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REVIEW ARTICLE

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ROUTING PROTOCOLS FOR VEHICULAR AD-HOC NETWORKS: A REVIEW

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Abstract: Vehicular Ad-hoc Networks (or VANETs) is a revolutionary concept in the field of wireless communications where on-road vehicles communicate with each other and with road side embedded sensor equipment through their On-Board Units(OBU) with an objective to smoothen the drive experience. VANET is an inter-vehicle network where environmental and road based information is shared for wellbeing. VANETs permit the vehicles to practise route management based on traffic and weather conditions, alarm with "chance of accident" warning, help to locate a place being queried by another vehicle. However, the hurdles that challenge the successful and effective working of a VANET include the routing. Routing is full of obstacles due to rapid mobility, negligible connection duration between vehicles, potential attackers, unpredictable vehicle density in an area. Routing decision may be based on the cost effectiveness or the security or both. This paper attempts to review a few position-based, clustering-based and biology-inspired VANET routing protocols proposed in the recent time.

Keywords: Road Side Units (RSUs), Ant Colony Optimization (ACO), Micro Artificial Bee Colony (MABC), Fuzzy System, Authentication.

I. INTRODUCTION

VANET is an emerging revolution in the field of wireless communications which aim to build road safety and comfort by allowing the vehicles moving on roads to communicate with each other and the Road Side Units (RSUs) and collectively form an information sharing smart structure. VANET is network of vehicles which is deployed by embedding memory and processing units, sensor units and wireless communication capabilities into the vehicles, they already contain power backup. They have their own communication range throughout which they can communicate directly, however, if the destination is beyond their communication range, then these vehicles get the support of intermediate vehicles which lie between the source and destination to forward the information packets. The vehicles keep storing some information regarding their vicinity on their local memory units which can used by the querying vehicles on demand via wireless communication. This information can be the traffic status of a road, road-under-construction alert, road-accident prediction, locating the market, or restaurants, getting optimal route to a place and much more.

To communicate with the beyond-range vehicles, store-and-carry strategy is used, where vehicles keep forwarding the information to next suitable hops whenever they come into each other's radio range with an aim to successfully deliver the information to the end point or destination within least time. These vehicles usually lack end-to-end connections due to rapid network structure change, high mobility of vehicles, varying vehicle density on roads and shorter radio ranges. To make the end-to-end vehicles communicate indirectly with each other even beyond the radio range can be done by routing the vehicles with best possible next hop selections. Therefore, effective communication in VANET requires efficient routing for smooth message forwarding. Major hurdles in VANET routing are the rapid mobility of vehicles [18] and frequently changing network structure. VANETs may include mobile node communications as well as fixed infrastructure also communicating with mobile nodes (or vehicle).

Recent advancements have been made in routing protocols to reduce the possible drawbacks of the previously existing ones either by mixing the better qualities of multiple protocols into one or by replacing the pre-established approaches with better ones. Routing protocols may be based on diverse classifications like, a) broadcasting protocols: they have high communication overhead and message congestion in the network [19]; b) route discovery protocols: they are not suitable for time-strict constraints; c) position based protocols: information about neighbors need to be maintained through frequent message exchange between each pair of vehicles, which increases overall communication cost [19]; d) clustering based protocols: only the cluster heads majorly maintain the information of neighboring vehicles, e) infrastructure based protocols: Road-Side Units (RSUs) are slow to deploy including high cost of deployment, f) biology inspired protocols: they attempt to mimic the behavior of organisms in searching food, to accomplish successful routing [14].

In this paper, we review a few protocols based on recent research and some prior ones.

II. POSITION BASED PROTOCOLS

Routing decision is based on the position of vehicles with respect to forwarder vehicle. Traditional position based greedy routing protocols fail due to "Local Maximum Problem (LMP)" when there is no next vehicle in the radio range of the current vehicle for packet

forwarding and the packet delivery fails eventually [17]. Position based protocols perform better than topology based protocols (for instance, AODV and DSR) [17]. A few position-based protocols are discussed below:

A. Geographic Source Routing (GSR) [1]

It uses geographical information for position based routing and the Dijkstra algorithm serves to find the shortest path in graphically represented network. LMP is dealt with by using carry and forward approach. Its limitation is that it does not consider the vehicle density and route connectivity which causes higher probability of LMP.

B. Anchor based Street and Traffic Aware Routing with Statically Rated map (A-STAR-SR) [2]

Selection of anchor path includes the analysis of route information. Whenever LMP occurs, the intersection (or vehicle) is declared "Out of Service" for some time and new anchor path is calculation. The limitation says that the simulation is done in only one network of roads and the number of roads and intersections is also not mentioned.

C. Greedy Traffic Aware Routing (GyTAR) [3]

It uses city map and the vehicle density and introduces greedy forwarding strategy by considering direction and speed of the vehicles. Carry and forward approach is used for LMP recovery. Limitations include the limited simulation done and comparison done only with GSR, avoiding the most recent A-STAR-SR protocol of that time.

D. Intersection-based Distance and Traffic-Aware Routing (IDTAR) [4]

Most robust routes are chosen using street map causing a decrease in probability of LMP and hence decreasing the recovery cost in this newer protocol. It considers the vehicle density and source to destination distance to dynamically select the intermediate intersections. Data forwarding is done by adding the next intersection location information in the packet being forwarded by current intersection. Each member maintains and updates a neighbor table by poking the neighbors. In case of LMP, the intersection is declared "Out of Service" till the time LMP stays. Vehicles update their local map with "Out of Service" intersections and avoid them. Hence new anchor point is calculated. A threshold value describes the maximum number of times a packet can be recovered.

IDTAR outperforms all the three protocols in terms of packet delivery ratio because it considers vehicle density in dynamic determination of path and the packet delivery ratio is proportional to vehicle density.

IDTAR outperforms all the three protocols in terms of end-to-end delay because it recalculates new anchors to avoid LMP which is better than carry and forward strategy.

III. CLUSTERING BASED PROTOCOLS

Clustering based routing protocols are one of the best approaches to VANET routing as they significantly reduce the amount of routing message exchange among vehicles as only the cluster head exchanges most of such messages.

A. Clustering based protocols common approaches

- Speed interval based clustering [5]: Speed interval is not a sufficient interval of clustering as the vehicles with speeds 39kmph and 41kmph will be in different clusters if the clusters are based speed intervals 20kmph to 40kmph, 40kmph to 60kmph and so on.
- Distance based centralized cluster management [6]: Distance between the vehicles alone is not enough as clustering criterion. Centralized cluster management will require centralized RSUs, which increases the deployment cost and the communication overhead. A decentralized approach is appreciated.
- Geographical grid based clustering [7]: They do not consider direction and velocity of a vehicle in the cluster. This reduces cluster lifetime.
- Affinity propagation [8]: Vehicles share their identity, velocity and location information to compute affinity function to select a cluster head. This may lead to message congestion in the network.
- Cluster head as the first claimer [5]: It is better to select a cluster head who has best approach to all the cluster members, rather than first come basis as it ignores the change in mobility of other vehicles either inside or outside the cluster.
- Cluster head based on travel time and speed deviation [9]: Vehicles with higher travel time and lower speed deviation is prioritized as the cluster head, vehicles share their self-calculated own priority with each other causing communication overheads.
- Cluster head based on velocity and location [10]: Vehicles need to send frequent updates of their velocities and location to neighboring vehicles, which increases the communication throughput.

Two clustering based routing protocols are discussed below, most recent one is the MoZo protocol with lower communication overhead and higher delivery rate.

B. Clustering Based Directional Routing Protocol (CBDRP) [11]

Clustering is done based on equal length segments of roads. Vehicles with same road segment and same direction are clustered together. Cluster member closest to the center is the cluster head. Whenever a message is to be sent to the member vehicle of some other cluster, the source member vehicle sends the message to its cluster head, cluster head then sets the path towards destination and then forwards the message. Limitations of this protocol are: a) fixed segmenting of roads ignores the vehicle mobility, leads to frequent message sharing between vehicles and cluster head causes large communication overhead, b) beforehand path establishment also requires path maintenance and long path becomes the worst situation. Long distance causes longer delay.

C. Moving Zone (MoZo) base routing [12]

In this newer approach, clustering is done based on vehicle's movement as a linear function of time, vehicle's direction of movement, it's speed and location. Movement function is a better metric than position alone. The Captain Vehicle (CV) maintains the moving object index, while the Member Vehicle (MV) sends timely updates to the CV. During VANET entry, a vehicle sends hello to nearby CVs along with its own information to join their zone, those CVs reply their own information to

the vehicle. The vehicle then calculates the similarity scores of different CVs and it selects the highest scoring CV. It becomes the MV of that CV's zone after executing joining request. The CVs of the other hand keep track of all the MVs of their zone in a Combination Location and Velocity Tree (CLV-tree) and a Leaving Queue Event (LQE). LQE contains the vehicle's leaving timestamps. The vehicle whose timestamp ends, is informed by the CV about its splitting. Managing vehicle updates, CV reassignment, zone splitting and merging, they all work separately to keep the communication overhead low by reducing the number of exchanged messages.

This protocol works by initiating a message from source MV, transferring it to the CV, calculation of MV of same zone nearest to the destination vehicle (using Dijkstra for shortest path). Now, this nearest MV is responsible for transferring the message to nearby moving zone (either to an MV or to the CV of another zone). If an MV receives the message, it forwards it to the CV of its zone.

IV. BIOLOGY INSPIRED PROTOCOLS

Patterns in the behaviors of tiny organisms have gained lots of attention since, these simple organisms can perform complex tasks without the use of any complex algorithm [14]. Their food search simply depends upon finding the optimal routes leading to their food through the secretion of bio-enzymes called "pheromones" [13] to which, the members of same species get attracted. Work of single organism in not worthy but when they work in groups, they perform amazing tasks. This is usually listed under "Swarm Intelligence algorithms". They are highly suitable for NP-complete problems. Heuristic algorithms and computational algorithms like Particle Swarm Optimization based differential evolution neighborhood field optimization and Artificial Bee Colony (ABC) have been previously used. Two recent protocols are discussed below:

A. Micro Artificial Bee Colony (MABC) based Routing

This is a multicast routing approach, used in case of sensor failure, highly mobile vehicles or vehicle breakdown where source to destination paths need to frequently reconstructed. Source broadcasts in multicast routing, rather than finding just one next hop. MABC [15] maximizes the network lifetime and minimize the delay cost. It is a modified version of ABC to tackle with Steiner Minimum Tree Problem in multicast routing in a binary form. Computational time is saved by using micro population instead of regular colony size.

Steiner Minimum Tree (SMT) is built after considering the Steiner Points between the source to destination nodes in a graphical view of the VANET. Steiner Points are the points which lie between the source and destination and SMT attempts to select only those Steiner Points which keep the communication cost lesser. The function value of each solution is the sum of corresponding tree's energy consumption function and transmission delay cost function:

$$f(x_i) = c(T)^s + c(T)^d,$$

where T is the corresponding SMT of solution x_i.

The MABC consists of 3 stages in each cycle just like the natural bee colony. These are – a) Employed Bee stage, b) Onlooker Bee stage, c) Scout Bee stage. All the three bee groups are sent one after the other to search for food with an aim to minimize the objective function and maximize the fitness function. Similarly, artificially, a) the employed bees generate fitness function for each of the solutions available, b) the onlooker bees choose the best solution out of those based on the fitness value, c) the scout bee searches the next solution space to get a solution with better fitness compared to the currently held fitness value this is done by checking the value of Limit flag which signifies if a solution can still be updated or not after multiple evaluations. Physically, it means that the bees will traverse the space in a tree like path moving towards better solutions while moving away from worse solutions to reach the destination within an economical computational time and minimized delay cost.

B. Security Aware Fuzzy Embedded ACO (SAFACO) based routing

SAFACO routing protocol [16] integrates Digital Signature Authentication Mechanism with Fuzzy logic embedded ACO to deal with the activities of malicious vehicles in a VANET. The protocol is yet to be simulated under a suitable simulator. It can deal with four types of attacks – a) when a vehicle returns fake information to the querying vehicle (Masquerading attack), b) when a vehicle disrupts the communication by modifying the information packets (harming data consistency), c) when a vehicle steals the confidential information like electronic license plate information of a vehicle by evaporating the data packets (privacy disclosure), d) when a vehicle drops the query received from another vehicle to save energy (selfishness which challenges the core idea of setting up a VANET).

This protocol uses ACO [13] for choosing the next hop, which works on the pheromone values of vehicles. The fuzzy logic, which is well suited for decision making procedures based on assigning fitness values to the solutions and then picking up the solution with highest fitness, is used in integration with ACO. It is considered that fuzzy decision making is based on a valid and accurate model i.e. Fuzzy Logic System, and hence it is willing to make better decisions. It includes Digital Signature based authentication mechanism for tackling with a) & b) types of attacks; sharing of Anonymous Key Pairs for type c) attacks; and using fuzzy logic algorithm to recognize the selfish vehicles and abandon them.

- Authentication: Elliptic Curve Cryptography (ECC) is used for digital signatures. The sender vehicle signs the message with private key and public key certificate issued by the Certificate Authority (CA). The receiver extracts the sender's public key by using his own public key with the sender's certificate. It verifies if the sender's signatures match his public key. The attacker can masquerade the actual sender but cannot create the sender's signatures in the absence of its private key.
- Data consistency: Altering the data consistency requires sender's private key.
- Privacy: Unique public-private key pairs hide the vehicle's identity and its location.
- Detection of malicious vehicles: A sender sends Forward ANTs (FANTs) to the next vehicle and the next vehicles sends back the Backward ANTs (BANTs) through the same path. The ANTs record the packet drop rate, authentication fail rate, link

stability and packet transmission delay information into a fuzzy system. Fuzzy system provides a Trust Value to each vehicle based on these metrics, which is further used to calculate its Pheromone (Ph) Value. New Ph value of a vehicle is a function of its old Ph and new Trust Value. A vehicle that selfishly drops the received FANTs, gets lowered Pheromone Value than a predefined threshold and is isolated from the network by the normal vehicles.

Table I. summarizes the latest routing protocols.

Table I. Latest protocols in a nutshell

Sr. No.	*Routing Protocol*	*Approach used*	*Results*
1	Intersection based Distance and Traffic Aware Routing (IDTAR)	It considers vehicle density and selects the next vehicle hops dynamically. "Local Maximum Problem (LMP)" causing vehicles are avoided beforehand.	Increment in packet delivery ratio and decrement in end-to-end delay.
2	Moving Zone (MoZo) based routing	It uses cluster based message forwarding where the Captain Vehicle monitors the nearby vehicles with their consent based on their movement function.	Cut off communication overhead and inflated delivery rate.
3	Micro Artificial Bee Colony (MABC) based routing	Steiner Minimum Tree based network traversal is done by the micro population and the Steiner points are selected considering the communication cost to be minimum. Bees keep moving towards the destination optimally.	Deflated energy consumption cost, computational time consequently delay cost.
4	Security Aware Fuzzy embedded ACO (SAFACO) based routing	It uses digital signature generation for security and uses Ant Colony Optimization (ACO) based on fuzzy decision making by simply fuzzifying the pheromone values of each vehicle. ACO also serves in security against selfish vehicles.	Expectedly more secure network with advanced problem handling technique like fuzzy decision making and optimization using ACO.

V. CONCLUSION AND FUTURE SCOPE

Clustering based routing protocols are well performing to reduce the message flooding in the network by the centralizing the control within the zones. Whereas the biology inspired protocols reduce the cost energy consumption. These may be further harmonized to get the more optimal results.

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