Bee Optimized Fuzzy Geographical Routing Protocol for VANET

P. Saravanan, T. Arunkumar

Abstract—Vehicular Adhoc Network (VANET) is a new technology which aims to ensure intelligent inter-vehicle communications, seamless internet connectivity leading to improved road safety, essential alerts, and access to comfort and entertainment. VANET operations are hindered by mobile node's (vehicles) uncertain mobility. Routing algorithms use metrics to evaluate which path is best for packets to travel. Metrics like path length (hop count), delay, reliability, bandwidth, and load determine optimal route. The proposed scheme exploits link quality, traffic density, and intersections as routing metrics to determine next hop. This study enhances Geographical Routing Protocol (GRP) using fuzzy controllers while rules are optimized with Bee Swarm Optimization (BSO). Simulations results are compared to conventional GRP.

Keywords—Bee Swarm Optimization (BSO), Geographical Routing Protocol (GRP), Vehicular Adhoc Network (VANET).

I. INTRODUCTION

VANET, which is a vehicle to vehicle and vehicle to roadside wireless communication network, is a special MANET type which is autonomous and self-organizing wireless communication network, where nodes are servers and/or clients to exchange and share information. VANET network architecture is classified as pure cellular/WLAN, pure adhoc, and hybrid. VANET has unique characteristics which differentiate it from MANET. Designing VANET applications is also a challenge [1].

Communication between vehicles or between vehicle and a Road Side Unit (RSU) is through a wireless medium called Wireless Access in Vehicular Environments (WAVE) which ensures a range of information to drivers/travellers enabling safety applications to improve road safety and driving. On Board Unit (OBU), Application Unit (AU), and RSU [2] are main system components. RSU hosts an application which ensures services and OBU is a peer device using provided services. Application may reside in RSU or OBU; the device hosting the application is the provider and that which uses the application is user.

Every node in a VANET is both participant and network router, as nodes communicate with each other via intermediate node that are in transmission range. In VANETs vehicles are nodes [3]. Unlike MANET, vehicles move on predefined roads and vehicle velocity is based on speed signs. Vehicles have to follow traffic signs and signals. Many VANET challenges need to be solved to ensure reliable services. A

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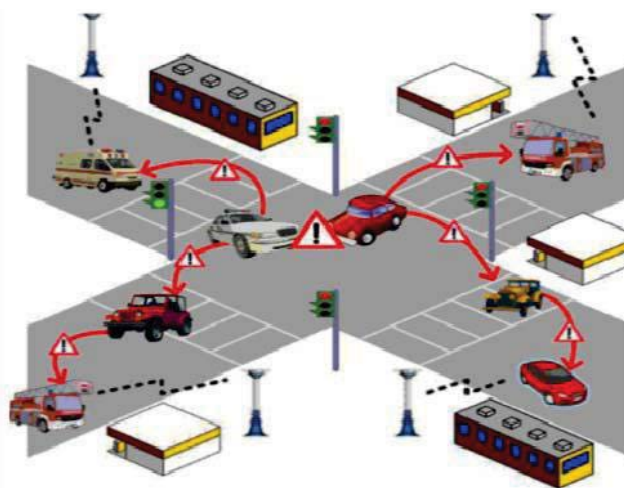
major issue is stable and reliable VANET routing.

Fig. 1 Vehicular Ad hoc Networks Scenario

Routing protocols control how nodes route incoming packets between devices in wireless domain and also distinguish the types. VANET routing shows different features from regular adhoc networks. First vehicle mobility is restricted by road layout, other vehicles movement and rules. External factors like weather and time frame also affect it [4]. Due to many vehicles participating in a VANET, routing protocols should be local to ensure scalability, as vehicles routing decisions are based on information available in close vicinity. Hence, exchanging information with neighboring vehicles through beacon message is a basic part of routing protocol as vehicles get position information from GPS and Galilo.

VANET routing protocols are broadcast, unicast, multicast, geocast or hierarchical. Routing strategies are either proactive following table driven approaches or reactive, where routes discovery is on demand using on-the-fly techniques. Data packet transmission in unicast routing protocols is from one source to one destination. Unicast routing protocols are further divided into position based, topology based, cluster based and hybrid protocols.

A node's forwarding decision is based on position of a packet's destination and position of node's one-hop neighbors in geographic (position-based) routing. Destination position is stored in packet header by source. Node's one-hop neighbor's position is got by beacons sent from time to time with random jitter (to prevent collision). Greedy Perimeter Stateless Routing (GPSR) chooses a node closest to final destination by using beacon. Greedy forwarding algorithm is resorted to if it

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fails when it uses perimeter forwarding to select a node through which a packet travels [5]-[7].

Geographic routing is promising for large-scale wireless adhoc networks due to its simplicity, scalability and its taking advantage of nodes location information which makes it valuable for wireless networks. GRP work assuming that nodes are aware of their network positions; via GPS or distributed localization schemes. Also, network's physical topology is a good approximation of network connectivity [8]. An advantage of geographic routing schemes is there being no need to send out route requests/connectivity updates saving protocol overhead, and so nodes energy.

GRP scale better for adhoc networks [9] because there is no necessity to update routing tables, and for a global network topology view and its changes. This allows routers to be stateless as forwarding decisions are destination location information based and that of all its one-hop neighbours. Most protocols keep state only about local topology (neighbours' location information). Routing tables are not constructed. So, route establishment and maintenance are not required thereby reducing overhead.

Greedy Perimeter Stateless Routing (GPSR) is a popular GRP in adhoc networks [10] which uses network node's location to selectively forward packets based on distance. Greedy Other Adaptive Face Routing (GOAFR) algorithm begins with greedy forwarding but changes to face routing on reaching a local minimum regarding distance of current node from destination. Geographic and Energy Aware Routing (GEAR) protocol assumes localization system and targets increased network life.

Greedy Traffic Aware Routing protocol (GyTAR) is a new intersection-based GRP to locate robust routes in city environments. Various junctions are chosen dynamically one by one for traversing a packet to reach destination and vehicular traffic variation, destination distance are considered in GyTAR. When destination junction is determined, improved greedy strategy forwards packets to selected junctions [11]. On receipt of a packet a vehicle computes its next junction with highest score considering traffic density and curve-metric distance to destination. Junction with highest score is geographically close to destination vehicle and has highest vehicular traffic. Between two adjacent junctions, packets are forwarded through vehicles between successive junctions through improved greedy forwarding [12].

Each vehicle has a table containing position, velocity and direction of neighbouring vehicles, the table being updated through periodic exchanges of HELLO messages among vehicles. Using table information, forwarding vehicles select next hop neighbour closest to destination junction. GyTAR uses real time traffic density and movement prediction information to forward packet to VANET destinations through V2V communications [13]. So, GyTAR protocol can forward packet successfully to destinations along streets where there are many vehicles ensuring connectivity.

Fuzzy logic is a precise logic dealing with information of sets with no rigid boundaries, which are also called Fuzzy Sets. Fuzzy logic is a generalization of multivalued logics, which are generalizations of bivalent logics. While no degree of truth (or membership) is allowed in bivalent logics, only true or false is possible in multivalued logics to define intermediate values. Linguistic variables ensure ability to express common measures in natural language formally. If-then rules, which use linguistic variables, ensure a way to describe desired behaviours according to situations with associated imprecision. Knowledge to deal with known situation is modeled through this to automatize decision process.

A knowledge database is a set of if-then rules, which using natural language describes all reactions a system must have when faced with specific situations [14]. A fuzzy logic controller has 4 components [15]: rule base, fuzzification interface, inference mechanism and defuzzification interface. When activated at k-th instant, fuzzification interface translates numeric inputs $e(k)$ and $de(k)$ to fuzzy sets illustrating linguistic variables E and DE. Inference mechanism applies a predetermined linguistic rules set in rule-base regarding linguistic variables producing fuzzy sets of output linguistic variable DH. Finally, defuzzification interface converts fuzzy conclusions when inference mechanism reaches a numeric value $dh(k)$.
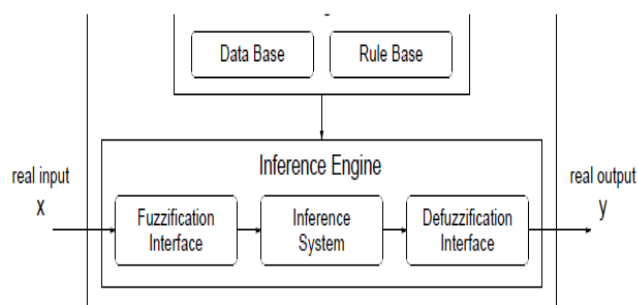

Fig. 2 Generic structure of a linguistic Fuzzy Rule-Based System

Fuzzy rule generation methods are split into 2 approaches based on strategies to divide input space into fuzzy subspaces. One is a grid-type fuzzy partitions based approach where each input's domain interval is divided into antecedent fuzzy sets with linguistic labels. The next approach uses input space [16] defined multidimensional antecedent fuzzy sets. A two-stage fuzzy rule selection approach is proposed in literature. Heuristic rule extraction is the first stage where tractable promising candidate rules are extracted from numerical data with a heuristic rule evaluation measure similar to data mining. Evolutionary rule selection is the second stage where evolutionary optimization algorithms find extracted candidate rules non-dominated subsets regarding accuracy and complexity [17].

This study proposes a routing algorithm named Fuzzy QoS GRP (FQ_GRP) and extended for rule selection using BSO. The fuzzy controller output is next hop selection. Using this, traffic is distributed through nodes to increase throughput and lower average latency. Section II reviews related works in literature. Section III describes methods used in the work. Section IV explains the experimental results and Section V

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concludes the work.

II. Related Works

A vehicular mobility model replicating real-world vehicle movement was suggested by [18] who studied packet-routing protocols performance. A two-phase routing protocol incorporating road map information was introduced. The new protocol defined an overlay graph with high vehicular density roads and access graphs connected to the overlay. To validate the new design philosophy and routing protocol, various areas were used in Orlando city, Florida generating vehicular mobility traces, following the new mobility models. Traces were fed to network simulators and routing behavior studied. Simulation proved the proposed routing protocols performance and effectiveness for large-scale VANET scenarios.

Using VANETs to collect and aggregate real-time position and speed information on individual vehicles to improve signal control at traffic intersections was proposed by [19]. An online algorithm assuming that all jobs were of equal size was given, and called Oldest Job First (OJF) algorithm, to reduce intersection delays. Simulation revealed that under light and medium traffic loads, OJF algorithm reduced vehicles delays when they pass through an intersection compared to vehicle-actuated methods, Webster's method and pre-timed signal control methods.

An experiment in Beijing city involving tens of thousands of operational taxis was carried out by [20]. Observations provide fundamental guidelines to design new, urban VANET routing protocols and performance evaluation.

An analytical model to evaluate performance of emergency messaging through wireless Collision Avoidance (CA) systems was proposed by [21]. The model's numerical results showed that number of car crashes per accident was much higher when wireless CA system was not used. The new model ensured useful insights for future intelligent transportation through integration of flow theory into VANET analysis.

A weight-of-evidence-based classification algorithm to identify different road traffic conditions was presented by [22] which was tested using data generated by microscopic modeling of traffic flow, simulating adhoc networks vehicle mobility. Test results depicted, vehicles different percentage levels all having communication capability.

The steady-state statistical properties of continuous communication path availability in VANETs were studied by [23]. Mean durations of continuous availability/unavailability times and mean packet delay for end-to-end communications in paths was presented. Numerical results illustrated effects of mobility/traffic arrival process on continued communication path availability and packet delay. Results revealed that path availability, mean packet delay, and mean durations increased with increasing transmission range. Analytical results were compared with available experimental studies and verified through 2 different simulation approaches.

An Opportunistic Service Differentiation (OSD) scheme as an improvement to WAVE proposed by [24] entailed designing a linear programming model for OSD scheme verification. A study of OSD-enhanced WAVE and classical WAVE was performed analytically in a VANET simulator. Both simulation and analytical results substantiated improved performance of OSD-enhanced WAVE over classical WAVE.

A Distributed Multichannel and Mobility-Aware Cluster-based (DMMAC) protocol was proposed by [25]. DMMAC's reliability and connectivity were analyzed regarding average cluster size, communication range in a cluster and between Cluster Heads (CHs), and path life. Simulation revealed the new protocol supporting traffic safety, increasing VANET's efficiency, reliability and stability of cluster topology by increasing CH's life and members dwell time.

A mobility model based on product-form queuing networks for VANETs proposed by [26] represented a sparse VANET situation. The new model's flexibility was shown through many numerical examples and confirmed through simulation.

A VANET security system to achieve traceability required by law enforcement authorities and privacy desired by vehicles was proposed by [27], in addition to satisfying fundamental security requirements like non-repudiation, authentication, confidentiality, and message integrity. A privacy-preserving defense technique to handle VANET access misbehavior was proposed, as privacy provides avenue for misbehavior. The proposed system's fulfillment and feasibility was shown regarding security goals and efficiency.

An efficient routing protocol that found minimum possible path length between source and destination involving minimum nodes for data transmission was developed by [28]. The new protocol was compared with Dynamic Source Routing (DSR) and DSR with Stale Route Removed (DSR-SRR). Implementing the new protocol established that the new protocol was better than DSR and DSR-SRR regarding (i) average power consumed during transmission, (ii) transmission throughput and (iii) control packets used. The new protocol worked relatively efficiently under dense traffic conditions.

A routing architecture for VANETs was presented by [29]. A very important technical feature for VANET routing was grouped in routing architecture. To validate the new architecture many current protocols were unified in architecture producing a new VANET routing protocol. Generic Vehicular Dynamic Source Routing (GVDSR) is the produced protocol. GVDSR simulations were made in Malaga city revealing routing performance contributions and advantages. The new architecture was simulated in NS 2 featuring improved performance compared to other protocols.

Road-Based using Vehicular Traffic (RBVT) routing presented by [30], outperformed current routing protocols in city-based VANETs. A reactive protocol RBVT-R and proactive protocol RBVT-P were designed, implemented and compared with protocols representing MANETs and VANETs. Simulation in urban settings proved that RBVT-R performed best regarding average delivery rate with up to 40% increase compared to current protocols. As regards average delay, RBVT-P performed best, with 85% decrease compared to other protocols.

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A new clustering scheme called Robust Mobility Adaptive Clustering (RMAC) to enable and manage highly dynamic VANETs for future 'ITS' was proposed by [31]. Simulations proved that RMAC on IEEE802.11 adhoc WLAN protocol was highly effective in a highly dynamic VANETs environment, as it was robust on link failures, having very high cluster residence time compared to popular distributed mobility clustering scheme.

A new hybrid location-based routing protocol was proposed by [32]. The new protocol had features of reactive and location-based geographic routings that efficiently used all available location information. The protocol was meant to exit reactive routing when location information degraded. Analysis and simulation proved that the new protocol was scalable and had optimal overhead, even when high location errors were present. The new protocol ensured enhanced and pragmatic location-enabled solution deployable in all VANET environments.

A survey of Vehicle-to-Vehicle (V2V) MAC methods (including VANET standards) proposed for VANETs over years was presented by [33]. The authors focused on benefits and limitations of new MAC techniques and ease of implementation in practice and deployment. Also discussed were challenges that needed to be addressed to ensure implementation of efficient and high performance MAC protocols for V2V communications. Finally, innovative solutions to address challenges were proposed.

III. METHODOLOGY

In this paper, it is proposed to select Fuzzy Rule using Bee Swarm Optimization (BSO). MFs tuning, needs an initial model with many rules to get appropriate accuracy. To obtain many initial rules, methods which ensure covering levels higher than needed are used. This way, rules are obtained that at first are unnecessary once tuning is applied or rules that impede tuning of remaining ones to get global optimum regarding accuracy (better rules configuration to get minimum error after parameters tuning). So, the following rules are found regarding global optimum in complete rules set: Bad Rules (erroneous or conflicting rules) which degrade system performance (rules not included in most accurate final solution); Redundant or Irrelevant Rules that do not improve system performance; Complementary Rules that complement others slightly improving system performance; and Important Rules which should not be removed to get reasonable system performance. Obviously, this is a simplification only considering in principle most accurate solution to have an idea of the optimum Pareto shape. But, to determine rules types in advance is impossible as it directly depends on every concrete rules configuration and more on the optimal MF parameters configuration for every rule configuration. Hence, it is impossible to establish any criteria for use in search process [34].

Genetic fuzzy system is the current, best-known evolutionary fuzzy system and it is the focus of many studies. In contrast to evolutionary algorithms, a new swarm intelligence optimization technique, Artificial Bee Colony (ABC) [35], [36] optimization is used. In this optimization algorithm, a possible solution is obtained based on the position of the food source and the fitness of the solution is identified using the nectar amount of food source obtained. Number of employed/onlooker bees can be identified based on the number of solutions in population presented. BSO algorithm can be used to minimize the number of fuzzy rules. The fitness value finds the probability of occurrence of each rule and then it is optimized by the fuzzy association rule. To find the best rule, fitness value is obtained for each rule.

The fitness value is a function of which solutions is tested for its suitability to the problem in hand. After producing v_i within the boundaries, a fitness value for a minimization problem can be calculated to the solution v_i by (1):

$$Fitness_i = \left. \begin{array}{l} 1/(1+f_i) \text{ if } f_i \geq 0 \\ 1+abs(f_i) \text{ if } f_i < 0 \end{array} \right\} \qquad (1)$$

The steps involved in this process are:
- Initialize the population of rules
- Evaluate the population
Cycle = 1
- Repeat
- Produce new solutions for the employed bees by using (2):

$$v_{ij} = X_{ij} + \phi_{ij}(X_{ij} - X_{kj}) \qquad (2)$$

- Apply greedy selection process for the employed bees
- Calculate the probability values $P_{i,j}$ for the rules $x_{i,j}$ using fitness of the solution as in (3):

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \qquad (3)$$

- For each onlooker bee, produce a new solution v_i by (4):

$$v_{ij} = X_{ij} + \phi_{ij}(X_{ij} - X_{kj}) \qquad (4)$$

- In the neighborhood of the solution selected depending on p_i and evaluate it
- Apply selection process between v_i and x_i based on greedy method for onlooker bee
- If Scout Production Period (SPP) is completed, determine the abandoned solutions by using-limit parameter for the scout, if it exists, replace it with a new randomly produced solution by (5):

$$X_i^j = X_{min}^j + rand[0,1](X_{max}^j - X_{min}^j) \qquad (5)$$

- Memorize the best solution achieved so far
- Cycle = cycle + 1
- Until cycle = MCN

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The basic rule formulation [37] is that the knowledge base comprises of a rule base. This helps to categorize the control policy and goals. The rules form is:

$$\text{Rule 1 if x is } A_1, \text{ then f(x) is } B_1$$
$$\text{Rule 2 if x is } A_2, \text{ then f(x) is } B_2$$
$$\text{...}$$
$$\text{Rule N if x is } A_N, \text{ then f(x) is } B_N$$

where x and f(x) means the independent and dependent variables, A_i and B_i are constants. This rule is named as "if-the-rules" since it is in that form. "if" is the antecedent and "then" is the consequences.

To apply BSO algorithms to fuzzy rule problem, it should be seen as a combinatorial optimization problem capable of graphic representation.

To construct graph, the following steps are needed:

Determine rules: A rule R_i and $i=1,...,N_r$ defined by an antecedent combination,

R_i: IF X_1 is A_{i1} and ... and X_n is A_{in}, Will take part in graph only if:

$$\exists e_1 = \left(x_1^l,...,x_n^l, y^l \right) \in E \text{ such that } \mu_{A_{in}}\left(x_n^l \right) \neq 0 \qquad (6)$$

i.e. there is at least one example located in fuzzy input subspace defined by antecedents in rule.

Link rules to consequents: Rule R_i will be linked to consequent B_j and $j = 1,...,N_c$,(taken from set of labels of output fuzzy partition) only if it meets the condition:

$$\exists e_1 = \left(x_1^l,...,x_n^l, y^l \right) \in E \text{ such that } \mu_{A_{i1}}\left(x_1^l \right) \; ...$$
$$\mu_{A_{in}}\left(x_n^l \right) \mu_{B_j}\left(y^l \right) \neq 0 \qquad (7)$$

That there is at least one example located in fuzzy input subspace covered by such a consequent.

IV. RESULTS AND DISCUSSION

Simulations are conducted for 40 nodes with one base station situated in around 9 square kilometers. Geographical Routing, Proposed ABC method and Fuzzy QoS GRP are applied. For results comparison, parameters like retransmission attempts, throughput, end to end delay, hops number to destination and control overheads are considered. Figs. 3-7 show a graphical representation of results.

The proposed BSO method increased throughput by 59.76% when compared with GRP and by 7.79% when compared with ACO Fuzzy GRP.

The proposed ABC method increased Retransmission attempts by 23.24% when compared with GRP and by 1.33% when compared with ACO Fuzzy based GRP.

The proposed method decreased End to end delay by 8.26% when compared with GRP and by 1.25% when compared with ACO Fuzzy based GRP.

The proposed ABC method has higher control packet overheads by 20.95% when compared with GRP and less by 1.33% when compared with ACO Fuzzy based GRP.
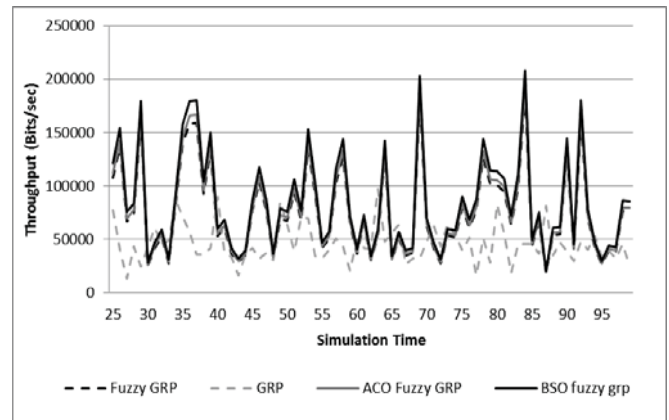
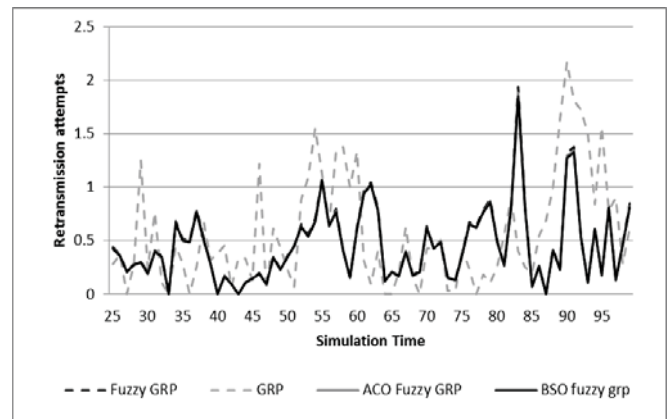

Fig. 3 Throughput in bits/second
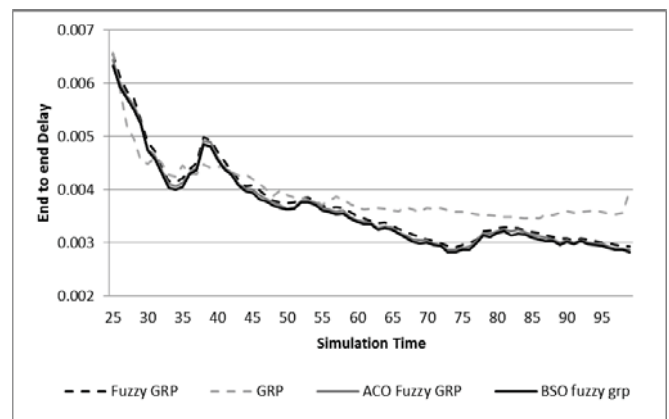

Fig. 4 Retransmission attempts (packets)

Fig. 5 End to end delay in seconds

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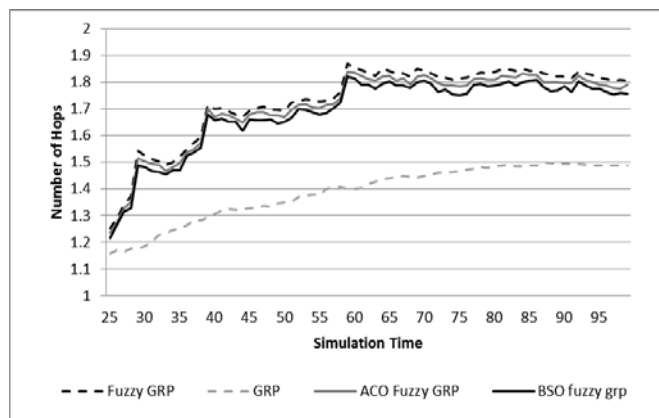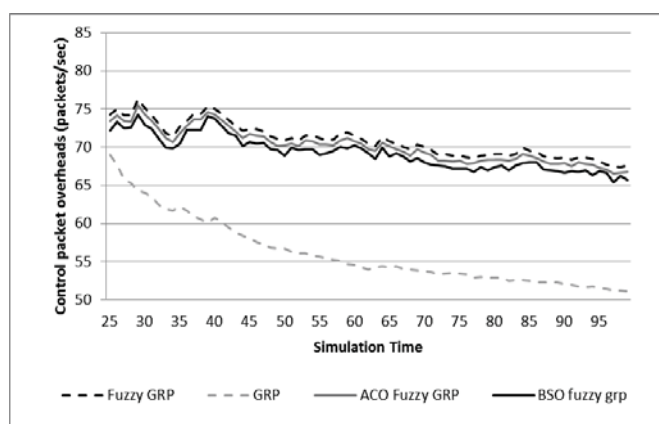Vol:8, No:12, 2014

Fig. 6 Number of hops

Fig. 7 Control packet overheads in packets/sec

V. CONCLUSION

Similar to MANETs, VANET nodes self-organize and self-manage information in a distributed fashion without central authority or a communication dictating server. This study conducted simulations with 40 nodes and with one station situated in around 9 square kilometers. Throughput in bits /second, end to end delay, retransmission attempts, control packet overheads in packets and hops number of the new method are compared with GRP and Fuzzy GRP. The results reveal that the proposed GRP's average throughput increased by 52.58% when compared to conventional GRP and by 4.2035% when compared with Fuzzy based GRP.

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