Vehicular Ad-hoc Networks (VANETs) is a revolutionary concept in the field of wireless communications where on-road vehicles communicate with each other and with roadside embedded sensor equipment through their On-Board Units (OBU) with an objective to smoothen the drive experience. VANETs are 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.

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 roadside 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 be 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 Static route 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 velocity and introduces greedy forwarding strategy by considering direction and speed of the vehicle. 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
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 is 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:

\[ f(x_i) = c(T)^{e} + c(T)^{d}, \]

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 (privacy 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 to the currently held fitness value.
- 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 1. 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.

VI. REFERENCES

[1] Locher,C., Hartenstein,H., Tian,J., Fussler.H., Hermann.D., Mauve,M., “A routing strategy for vehicular ad hoc networks in city environments”, Intelligent Vehicles Symposium, in Proceedings, IEEE, June 2003.
[2] Seet.B.-C., Liu,G., Lee.B.-S., Foh.C.H., Wong.K.J. and Lee.K.-K., “A-STAR: A Mobile Ad Hoc Routing Strategy for Metropolis Vehicular Communications”, NETWORKING 04, 2004.
[3] Jerbi.M, Senouci.S.M., Meraiki.R and Ghamri-Doudane.Y, “An improved vehicular ad hoc routing protocol for city environments”; in Communications (ICC 07), IEEE International Conference, pp. 3972–3979, June 2007.
[4] Ahmed, Abdelmuttlib Ibrahim Abdalla, et al. "Intersection-based Distance and Traffic-Aware Routing (IDTAR) protocol for smart vehicular communication." Wireless Communications and Mobile Computing Conference (IWCMC), 2017 13th International. IEEE, 2017.
[5] O. Kayis and T. Acarman, “Clustering formation for inter-vehicle communication,” in IEEE Intelligence Transportation Systems Conference, 2007, pp. 636–641.
[6] J.Chen, C. Lai, X. Meng, J. Xu, and H. Hu, “Clustering moving objects in spatial networks,” in International Conference on database systems for advanced applications, 2007, pp. 611-623.
[7] Y. Luo, W. Zhang, and Y. Hu, “A new cluster based routing protocol for vanet,” in International Conference on Network Security Wireless Communications and Trusted Computing, 2010, pp. 176–180.
[8] C. Shea, B. Hassanabadi, S. Valae, “Mobility-based clustering in VANETs using affinity propagation”, in IEEE Global Telecommunications Conference, 2010, pp. 1–6.
[9] Z. Wang, L. Liu, M. Zhou, and N. Ansari, “A position-based clustering technique for ad-hoc intervehicle communication,” IEEE Transactions on systems, vol. 38(2), p. 201, 2008.
[10] R. Goonewardene, F. Ali, and E. Stipidis, “Robust mobility adaptive clustering scheme with support for geographic routing for vehicular ad hoc networks,” IET Intelligent Transport Systems, vol. 3, no. 2, pp. 148–158, 2009.
[11] T. Song, W. Xiz, T. Song, and L. Shen, “A cluster-based directional routing protocol in vanet,” in IEEE International Conference on Communication Technology, 2010, pp. 1172–1175.
[12] Lin, Dan, et al. "MoZo: A Moving Zone Based Routing Protocol Using Pure V2V Communication in VANETs." IEEE Transactions on Mobile Computing16.5 (2017): 1357-1370.
[13] Prabha, Chander, Ravinder Khanna, and Surender Kumar. "Optimising social information by game theory and ant colony method to enhance routing protocol in opportunistic networks." Perspectives in Science 8 (2016): 658-660.
[14] Bitam, Salim, Abdelhamid Mellouk, and Sherali Zeadally. "Bio-inspired routing algorithms survey for vehicular ad hoc networks." IEEE Communications Surveys & Tutorials 17.2 (2015): 843-867.
[15] Zhang, Xiu, Xin Zhang, and Cheng Gu. "A micro-artificial bee colony based multicast routing in vehicular ad hoc networks." Ad Hoc Networks 58 (2017): 213-221.
[16] Zhang, Hang, Xi Wang, and Dieter Hogrefe. "A Security Aware Fuzzy Embedded ACO Based Routing Protocol (SAFACO) in VANETs." International Conference on Information Science and Applications. Springer, Singapore, 2017.
[17] Liu, Jianqi, et al. "A survey on position-based routing for vehicular ad hoc networks." IEEE Communications Surveys & Tutorials 17.2 (2015): 843-867.
[18] Singh, Surmukh, and Sunil Agrawal. "VANET routing protocols: Issues and challenges." Engineering and Computational Sciences (RAECS), 2014 Recent Advances in. IEEE, 2014.
[19] Ghafoor, Huma, and Khurram Aziz. "Position-based and geocast routing protocols in VANETs." Emerging Technologies (ICET), 2011 7th International Conference on. IEEE, 2011.