Swarm Intelligence based efficient routing algorithm for platooning in VANET through Ant Colony Optimization

Gagan Deep Singh, Manish Prateek, Hanumat Sastry G

Abstract*: *Today's era is of smart technology, Computing intelligence and simulations. Many areas are now fully depended on simulation results for implementing real time workflow. Worldwide researchers and many automobile consortium are working to make intelligent Vehicular Ad hoc Network but till yet it is just a theory-based permutation. If we take VANET routing procedures then it is mainly focussing on AODV, DSDV and DSR routing protocols. Similarly, one more area of Swarm Intelligence is also attained attention of industry and researchers. Due the behavior of dynamic movement of vehicle and ants, Ant Colony Optimization is best suited for VANET performance simulations. Much of the work has already done and in progress for routing protocols in VANET but not focused on platooning techniques of vehicle nodes in VANET. In our research idea, we came up with a hypothesis that proposes efficient routing algorithm that made platooning in VANET optimized by minimizing the average delay waiting and stoppage time. In our methodology, we have used OMNET++, SUMO, Veins and Traci for testing of our hypothesis. Parameters that we took into consideration are end-to-end delay as an average, packet data delivery ratio, throughput, data packet size, number of vehicle nodes etc. Swarm Intelligence has proved a way forward in VANET scenarios and simulation for more accurate results. In this paper, we implemented Ant Colony Optimization technique in VANET simulation and proved through results that if it integrates with VANET routing scenarios then result will be at its best.

Index Terms*: Swarm *Intelligence, Simulation, VANET, platooning, Ant Colony Optimization.

I. INTRODUCTION

Traffic is increasing worldwide and we have no control over it. The best way to deal is to just to optimize in better way and make it a continual process of improvement. the World Health Organization has revealed in its first ever Global Status Report on road safety that more people die in road accidents in India than anywhere else in the world, including the most populous China. The road fatalities can be called an epidemic that will become the world's fifth biggest killer by 2030, if nothing was done today. In last 50 years, India's automobile population has grown 170 times while the road infrastructure has expanded only nine times. 90% of deaths on the world's road occur in low and middle income countries. These statistics motivates to develop a technology so that road casualties can be minimized. VANET simulation are used for predefined scenarios to churn out the best possible solution for Intelligent Traffic System. In near future VANET technology will be deployed to reduce the fuel consumption, traffic congestion, pollution and as well as driver's irritation due to undesired traffic conditions. The World Health Organization has revealed in its first ever Global Status Report on road safety that more people die in road accidents in India than anywhere else in the world, including the most populous China [1]. The road fatalities can be called an epidemic that will become the world's fifth biggest killer by 2030, if nothing was done today. In last 50 years, India's automobile population has grown 170 times while the road infrastructure has expanded only nine times. 90% of deaths on the world's road occur in low- and middle-income countries. At least 13 people are injured every hour in India due to road accidents. The number of accidents per 1000 vehicles in India as high as 35 while the figure ranges from 4 to 10 in developed countries. [2]. VANET routing protocols history starts with traditional MANET protocols such as AODV (Ad hoc on Demand Distance Vector Routing) [3] and DSR (Dynamic Source Routing) [4]. AODV and DSR have been considered efficient for Multi hop wireless ad hoc networks [5]. Routing plays a major role when we design any of the VANET scenarios for Vehicle-to-Vehicle communication. Now the technology is upgrading in a random manner. Therefore, after launch of 5G network on GSM spectrum then Vehicle-to-Infrastructure will be able to establish its roots in Urban Intelligent Transportation System (UITS). Vehicular ad hoc network constitutes of vehicle, here referred as nodes with capability to establish wireless communication with other nodes, thereby transforming the network into a self-organized shared mesh. This network of vehicles makes VANET, which gives numerous applications so as to make the road travel experience more safe, effective, convincing, easy, efficient and pleasant by decreasing traveling time, traffic congestion, avoiding congested areas, increasing road capacity and emergency situations resulting in lesser fuel wastage [6]. That also helps to makes our environment clean. Many of the VANET routing protocols and Wireless standards are already available but none of yet is able to provide the concrete routing solution for VANET [7].

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II. SWARM INTELLIGENCE

The newly emerged Swarm algorithm is capable to simulate the behavior of various animals such as birds, fish, bees and ants. Swarm intelligence algorithms are newly emerged Swarm intelligence techniques that replicate the behavior of existing living organisms are also used in literature for routing in VANETs. Swarms have the unique talent to answer any given real-time and complex tasks, which are a challenging to answer through normal algorithms and hence are suitable for the real-time traffic scenario. Ant colony optimization (ACO) is an artificial Swarm algorithm that can be used for building paths in communication and networking domains. It has the ability to develop self-organizing methods that help in solving real-time routing problems [8]. In ACO, a chemical called pheromone is dropped, by ants on its route while passing through that route, which is sensed by other ants to help them follow the path [9]. Other ants in the group can discover the accumulation of the pheromone and if encountered with higher concentrations of pheromone then, follow that path. Pheromone starts evaporating in the situation where the route remains unused by the vehicles for some time [10]. A modified version of ACO for the vehicular traffic environment to yield more optimized results on complex road network [11]. The core objective is to minimize the waiting time during journey, which in turn reduces the total travel time irrespective of the path length used by the vehicle [12].

III. ANT COLONY OPTIMIZATION TECHNIQUE

Ant Colony Optimization Ant Colony Optimization (ACO) is a meta-heuristic approach proposed by Colorni et al. in 1991 and further modified by Dorigo et al. in 1996 for the Ant Colony System [13]. It is used to solve numerous disconnected optimization problems and is considered as one of the swarm intelligent algorithm types [14]. ACO simulates the real ants to find shortest path between source and their nest, while searching the ant deposit chemical substance called pheromone along the past path. This pheromone value can be used by other ants as indicator to find the shortest path to food places. The path with stronger pheromone value will be preferable for coming ants. If the number of ants decreased in a specific path, the pheromone evaporates with passed time and vice versa [15]. Different Ant Colony Optimization algorithms have been proposed. All of them share the same idea. The original ant colony optimization is known as ANT system, and the two most successful variants max-min Ant system and ant colony system [16]. ACO is iterative algorithm, a number of artificial ants are generated at each time and build a solution to the considered optimization problem and exchange the quality information of these solutions via communication scheme. A distributed heuristic solution like ACO routing algorithm shows many features that makes it particularly suitable for wireless sensor network [17]. Algorithm is fully distributed that mean there is no single point of failure. The operations done in every node are simple. Autonomous interaction of ants, and the algorithm based on agents‟ synchronous. It is self-organizing, thus robust and fault tolerant. There is no need to define path recovery algorithm. Intrinsically adapts to traffic without requiring complex, and yet inflexible metrics. It inherently adapts to all kinds of variations in topology and traffic demand, which are difficult to consider into account by deterministic approaches.

IV. PROPOSED EFFIECENT ROUTING ALGORITHM FOR PLATOONING

The new area of research has emerged in VANET so that time spent on roads can be reduced, that includes waiting and travelling time for commuters at stoppages and waiting locations. Now, every theory suggests that travel time can be reduced through using shortest path between sources to destination, but what happen if all the vehicle nodes opts for shortest routing path, and then this solution will itself become a problem and results in congestion of opted route. Hence, it is always not true that shortest path is the optimal route [18]. Therefore, commuters can also choose a longer path because they want to avoid congestions through less frequency of traffic signals and waiting time for much smoother mobility of vehicle nodes. Hence, we devised a new algorithm based on Ant Colony Optimization techniques. We have reviewed other bioinspired algorithmic techniques also, but ACO is best suited for VANET because the mobility pattern and behavior of ants movement in ACO is mostly matched with it. Hence, in this paper we incorporated our methodology through Swarm intelligence in VANET to devise fresh new algorithm for platooning of vehicles in VANET, which we have termed as GaganManishHanumatUPES Algorithm (GMHU). Our new GMHU algorithm is able to reduce the congestion on the routes that has opted by the vehicle nodes depending on traffic signals. Through this, our GMHU algorithm also plays an integral role in reducing the hydrocarbon fuel consumptions of vehicles. We are able to get the optimum results as we our proposed system decreases the where vehicle waits for green signals and then they go forward by choosing the best optimum route while no focusing on the length or distance of the path. To design this system we have also proposed the GMHU suited traffic signal system that reduces the waiting period of the vehicles at the junctions and traffic signals. Parallel to it our GMHU optimization able us to reduce the congestion on the routes. In our hypothesis, we are assuming that all the routes/roads and vehicle/nodes at real time scenarios are in best working conditions. As per the fig. 1(a,b,c) below when Ant opts the final route, then this optimization in itself causes the congestion in real-world traffic scenario[19].

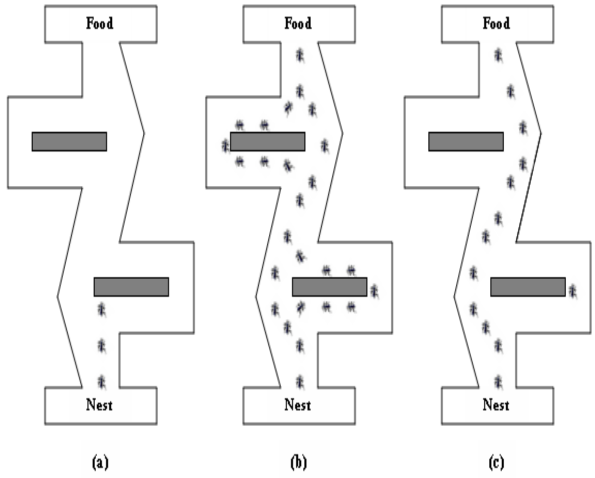

Figure 1: self-adaptive behaviour of Ants

Hence, to resolve this issue we have integrated preemptive traffic signal algorithm [20] with existing ACO algorithm to devise our new GMHU algorithm for VANET Platooning. Preemptive approach shown in fig.2 as per the given flowchart below:

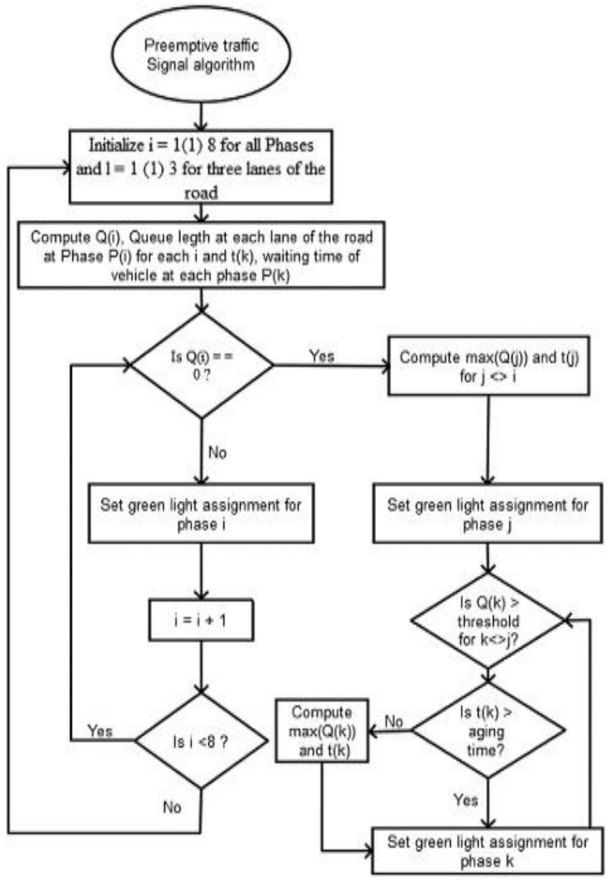

Figure 2: Preemptive traffic signal process flow

The proposed GMHU algorithm works under the assumption that all roads are in best working condition. The GMHU algorithm summarized as below:

Scenario1 = Simple road network
Scenario2 = Complex road network
Scenario3 = Clock tower to Mussoorie diversion from openstreetmap.org
Parameters = As shown in Table1
Python Script of Ant Colony Optimization = P_{ACO}
Python Script of Modified Ant Colony Optimization = MP_{ACO}
Python Script of Preemptive Road Traffic Algorithm = $PPre_{RTA}$

STEP1: Set scenario1, scenario2, scenario3 for VANET simulation
STEP2: Set common parameters for all three scenario using Dijkstra
STEP3: Implement simulation as per the parameters for scenario1
STEP4: Repeat for Scenario2
STEP5: Repeat for Scenario3
STEP6: Run simulation for 100 times
STEP7: Deploy P_{ACO} *for all scenario*
STEP8: Follow STEP6
STEP9: Export data
STEP10: Deploy python MP_{ACO} *for all three scenario*
STEP11: Follow STEP6
STEP12: Export data
STEP13: Repeat STEP10 to deploy $PPre_{RTA}$
STEP14: Run simulation
STEP15: Start routing nodes in simulation through STEP13
STEP16: if congestion at intersection for green signal
STEP17: Check for threshold
STEP18: if congestion > threshold
Apply preemptive road traffic algorithm and apply Routing of nodes
else continue
STEP19: Follow STEP6
STEP20: Export Data
STEP21: Perform Ttest for data acquired in all scenario
STEP22: Analysis of result
STEP23: Compare
STEP24: Conclusion
STEP25: END
STEP20: Export Data
STEP21: Perform Ttest for data acquired in all scenario
STEP22: Analysis of result
STEP23: Compare
STEP24: Conclusion
STEP25: END

V. METHODOLOGY OPTED

However, we have tried to execute it on our laptops equipped with Corei3 processor and 4 GB of RAM but response on that was dead slow. Therefore, we used same pack of software on HP workstation MODEL HP Z4 G4 and then we were able to get results without lagging. Hence, here we can suggest to other researches that always use high-end computing workstations for these types of processing and experiments otherwise you will be stuck up with computing resource issues. The methodology followed shown here is as per fig. 3 below.

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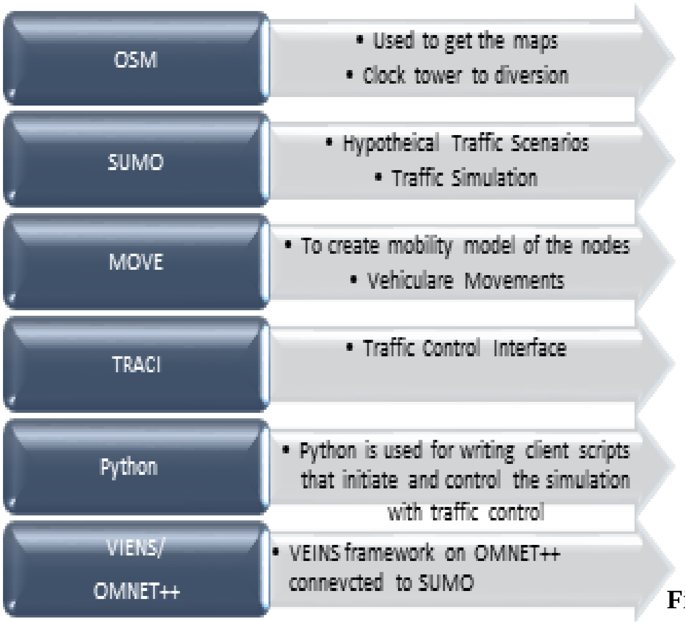

Figure 3 : Methodology Used

We utilized only open source software available online for our experimental setups.

1. OSM
2. SUMO (Simulation of Urban Mobility)
3. MOVE (MObility model generator for Vehicular networks)
4. Python
5. TraCI (Traffic Control Interface)
6. Instant VIENS 4.7.1.
7. OMNET++ 4

We have used instant Veins 4.7.1 because, it is a virtual, that can be directly deployed on our system. Veins is distributed as a single-file virtual appliance, ready for one-click import into software like Oracle VM VirtualBox, VMware Workstation Player, or any other software supporting the open virtual format. We integrated two existing algorithm of the VANET. Then we devised our own new algorithm that we have named as GMHU algorithm for optimizing VANET routing. Scripted the algorithm in python adopted from github. Used different VANET scenarios along with Dehradun road network as shown in fig. 4 that was taken through www.openstreetmap.org. Used SUMO, OMNET++, VEINS, MOVE, over TraCI as an interface to run simulation tests. The test results are exported in to excel format and then then compiled test data is used in t-test to conclude our hypothesis. The t-test outcome proved that our proposed newly devised algorithm is able to minimize the travel time as well as waiting time also. Hence, our hypothesis is valid.

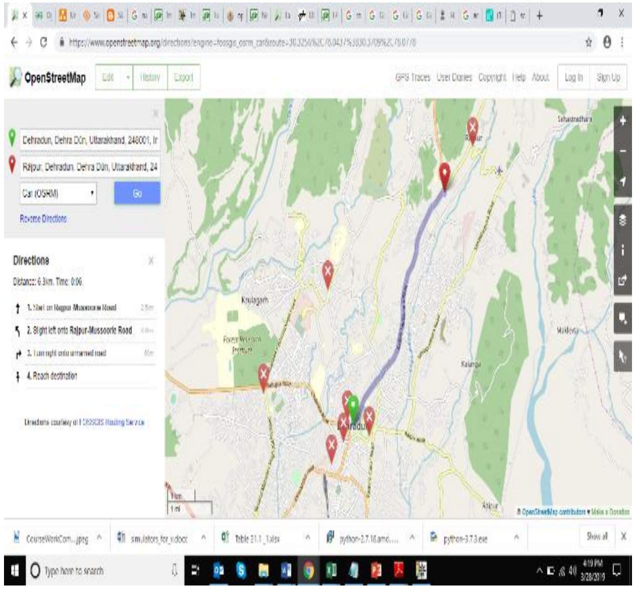

Figure 4 : Dehradun map from www.openstreetmap.org

In this simulation test, we have used ant colony routing protocol Annet which is already available in the library. Total number of vehicles was limited to 30 only so that we can get results faster. The three different speed scenarios were ran on simulation. 20ms, 40ms and 80ms respectively. Parameters for simulation test are shown in table 1 as below.

Table 1 : Simulation Parameters

Parameters	**Values taken for simulation configuration**
Routing Protocol	Annet
Wireless Terrain	1300 X 1300
Node Density	30
Velocity	20ms, 40ms, 80ms
Packet size	100bytes
MAC Protocol	MAC 802.11p
Type of Traffic	CBR
Propagation Model	Nakagami
Sampling interval	2.5ms
Simulation time period	10 seconds
Network Simulator	OMNET++ through instant Veins
Simulation Scenarios	Simple Road Network, Complex Road Network and OSM from www.openstreetmap.org

VI. EXPERIMENTAL SETUP AND IMPLEMENTATION

We have done the simulations through VEINS framework on OMNET++ which is connected to SUMO as shown in fig. 5, via local client server model, and to establish this we take help of TraCI(TRaffic Control Interface) which is distributed along with SUMO bundle in src folder[21]. TraCI works as middleware to connect SUMO and OMNET++. VEINS framework which is running inside OMNET++ provide a python script named sumo-launchd.py, this script creates a client-server connection between SUMO

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TraCl server connection and VEINS via OMNET++, the sever waiting on terminal listening on port 9999 at localhost. When simulation starts on OMNET++ it sends a request to TRaCI server and gets nodes location in response, thereby creating a real-time road network on OMNET++ Simulation panel. This step is to share SUMO mobility on OMNET++, now comes the role of Network Simulator OMNET++, which implies communication between the nodes and make vehicles exchange data. Using Veins framework in OMNET++ we simulate our scenario and took various parameters specified in omnetpp.ini file, which is required by OMNeT simulator to run simulations. We have used scenario specific parameters such as playground size that was taken as 25000m by 25000m and simulation time is set to 6000s. The configuration parameters for WaveAppLayer used for communication between nodes/vehicles, here applType represents the protocol used for information exchange [22].

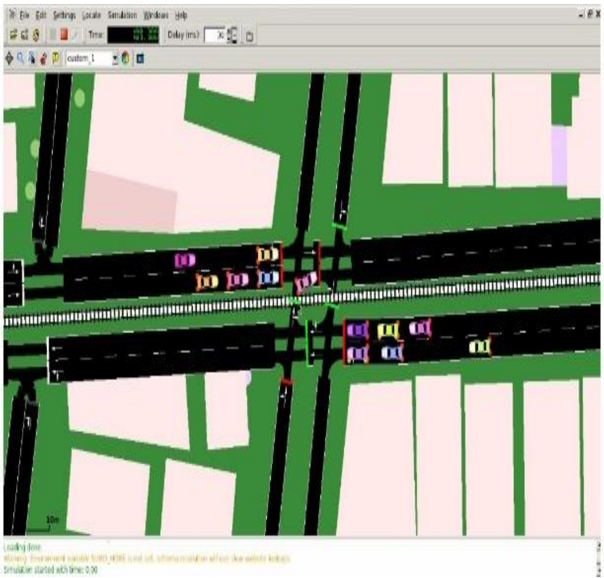

Figure 5 : Simulation Scenario implementation in SUMO

We designed three types of road networks, viz. simple, complex, Dehradun road network using the open source simulator: SUMO along with MOVE. We use simulators to check the efficiency of the proposed GMHU platooning algorithm. For this, the road network is simulated. During the journey, whenever a traffic signal comes in the compared with both the modified Ant Colony and Dijkstra's algorithms. The GMHU platooning algorithm provides considerable decrement in the total travel time for the vehicles because of the reduction in waiting time. It was assumed that the network consists of too many vehicles with congestion on many of its routes. Vehicles follow the modified ACO path only when vehicles in the network exceed some set threshold, i.e., some congestion exists, otherwise the path followed by vehicles is the default path given by the Dijkstra's algorithm.

The implementation of the algorithms was done in Python. Testing was performed over all the three selected simulated road networks and results were compared. The two parameters on which comparisons are performed are overall travel time for reaching the destination and the overall waiting time in the entire route. The results justify that GMHU outperforms the other two algorithms: Dijkstra's algorithm and modified Ant Colony algorithm, when there is congestion in the network returning the optimal route that is obstruction free. Table 2 and 3 summarizes the results obtained by implementing the GMHU platooning algorithm in our simulated networks over the parameters specified in Table 1 as above.

Table 2 : Data Analysis for Dehradun road simulation

	Waiting Time			Travel Time		
	Dehradun road simulation					
Vehicle Nodes	**Dijkstra's**	**ACO**	**GMHU**	**Dijkstra's**	**ACO**	**GMHU**
600	2878	529	342	46,789	42,967	40,215
900	10,975	1371	1125	75,277	46,630	42,541
1200	21,624	3101	2541	107,066	101,207	65,489
1500	36,361	7286	3627	140,261	135,160	85,476
1800	45,967	9487	5487	173,127	170,757	96,587
2100	59,248	12,209	7825	208,321	205,078	108,541
2400	78,841	17,264	8964	249,799	222,477	112,547
2700	94,210	22,005	9247	287,198	238,850	146,547
3000	120,114	23,922	9876	335,756	282,950	152,598
3300	140,041	36,941	10,054	377,792	294,444	179,876
3600	177,282	44,251	10,265	436,553	382,338	185,478
3900	209,047	50,279	11,429	490,118	399,071	216,547

Fig. 6 and 7 shows the graphical results of overall waiting time and travel time in our simulated network. While waiting at the intersections, often the engine of the vehicles is kept on, which results in wastage of precious fuel. The proposed platooning algorithm is also able to reduce fuel consumption by reducing the overall waiting time on both intersections as well by avoiding congested routes. Further, it is also observed that the amount of the pollution emitted by the vehicles is less due to reduced waiting time on the roads. This also reduces various health hazards and leads to an eco-friendly atmosphere. Tested with simulated networks on varied number of vehicles in each simulation, the GMHU algorithm reduces congestion at intersections by handling heavy traffic.

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Table 3 : Clock Tower to diversion, simulation data analysis

	Waiting Time			Travel Time		
	Clock Tower to Diversion road simulation					
Vehicle Nodes	Dijkstra's	ACO	GMHU	Dijkstra's	ACO	GMHU
600	18,618	1600	1325	90,051	74,162	65,478
900	49,856	3729	1987	150720	101,590	79,543
1200	61,750	7490	2354	198286	143,385	85,479
1500	120676	11,677	4529	279660	175,432	93,157
1800	158252	15,051	6587	365911	228,537	101,598
2100	243077	48,684	7896	486826	241,382	106,587
2400	389057	58,004	9648	667761	289,037	112,689
2700	670521	69,547	10,254	983066	405,814	126,926
3000	1,057,375	79,428	10,658	1,603,810	425,784	148,756
3300	1,131,682	88,751	11,025	2,413,606	454,785	178,542
3600	1,201,634	96,547	11,542	3,418,917	485,478	198,755
3900	1,692,484	131,524	25,487	4,545,012	504,125	254,139

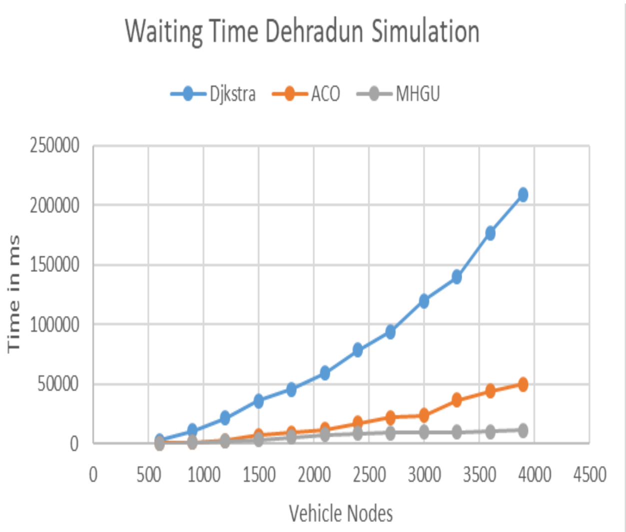

Figure 6: Graph generated for the waiting time for Dehradun Simulation

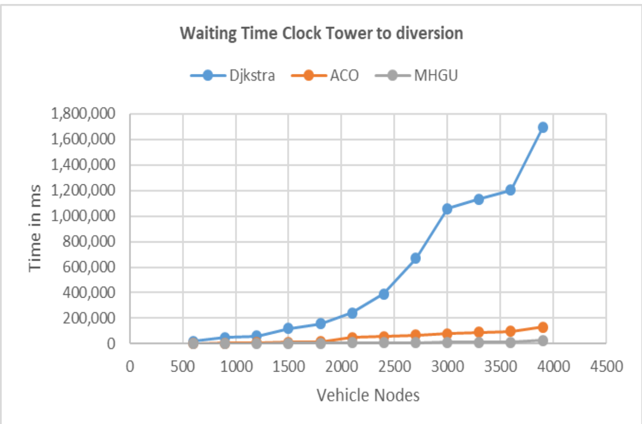

Figure 7: Graph generated for the waiting time for clock tower to diversion

The graphs shown above as in figure 6 and 7 clearly emphasize that GMHU is taking minimum duration of waiting time period as compared to ACO and Dijkstra's routing simulation of vehicle nodes. Hence, here we can conclude that in any of the simulation test if researchers adopt our mentioned VANET scenario and parameters. Then our proposed GMHU platooning algorithm will surely give better results as compared to other routing algorithms that are available for VANET simulations.

VII. CONCLUSION

In our hypothesis, we concluded through our research and experiments that our newly devised swarm based efficient routing platooning algorithm using ACO techniques is able to reduce the travel time in VANET through two factors: first is by providing green time at traffic signals and hence, choosing the optimal congestion-free route for the vehicles. GMHU algorithm was designed by integrating the preemptive traffic signal algorithm with existing modified ant colony optimization algorithm. This made our GMHU platooning algorithm efficient by reducing the waiting time of the vehicle nodes. This combination provides both the optimization of waiting time at the intersection by reducing the average queue length using preemptive algorithm and optimization of the path length chosen for the vehicles using the pheromones to avoid congestion in the network. The GMHU algorithm has the ability to pick any phase for the allotment of green time using the current vehicle density with the avoidance of starvation at any of the phases. Furthermore, GMHU platooning algorithm is able to optimize the path length of vehicles and ensure the avoidance of the congestion by imitating the ant behavior. Here, we also wish to state that there are tremendous area of scope for the improvement of VANET optimization. Hence, experts of this domain can come together for more better and optimize solutions.

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