongly, because of the miscalculation of distance due to the presence of obstacles. Hence, it is crucial to develop a protocol that incorporates precise link availability and link quality measurements in router selection.

This work proposes a Ant Colony Optimization based QoS Routing Protocol (ACORP) that improves the speed in safety and comfort message broadcasting.

A. Contributions

- The ACORP selects reliable next hop routers by measuring a pheromone value based on link quality and link availability. Thus, it improves reliability and speed in forwarding comfortable travel messages.
- To select a terminal intersection for data forwarding, the link availability measurement takes into account the direction of destination node and neighbor density in intersection area.
- The ACORP integrates an appropriate distance measurement technique in ACO based data forwarding to reduce the impact of intra intersection neighbors in reliable router selection.
- The simulation results show that the ACORP achieves better results in terms of intersection impact on communication, throughput, and delay.

B. Paper organization

The remaining part of the paper is organized as follows. Section II surveys the papers related to ACORP. Section III describes the system model of ACORP and Section IV briefly explains the overview of ACORP. Section V analyzes the performance of ACORP using various performance metrics. Section VI concludes this paper.

II. RELATED WORK

A traffic-aware intersection-based geographical routing protocol, TIGeR, has been proposed in [6]. In TIGeR, the vehicles which ate at intersections only make the routing decision by utilizing the traffic information on various roads and the angle of the roads.

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The work in [7] presents a multi-objective Heuristic Algorithm Based on Ant Colony Optimization (ACO), called as AntRS. The AntRS discovers alternative paths for communication when the signal transmission is affected by the roadside obstacles.

A Vehicular routing protocol based on Ant Colony Optimization (VACO) has been proposed in [8]. The VACO is an adaptive multi-criteria VANET routing protocol that detects the best routing paths from a source to the destination with some quality metrics estimated regarding latency, bandwidth, and delivery ratio. The work in [9] presents a Situation Aware Multi-constrained QoS (SAMQ) routing algorithm. The SAMQ discovers feasible routes for data transmission by considering multiple QoS constraints. The SAMQ algorithm ensures routing reliability by considering both the Situation Aware (SA) algorithm with Ant Colony System (ACS). An Adaptive Routing Protocol based on QoS and vehicular Density (ARP-QD) has been proposed in [10]. The ARP-QD is an intersection-based routing protocol that establishes QoS assured routing paths by taking into account the link duration and connectivity for end-to-end data delivery. One of the straight forward and efficient methods to escalate the link stability is to determine the longest link duration. The work in [11] designs a Receive On Most Stable Group-Path (ROMSGP) algorithm that chooses the most stable routing path based on the link expiration time. The works in [12]and [13] discover high stable routing paths to avoid carry-and-forward delay. The links with good connectivity and least distance increase the number of hops in the selected stable paths, resulting in longer data delivery delay. A stable VANETs routing protocol in [14] considers the real road vehicle density to deliver the data packets with high reliability quickly. However, the real-time update of density vehicle information sustains a large amount of communication overhead, which results in its performance deterioration in large-scale VANETs. The work in [15] exploits the speed of vehicles and location information to detect relatively stable links. The work in[16] presents an intersection-based geographical routing protocol, named as connectivity-aware intersection based routing (CAIR) that aims to establish routing paths with high connectivity probability. The work in [17] proposes an Intersection-based Delay Sensitive Routing that utilizes Ant colony optimization (IDRA) for VANETs in urban environments. The IDRA establishes an optimal route between two terminal intersections and the route closest to the source and the destination vehicles. However, most of the previous works exploit the Euclidean distance and signal strength measurement to select the next-hop node. Thus it leads to unreliable data transmission. Hence, it is crucial to propose an appropriate distance measurement model to improve routing performance.

III. SYSTEM MODEL

A communication graph G(N,L) can be used to represent VANET. The number of nodes N consists of vehicles (V) and Road Side Units (RSUs). The term L represents direct communication links between vehicles v1 and v2 belonging to set V. Let us assume that navigation system, digital map and GPS are inbuilt in V . Each node in N has limited communication range with the condition that the range of vehicles(V) is less than the range of R_{RSU} and also the RSU has High computational power and storage capacity than vehicles. Each vehicle communicates with an RSU in single or multi-hop fashion

Each RSU is associated with the number of vehicles V with its identity (ID) and location (l_v). The road topology has several intersections. The vehicles move across the straight and curved path in each lane. The distance measurement model in ACORP takes into account the intersection points to attain fast and reliable delivery of and safety and driving comfort messages.

IV. OVERVIEW OF ACORP

The VANET plays a major role in providing safety and travel comfortable for the passengers. For reliable and rapid, message delivery, the ACORP integrates an ACO mechanism that measures a pheromone value based on link quality and link availability to select optimal next hop routers. The ACORP estimates the quality of links based on some QoS factors such as appropriate distance measurement, routing load on vehicles and relative speed of the vehicles. The ACORP measures the available links using node density in intersection and destination direction. Thus, the ACORP improves the reliability in safety and comfortable message delivery with acceptable delay.

Figure 1 depicts the block diagram of safety and comfortable message routing process of ACORP.

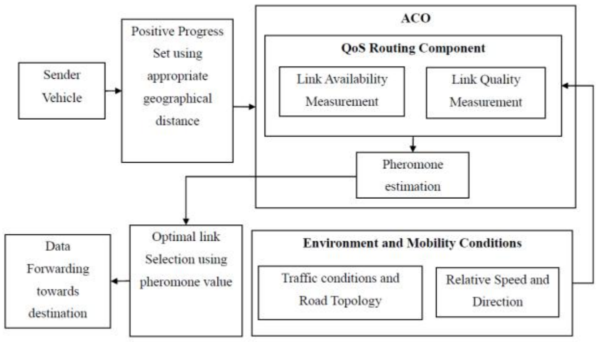

Fig. 1. Safety and Comfortable message routing process of ACORP.

A . ACO based Optimal Router Selection

The ACO is a metaheuristic technique that solves computational problems and optimizes the routing path selection. In the ACO algorithm, the ants random walk on a path for searching food. If the ants determine any shortest optimal path, they deposit a chemical named as pheromone along an optimal traveling path. The pheromone deposited by the ants assist future ants in selecting a better path. The ACORP exploits the advantage of ACO, and it evaluates pheromone value to the available routing paths by measuring link availability and link quality. The ACORP decides the path that has highest pheromone value as an optimal routing path.

B. Terminal Intersection Selection

To select the intersection, which provides excellent forwarding opportunity, the ACORP measures the node density and destination direction in terminal intersection selection.

Thus, it leads the vehicles to send the packets early to the destination. Initially, the source node discovers the neighboring intersections to reach the destination node by updating beacons. The links between two vehicles likely to disconnect frequently when the vehicles move with high speed in opposite directions. To avert this issue, the ACORP only selects the intersections in which the vehicles move towards the destination node. Hence, the vehicle density in intersections varies based on road conditions. The intersections that have a low vehicle density may create a communication hole during data forwarding. To select an optimal intersection, the ACORP measures the vehicle density in the intersections that has the tremendous forwarding opportunity to diminish the communication holes in data forwarding. The ACORP measures the vehicle density over the intersections using the digital map and navigation system. Moreover, the ACORP selects a terminal intersection, which contains huge vehicle density that moves towards the destination. The mechanism of terminal intersection selection results in enhanced connectivity and thus, improves the routing reliability while reducing the end-to-end delay. The terminal intersection selection process is repeated until the terminal intersection that is closest to the destination is selected

C. Appropriate Next-hop Router Selection

Consequently, the ACORP measures the link quality to select a reliable next hop router in the direction of the optimal intersection. The ACORP considers some QoS parameters such as curve based distance measurement, relative vehicle speed, and routing load to select reliable forwarder.

D. Impact of Inter Intersection Neighbors on Optimal Next Hop Selection

Greedy Geographic Routing is more appropriate for urban VANET that consists high vehicular density. Most of the existing greedy routing techniques select greedy routers based on distance measurement. The distance is measured in two ways such as Euclidean and signal strength. Euclidean distance is a straight line distance measurement metric that measures the distance between two points over a Euclidean space. The Euclidean distance measurement lacks in computing the accurate distance between two moving vehicles over real time VANET environment due to the complex road topology. For instance, in figure 2, the sourceFnode S1 wants to forward a comfortable message that comprises parking area information to the destination node D1. In VANET, each node knows its location using navigation system, and it finds the location of its neighbors by exploiting hello messages. Initially, the node S1 updates its neighbor list using hello messages and forms a positive progress set such that it contains the vehicles closer to the destination node m. The positive progress set comprises the possible routers to reach destination D1.

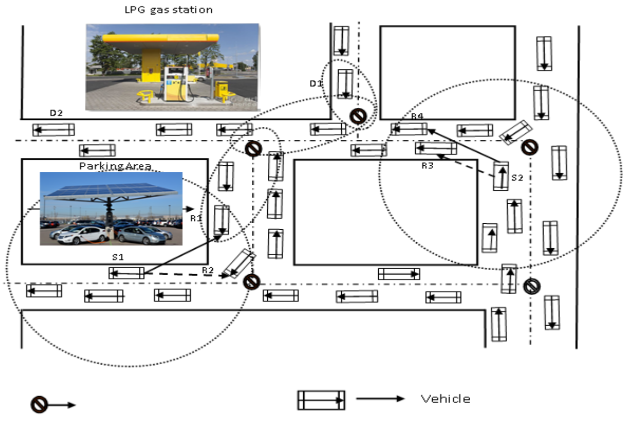

Fig . 2. Optimal Next Hop Selection

Further, node S1 measures the distance between itself and the routers (R1 and R2) in positive progress set. The S1 selects the router that has the least distance to reach the destination using Euclidean distance measurement. The Euclidean metric measures the distance between two points as a straight line, whereas the VANET road topology consist of straight and curved paths. Hence, the node S1 considers node R2 is far away from it, and it selects node R2 as r next-hop router. In real time, node R1 is far away from source S1. Moreover, the inappropriate next hop router selection degrades the routing efficiency in VANET. To overcome the issues associated with the Euclidean distance measurement, some current work exploits signal strength measurement to select appropriate next hop. In greedy routing, each node updates its neighboring nodes position using hello messages. Further, it selects a router that broadcasts a hello message with less signal strength. For instance, the source s2 node sends a request message for the location of an LPG station to node D2. It decides its positive progress set based on location information, and it selects node R3 as a router based on signal strength. Compared to node R3, node R4 lies far away from node S2. Relying on signal strength measurement lacks in considering the obstacles such as buildings and trees on roadways. Hence, it is crucial to introduce an appropriate measure to select an optimal next hop node with maximum progressive.

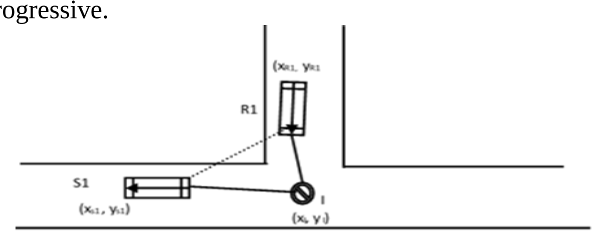

Fig. 3. Appropriate Distance Measurement of ACORP

The ACORP measures the progressive value of vehicles using a curve based distance measurement model that attempts to predict the accurate distance by considering the intersections into account. Figure 3 shows the appropriate distance measurement model of ACORP. In figure 3, the location coordinates of S1, R1, and intersection (I) are (x_{s1}, y_{s1}), (x_{R1}, y_{R1}), and (x_I, y_I) respectively.

The ACORP measures the progressive in terms of distance between S1 and R1 ($D_{s1\to R1}$).

$$D_{S1\to R1}=\sqrt{(X_{S1}-X_I)^2+(Y_{S1}-Y_I)^2}+\sqrt{(X_I-X_{R1})^2+(Y_I-Y_{R1})^2} \quad (1)$$

In equation (1), the sender vehicle measures the distance from itself to each vehicle in the positive progress set. Similarly, the ACORP measures the distance between S1 and D1 ($D_{S1\to D1}$) as depicted in figure 2. Furthermore, the ACORP selects a vehicle R1 that has maximum progress to reach the destination using equation (2).

$$D_{R1\to D1}= D_{S1\to D1}- D_{S1\to R1} \quad (2)$$

In addition to the progressive measurement, the ACORP considers some other factors such as relative vehicle speed and routing load in greedy selection for improving the routing efficiency. The ACORP measures the relative speed as follows.

$$RS(S1,R1) =[S_{S1}(t)-S_{R1}(t)] / S_{max} \quad (3)$$

In equation (3), the term $RS_{(S1, R2)}$ refers the relative speed of S1 and R1. The terms $S_{S1}(t)$ and $S_{R1}(t)$ represents the speed of vehicle S1 and R1 at t time respectively. The maximum speed is represented as S_{max}. The ACORP estimates the routing load of R1 (L_{R1}) using the equation (4).

$$RL_{R1}=1/K \quad (4)$$

$$F_P = RL_{R1} / (D_{S1\to R1} * RS_{(S1,R1)}) \quad (5)$$

In equation (4), the term K represents the number of flows in R1. Furthermore, the ACORP substitutes the equations (2), (3), and (4) in equation (5) to estimate the forwarding probability, F_p. A node receives high F_p when it has maximum progressive, Low relative speed, and minimum routing load. Moreover, the sender S1 selects a node that has high F_p value as an optimal greedy router and starts the packet forwarding process. The terminal intersection selection and appropriate distance measurement model of ACORP enhance the routing performance with minimum delay. Following algorithm explains the optimal router selection process of ACORP.

//Optimal Router Selection//

Aim: To select optimal router using ACO technique
Input: Vehicles in Positive Progress Set
Output: Optimal Router Selection, Reliable Message Delivery
Sender vehicle, S do {
Selects terminal intersection using node density and destination direction;
Forms positive progress set using geographical information;
For (all vehicles in positive progress set)
{
    Measure $D_{s\to R}$, $RS_{(S,R)}$, and RL_R;
    Estimate F_p value using equation (5);
    Selects a high F_p vehicle as router;
    Initiate packet forwarding process;
}

V. PERFORMANCE EVALUATION

The efficiency of ACORP is analyzed using Network Simulator-2 (NS-2). To analyze the performance efficiency of ACORP, it is compared with existing A Connectivity Aware intersection-based Routing in VANETs (CAIR) protocol [16].

Table 1 shows the simulation parameter of ACORP.

Simulation Parameters of QoRP	
Simulator	Network Simulator 2.35
Number of Vehicles	50,100,150 , 250
Area	2000m x 2000m
Communication Range of Vehicles	250m
Communication Range of RSU	500m
Interface Type	Phy / WirelessPhy
Mac Type	IEEE 802.11p
Queue Type	Droptail /PriorityQueue
Queue Length	50 packets
Antenna Type	Omni Antenna
Propagation Type	Nakagami
Routing Protocol	ACORP, CAIR
Transport Agent	UDP
Application Agent	CBR
Simulation Time	1000 seconds

A. Performance Metrics

The efficiency of the ACORP is measured using some performance metrics such as Impact of Intersection on Communication, Throughput, AND Delay.

The impact of the Intersection of Communication: It refers the impact of intersection on communication delay.

Throughput: It is the rate of data delivery at the destination vehicle.

Delay: It is the total time taken by a packet to reach the destination

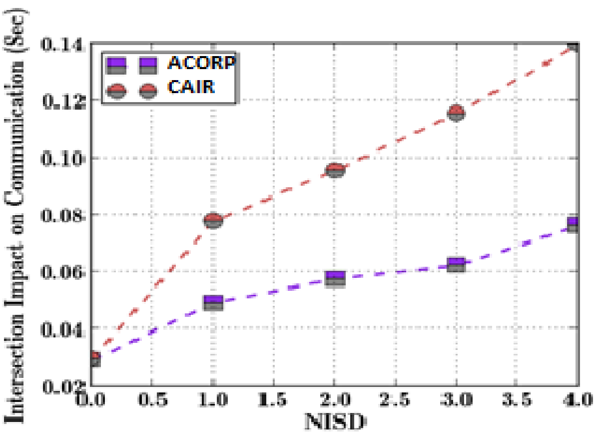

Fig 4. NISD Vs Intersection Influence on Communication

Figure 4 depicts the comparative results of intersection influence on communication obtained by varying the Number of Intersections between Source and Destination (NISD). From figure 4, the ACORP and CAIR escalate the intersection influence on communication, when increasing the NISD from low to high.

It is because of the huge number of intersections which increases the distance between source and destination, resulting in a significant communication delay. For instance, the ACORP rises the intersection impact on communication by 61.9%, when the NISD is varied from 0 to 4. However, the intersection influence on the communication of ACORP is minimum, compared to existing CAIR. The reason is that the Euclidean distance measurement in CAIR lacks to consider the intersections into account when selecting the relayer nodes. Thus, it increases the number of hops and leads to packet loss or delay in communication. Furthermore, the appropriate distance measurement in ACORP reduces the delay by considering the impact of intersections of communication. For example, the ACORP and CAIR attain 0.0762 Sec and 0.1396 Sec of intersection impact on communication respectively, when the NISD is 4.

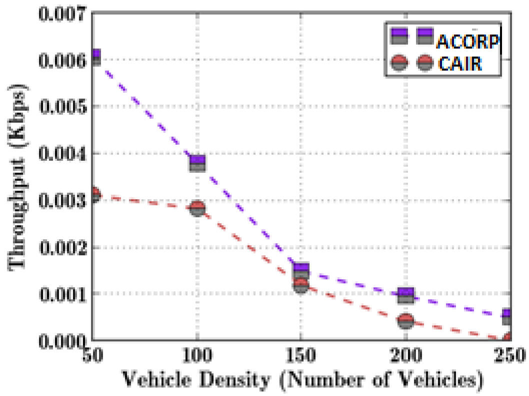

Fig 5. Vehicle Density Vs Throughput

Figure 5 compares the results of throughput of both ACORP and CAIR protocols by varying the vehicle density from low to high. Both protocols diminish the throughput with increasing vehicle density. The reason behind this that the number of flows involved is high in the communication under high-density scenario and thus, it improves the throughput of both protocols. For example, the ACORP decreases the throughput by 91.7%, when varying the vehicle density from 50 to 250. However, the ACORP attains higher throughput than CAIR, as it selects the routers based on three factors such as progressive, relative speed, and routing load. The Euclidean distance based router selection in CAIR is likely to lead to select an inappropriate router with high routing load. Thus, it increases the number of hops and decreases the throughput of CAIR. Moreover, the optimal router selection process of ACORP maximizes the throughput by 48.4%, compared to CAIR, when the vehicle density is 50.

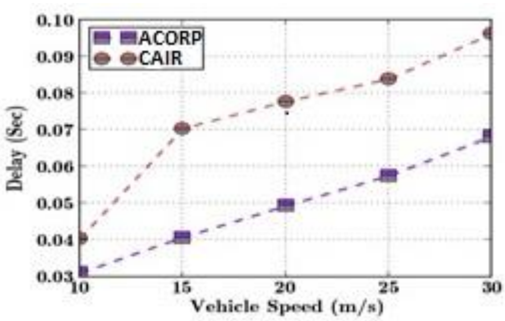

Fig 6. Vehicle Speed Vs Delay

Figure 6 demonstrates the delay results of ACORP and CAIR by varying the vehicle speed from low to high. Both protocols extend the delay with increasing vehicle speed. For instance, the ACORP increases the delay by 54.5%, when the vehicle speed is increased from 10 m/s to 30 m/s. However, the delay of ACORP is minimized, when compared to the existing CAIR protocol. The reason is that the ACORP includes the relative speed as a parameter in router selection and thus, it reduces the delay in packet delivery. On the contrary, the CAIR reduces the impact of vehicle speed on communication by allowing a current node to carry and forward the data packets when it moves into the communication range of other nodes. Thus, it reduces the delay in data forwarding under low mobility scenario. However, the ACORP outperforms the CAIR under high mobility scenario by selecting the most relative speed vehicle as a router. For example, the ACORP and CAIR obtain 0.0682 Sec and 0.0962 Sec of delay respectively under high mobility scenario.

VI. CONCLUSION

This work has proposed a ACORP protocol for VANET The ACO improves the terminal intersection selection accuracy by considering both destination direction and vehicle density. Further, the appropriate distance measurement in ACORP enhances the router selection efficiency and reduces the communication delay in safety and comfortable message delivery. The additional factors such as relative speed and routing load considered in router selection reduce the impact of packet loss in VANET. Moreover, the ACORP improves safety and travel comfort in VANET. The simulation results demonstrate the efficiency of ACORP by comparing it with the existing CAIR protocol. The ACORP maximizes throughput by 48.4% and reduces the intersection impact on communication by 45.4%, when compare CAIR .

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