Broadcast Scheduling Problem in VANETs: A Discrete Genetic Algorithm Approach

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Abstract*: *Mainstream Vehicular Ad-hoc networks (VANETs) are driving itself to the new era of Internet of Vehicles (IoV) which forms a major component in the revolutionary Internet of Things (IoT). With the recent improvements in the field of communication, controls and embedded system; vehicles these days act as a moving sensor. These vehicles get the ability to sense the information in the environment and are able to broadcast it to other vehicles and the infrastructure around. Like many other peripherals of Internet of Things (e.g., Smart City), the IoV will have the communications, storage, and artificial intelligence to aid the vehicle driver. Attracting a number of researchers and industries to work on this particular field, IoV has turned into a supreme research area. In this paper the problem of broadcast scheduling among the vehicles is addressed. Since there is an extensive usage of broadcast communication between the connected vehicles, the issue of scheduling for TDMA based VANETs is investigated. The proposed methodology utilizes an evolutionary approach to deal with the Broadcast Scheduling Problem (BSP). A discrete Genetic algorithm (dGA) was chosen to solve the issue and improve the transmissions in optimal time slots with increased channel utilization. On comparing with other TDMA based algorithms as mentioned in the literature, the proposed dGA increases the number of transmissions by reducing the TDMA channel length.

Index Terms*: *IoV, Genetic Algorithm, Intelligent Transport System, TDMA, VANET.

I. INTRODUCTION

Intelligent Transport Systems (ITS) form an essential part of Internet of Vehicles (IoV). Vehicular Adhoc Networks has received substantial attention from the researchers in academia as well as automobile industry all over the world [1, 2]. VANET increases the ability to enhance safety in transportation, communication between the vehicles and infrastructure, productivity and security. VANETs help in improving driver's decision making which is a key focus in Internet of Vehicles (IoV) [3]. Federal Communications Commissions (FCC), in the United States has designated 75 MHz bandwidth at 5.9 GHz band called dedicated short-range communication (DSRC) [4]. DSRC offers a data rate between 6-27 Mbps with two channels – a control channel (CCH) and a service channel (SCH). The control channel is employed for critical and safety messages, six service channels for non-safety allied data communication [5]. Wireless Access in Vehicular Environments (WAVE) established on IEEE 802.11p is the latest wireless standard for VANETs. An essential attribute of WAVE is that, the Road Side Units (RSU) which acts as static nodes are also considered in the network [6]. Researchers have started to work on nature inspired algorithm for challenges and issues faced in VANETs. Issues like stability, self-organizing, collaborative approach and many other complex problems are solved using evolutionary algorithms. Evolutionary Algorithms are approximation algorithms for optimization. They are extensively used for solving NP-Complete problems [6].

Several MAC protocols are schemed for VANETs based on communication channels which assist inter-vehicle communication aiding the development of applications in IoV [8]. Space Division Multiple Access (SDMA),Time Division Multiple Access (TDMA), and Code division Multiple Access (CDMA) are few major protocols. In SDMA, the channel is allotted on the groundsof the vehicles locations The SDMA protocol has three essential components such as a) road is fragmented into smaller parts addressed as cells, b) mapping of the time slots for each cell and lastly c) specification of the allowed time slots for a particular node. Similarly, CDMA suffers in allocating the Pseudo Noise (PN) code for each and every vehicle. As the density of vehicles increase the pseudo code assigned to the vehicles also increases which results in a long PN code [9]. These issues don't emerge when TDMA is received for communication between vehicles in IoV. ADHOC MAC convention is regulated in a time slots, in which time frames are divided into many slots [14]. The disadvantage of ADHOC MAC is that it functions in anindividual channel; however, DSRC standard requires seven channels, six for SCH and one CCH.

A probabilistic broadcasting algorithm for VANETs which focuses around three decision parameters in determining the functioning of the proposed broadcasting algorithm, is portrayed in [10]. Collision, propagation time, and the absolute number of transmissions were considered in breaking down the calculation. Notwithstanding, as the quantity of vehicles expands the algorithm endures to perform. A cluster based lightweight TDMA slot assignment algorithm is proposed in [11]. The extended TC-MAC is utilized in a multi-hop cluster and has greater reliability of safety/update messages than WAVE standard. Nonetheless, the problem of hidden terminal has not been addressed. VeMAC [9] proposes to increase the throughput in the control channel significantly. But VeMAC uses two DSRC radios one for SCH and one for CCH which is not according to IEEE802.11/p WAVE standard.

Many algorithms such as VeMAC [9] and ADHOC [10] have pre-defined number of frames which is not very effective in most of the scenarios. It either leads to a shortage of frames or increase in the number of empty frames thereby wasting the available bandwidth. This paper centers around diminishing the number of frames utilized per synchronization interim and to expand the absolute number of transmissions. An ideal broadcasting scheduling should ensure that there is minimal hidden terminal problem as well as collision in accessing the time slots. This instance of BSP has been set up as non-deterministic polynomial

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complete (NP-complete), alternatively not many accomplished algorithms are proven to provide optimum solutions in polynomial time [15].

It is seen in [6, 7] that the evolutionary algorithms are effective in solving problems such as routing protocols, Topology Management, broadcast scheduling. In Most of the cases Evolutionary algorithms seem to provide optimum solutions for NP – complete problems [6, 7]. Among various Evolutionary algorithms present, a discrete Genetic algorithm is chosen for solving the problem of Broadcast scheduling for TDMA based VANETs. On this ground our intention is to structure an effective TDMA based multichannel convention for VANET utilizing genetic algorithm supporting IoV.

With this thought in mind, this paper is arranged as follows. The following section depicts the Broadcast Scheduling in VANETs. Section 3 illustrates the fundamentals of Genetic algorithms and the proposed approach. Section 4 portrays the simulation results and conclusion in section 5

II. SYSTEM MODEL AND ASSUMPTIONS

The System model which has been taken into examination contains a group of vehicles travelling in both the directions and it also has a set of Road Side Units (RSU). The movement of vehicles is divided into two categories, one travelling from left to right and the other travelling from right to left as appeared in the Fig.1 RSUs are considered motionless vehicles with no direction. The Vehicles interact along each other in the network over DSRC with a single transceiver which is embedded on to a device in the car called as the on-board unit (OBU). Global positioning system (GPS) is installed in each and every vehicle for the location information and also for time synchronization with other vehicles and RSU. Mac address of every vehicle is used for their identification in the network. The Vehicular network under study is considered as a clustered network and the synchronization interval between the cluster members and the cluster head is 100ms. In that 100ms, 96ms are the usage time and the remaining 4ms is for the guard interval. This work also mainly focuses on the control channel as it carries safety and critical messages.

The Channel is segregated into time frames having fixed time duration for a particular slot. The quantity of time slots per channel h_n is indicated by l_n, where n = 0, 1, 2 …N. The Index is used for identifying a particular slot on the channel. The channel is then portioned into three arrangements of time slots, 'L' for the vehicles moving in the Left lane and 'R' for the vehicles in the Right lane and 'U' for the RSUs as shown in the Fig.2. All the channels in the model are slot synchronized and it consists of time frames as appeared in the Fig.2. Accordingly, at a specific time each node can decide its position in the present slot inside the frame on any channel h_n, n = 0, 1, 2 …N and likewise it can also find out if it has a place with 'L', 'R', 'U' fixed on channel c_0.

If there should arise an occurrence of any loss of signal in the GPS, the local oscillator of the GPS maintains the synchronization with the nodes to certain accuracy. The details of such an event and synchronization are beyond the extent of this paper.

For a specific node *a*, the resulting sets are endorsed.

- P(a) – signifies the one-hop neighbors of node a situated in channel h_0, through which node a has gotten packets on channel h_0 in the past synchronization interval for slots l_0
- T(a) – denotes the time slots that node a should avoid in the channel

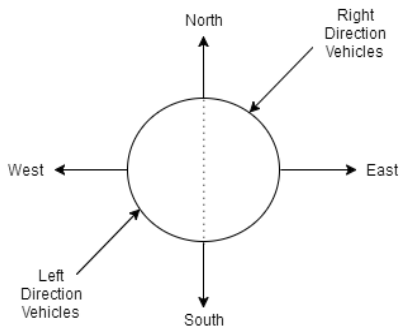

Fig..1 Vehicle directions

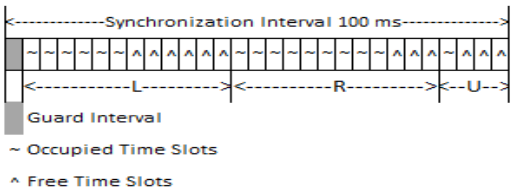

Fig. 2 Time Frame

III. BROADCAST SCHEDULING PROBLEM (BSP) FORMULATION FOR COMMUNICATION IN VANETS

Vehicular Adhoc Networks is represented as graph with no direction (un-directed Graph). G = (V, E), where every single node/vehicle is represented as vertices V = {1, 2,….., N}. E represents the arrangement of undirected edges symbolizing the transmission count in the Vehicular Network. N denotes the total count of vehicles. Therefore if there remains an edge e= (i,j) ∈ E , two vehicles are in the communication areatheyare termed as one-hop apart. The second scenario is when (i,j) ∄ E , but there remains a midway node k with the end goal that (i,k) ∈ E and (k, j) ∈ E, then the nodes i, j are termed as two-hop apart. Given the consideration, the vehicular adhoc network is illustrated by an NxN symmetric connectivity matrix C = (c_{ij}), characterized as given beneath

$$c_{ij} = \begin{cases} 1, if\ hosts\ i,j\ are\ one\ hop\ away \\ 0, \quad otherwise \end{cases} \quad (1)$$

The corresponding compatibility matrix D = (d_{ij})

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is gathered from matrix C, and is assigned as

$$d_{ij} = \begin{cases} 1, if\ hosts\ i,j\ are\ one\ hop\ or\ two\ hop\ away \\ 0, \quad otherwise \end{cases} \quad (2)$$

For the scheduling problem, the identified solution should contain a TDMA frame which is conflict free and satisfies the constraints for the packet transmissions. For this reason, it is assumed that there are M time slots in each time frame and employ an MxN binary matrix Y = (y_{mj}) to mention a TDMA frame, where each element is defined as given below

$$y_{mj} = \begin{cases} 1, if\ mth\ slot\ to\ be\ assigned\ to\ host\ j \\ 0, \quad otherwise \end{cases} \quad (3)$$

With all these definitions, the time slot utilization index ρ is given for the whole vehicular adhoc network. ρ is calculated by (4)

$$\rho = \frac{1}{M \times N} \sum_{m=1}^{M} \sum_{j=1}^{N} y_{mj} \quad (4)$$

The equation aims at identifying an optimum TDMA cycle having minimal frame length M and maximum slot utilization index ρ, and that is said to be an optimum broadcast scheduling (OBS) problem for VANETs. To be more specific, OBS problem could be depicted as given below

Shorten M and Maximize ρ, depending on

$$\sum_{m=1}^{M} y_{mj} \geq 1, \ \forall j \quad (5)$$

$$\sum_{m=1}^{M} \sum_{i=1}^{N} \sum_{j=1}^{N} y_{mi} y_{mj}\ d_{ij} = 0 \quad (6)$$

As mentioned earlier, the no transmission constraint is given in equation (5). This equation makes sure that every vehicle in the network is designated a minimum of one time slot. Conflict free constraint is given in equation (6). This equation guarantees that every two vehicle nodes which are one and two hops awayshould be transmitted in different time slots. For Vehicular adhoc networks, the TDMA frame length is dependent on the dynamic mobility of the network, and as mentioned in [15] it is computationally challenging due to its NP-completeness. In the given system, the most extreme level of a host G is utilized to discover tight lower bound for the frame length M, which is given in (7)

$$M \geq G + 1 \quad (7)$$

IV. PROPOSED DISCRETE GENETIC ALGORITHM (DGA) APPROACH FOR OBS PROBLEM IN VANETS

Motivation for choosing Evolutionary techniques to solve the OBS problem in VANETs was because of several factors. Artificial intelligence being one of the flourishing technologies for man machine interaction, is helpful in solving many problems such as OBS. Since OBS problem requires multiple optimization factors, Genetic algorithm has the capabilities of handling maxima and minima factors at the same time. Moreover, Genetic Algorithm has been successful in solving several scheduling problems such as travelling salesman problem (TSP) [17], Job shop scheduling [18], and flow shop scheduling [19]. The results from these literatures caused a major inclination in employing Genetic Algorithm approach for OBS problem.

The proposed approach employs a smallest position value (SPV) rule as illustrated by bean [20]. This rule is extended in our work for transforming a continuous optimization algorithm into a discrete algorithm which is required for solving the TDMA based scheduling algorithm. Literatures show that SPV has been used in the past for solving scheduling algorithms [21].

In this proposed approach, a discrete genetic algorithm is employedinsolving the OBS problem in VANETs, which portrays several context-oriented adaptations for the required VANET environment. The major assumption is that communication in Vehicular network is based on cluster communication. Clustering of Vehicles in the network is not covered in this research and it is outside the scope of this paper.

A. Implementation of dGA for OBS Problem

1) Solution Representation

Solution representation is one of the critical phases in solving a discrete problem. In a standard Genetic Algorithm, the search space contains n measurements as n number of nodes battling for a time slot m. The measurements are nonstop position values in the pursuit space. The SPV rule is utilized to alter the continuous position value into discrete solutions. The SPV rule is utilized to get the initial population in the form of unit matrix. A sample matrix is given below. Here [RelM] represents the relation matrix for a particular network with 8 nodes. The Columns in the matrix represents the nodes in the network and the rows specify if there are any links in between the nodes. For example, the first row shows the connection information of Node A. Each cell representing a connection between two nodes receives a value of 1 and 0 if there is no connection.

$$[RelM] = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

a) Chromosomes

In the system under consideration individual chromosome is characterized by an N-dimensional

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integer vector c = [c^1,……,c^N], where each component corresponds to the short ID (SID) given for every vehicle for its unique identification. The size of the search space is N!, and since there are no constraints on the node all the chromosomes are valid. The system does not employ any penalty functions to penalize infeasible output as seen in [22].

b) Initialization

The initial population of chromosomes is generated using the elite population method with permutations of 1 to N, where P is the size of population. It is discovered from the results that elite population method functions efficiently for both small and large networks. The initial population is depicted as given below

$$\{c_p = [c_p^1, \ldots\ldots, c_p^N], \qquad p = 1, \ldots\ldots P\} \tag{8}$$

B. Fitness Evaluation

Following is the algorithm for the time slot assignment with the given host number

Algorithm 1 Time slot assignment

Input: $c_p = [c_p^1, \ldots\ldots c_p^N]$

Output: M and ρ

Initialize M = 0

1. *Identifying the host number in* c_p
2. *Look for assigned time slots to accommodate the host without violating the rules*
3. *If found a time slot allocate it to the host*
4. *If not found designate a new time slot and increase M*
5. *Repeat steps to 2 to 4 until all the hosts are assigned a time slot*
6. *Analyze all the allocated time slots to check if any other host could be accommodated without violating the necessities*
7. *Calculate ρ and get the final count of M*

The objective of this research focusseson minimizing the length of TDMA frame and increasing the utilization index ρ of the time slot. The following fitness function qualifies the chromosomes with their calculated fitness value. The lowest value of the fitness function signifies the best chromosomes.

$$f(C_p) = M - \rho \tag{9}$$

C. Genetic Operators

Selection, crossover and mutation are the three basic operations of Genetic algorithm. The initial population which has been generated using the elite population method is the input for the first operator, which is selection. This section will portray more about the three operators in Genetic Algorithm

1) Selection

Selection operation includes reproduction involving two parent chromosomes for the next generation. In this study, a rank-based selection method is chosen. The selection method sorts the population based on the objective value and the fitness function. This method is said to be better than tournament selection in [23]. Each individual corresponds only on its position in the sorted order and not on the actual objective value

2) Crossover

Crossover is a pivotal operation in the GA operators. The activity consolidates two parent chromosomes to deliver new posterity chromosomes. Two-point cross-over is used as the crossover technique. It is similar to single point crossover, except that there are two cut points in the given input.

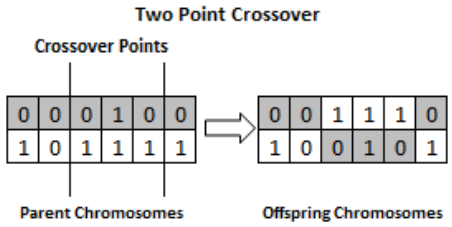

Fig. 4 Two Point Crossover

3) Mutation

The mutation operation reforms values in the chromosomes at random to achieve new offspring chromosomes. The mutation probability chosen for the study is 0.01%.

4) Reconstitution

On completion of the above genetic operators, the new generation of offspring chromosomes has to replace the old parent chromosomes. The offspring will have the chance to compete with the parents based on their fitness values. If the offspring chromosomes are found to have a better fitness than the parent then they are replaced in the next cycle of GA operations. This operation safeguards the chromosome with the best fitness from being lost

5) Terminating Criteria

This is the operation which decides whether to stop the cycle or carry on for the next iteration. Even though the fitness is calculated using the equation (9), frame length M has a lower bound, however slot utilization index ρ is not known to us beforehand; consequently, a hybrid strategy takes both the factors into consideration for terminating the iteration is employed. In addition to this the cycle will stop if it has reached the maximum iteration G_{max} or if there are no improvements in the last 50 (pre-defined) successive generations.

Parameter	Value
Direction/Lane	2
Transmission Range	200m
Synchronization Interval	100ms
Guard Interval	4 ms
Selection	Rank based method
Crossover	Two Point Crossover
Mutation Probability	0.01
Termination	Hybrid Stopping criterion or 500 Generation

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. Table 1 Simulation Parameters

V. Simulation Results and Discussion

In this segment, experimental results are presented to display the different part of the proposed dGA scheduling approach for VANETs. dGA parameters utilized are given in Table1. It is essential to review the behavior of dGA' s scheduling approach with three GA parameters. The crossover rate set in this approach is 0.5, which provides a good composition between the performance as well as the complexity. Next operation mutation is involved in achieving the space which the crossover probability may not be able to achieve. 0.01 is the mutation probability which has been set in the simulation of the scheduling approach for VANETs. As discussed in the earlier section, the genetic operations have to be analyzed on their performance. Figure 5 depicts the reduction in the number of frames as the generations keep increasing. The Figure is achieved for a 25-node network with the maximum node degree being 5. It is noticed from Figure 5 that in the first generation the simulation uses all the 25 frames and as the dGA operations iterate the optimal frame required for the given network of 25 nodes and with maximum node degree 5 is 6 frames. The simulation was run for 50 generations.

In analyzing the optimum scheduling performance various scenarios were considered to quantify the proposed approach. For benchmarking, a comparison study with other similar researches, simulations are carried out for different number nodes (N =15, 30, 50, 100). For all the scenarios, the algorithm was run 25 times having maximum of 500 generations (G_{max} = 500) with the termination criteria as mentioned in section 4.6. The initial population for a small network had P = 50 and for a large network P = 100. All the simulations were run in MATLAB and the CPU time shown in the work are from a 2.30 Ghz with Intel core i3 processor and 4GM DDR2 RAM. Table 2 denotes the results acquired from 25 runs for respective instances

It is noticed that the GA based approach shows optimal solution in comparison with VeMAC [9], TDMA-CCA [13], and ADHOC [14]. Table no 3 denotes the comparison between them and figure no. 6 shows the variation in terms of the curve. Fig 6a shows the results of ADHOC, VeMAC, TDMA-CCA, and the GA based approach for a network of 100 nodes (N = 100) and 100 connections (K = 50). The Fig 6b shows the results of the same four approaches for a network of 100 nodes and 100 connections. The results obtained in both the scenarios are very much in favor of the proposed GA based approach for TDMA based scheduling in VANETs. On seeing the above results and comparison, it signifies that GA based approach delivers near optimal solution, where the optimum solution is M = G+1. Figure 7 represents the comparison of various benchmarked scheduling methods with GA. The results show a comparison of both 50 and 100 node network. Figure 7 clearly shows that GA performs well with a maximum channel utilization of 0.21 for a 50-node network; however, it does not utilize the channel well for a 100-node network. Thus, the future work will focus on forming small vehicular clusters and then to use evolutionary approach for TDMA scheduling in the formed clusters.

No. of Nodes	No. of Links	Max ND	Minimum TDMA Frame Length (M)	Avg (ρ)	Avg No. of Generations
15	22	5	6	0.200	32.6
30	42	8	9	0.203	28.4
50	85	8	9	0.205	89.3
100	125	9	10	0.210	112.6

Table 2 GA simulation results

No. of Nodes	Average Frame Length (M)			
	AD-HOC	VeMAC	TDMA-CCA	GA
15	2	1.3	1.2	0.9
30	4.3	4	1.9	1.6
50	12	11	9	7

Table 3 Comparison of Ad-Hoc, VeMAC, TDMA-CCA and GA

A. Result Analysis

A sample test case was conducted to verify the results. Openstreet Map (OSM) was used to collect the traffic data and Simulation of Urban Mobility (SUMO) was selected for generating the mobility models. The output from the SUMO was then fed into MATLAB for optimizing the solution. The transport Map and Route Map of Vandalur, Chennai, India with the roads and intersections are used for the sample test case. It is in the Figures 8a and 8b. The simulation was run for 50 times with the simulation parameters as found in Table 1. Figure 9 depicts the pareto optimal solutions for both the parameters under consideration, the Time frame reduction and Channel utilization are given. In Fig 8a and Fig 8b

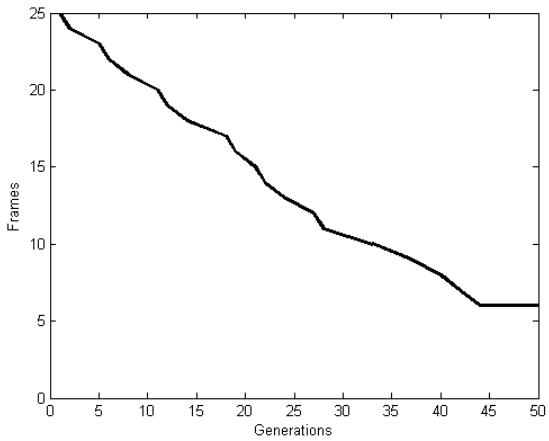

Fig. 5 Optimized frame for a sample 25 node network

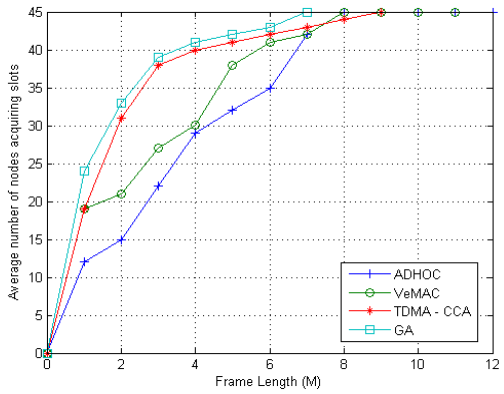

Fig 6a Average no. of nodes acquiring slots within M frames N =100 and K = 50

Fig 8a Transport Map of Vandalur, Chennai, India

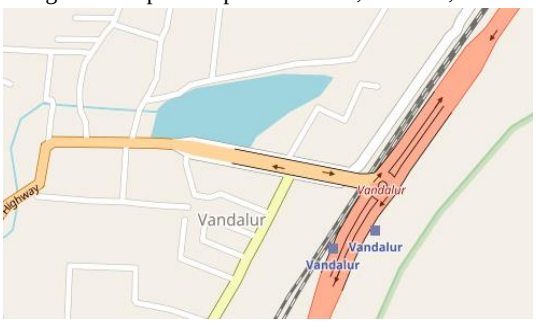

Fig 8b Route Map of Vandalur, Chennai, India

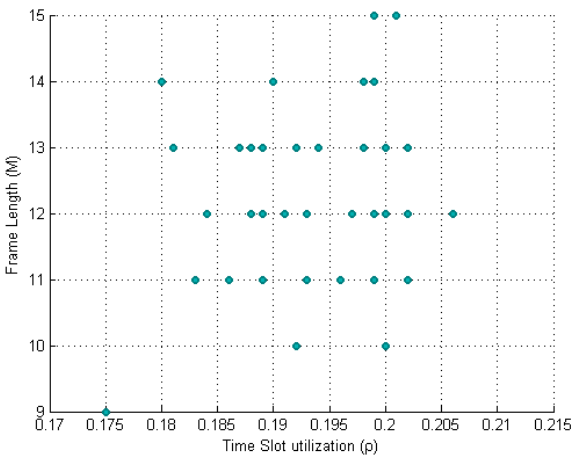

Fig 9. Sample Test Case's Pareto Optimal Solutions

VI. CONCLUSION

In this article, a TDMA based scheduling algorithm using discrete Genetic algorithm was proposed for efficient communication between vehicles in IoV. dGA employs a strategy of using the Smallest Position Value (SPV) to make the standard GA into a discrete approach. The proposed approach typically identifies the vehicular nodes fitness and objective value, and by virtue of finding them; operations like selection, crossover and mutation were employed for finding the best chromosome and eventually the optimum scheduling after few generations. Simulation results portray that proposed dGA approach outperforms other TDMA based scheduling in VANET algorithms such as the ADHOC, VeMAC.

On the subject of improving dGA, it is found that certain necessary modifications had to be made to make the dGA more efficient than the traditional GA. The modifications were by engaging an elite population selection method, combination of operations and a mixed termination criterion and most importantly the SPV rule being applied. Future research in this area will be on employing dGA approach for clustering of vehicular nodes in the network. It is essential to form a stable cluster for an effective scheduling to happen in environments such as VANETs. Suitable tests will be investigated for the problem

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