

Optimizing Broadcasting Scheme for VANETs using Genetic Algorithm

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Abstract—Broadcasting is one of the communication mechanism utilised in VANET architecture through which an up-to-date traffic data can be disseminated among the commuters and this can help reduce traffic jams/congestions. Broadcasting storm (broadcasting) is considered to be an NP-hard problem consisting of multiple objectives. Conventional techniques use Multi-Objective Genetic Algorithms (MOGAs) to solve such optimization problems. Performance of such algorithms depend on fitness function used to optimize the objective. In this paper, we propose a novel and improved fitness function for MOGA to solve the broadcasting problem in VANETs. The proposed fitness function has enhanced the rate of evolution, resulting in more generations and producing better optimization results. We consider a highway scenario for simulation to evaluate performance of the proposed solutions. We compare the results of the proposed algorithm with existing state-of-the-art (Smart Flooding)(SF) technique [1]. Our results show improvement in reduction of the propagation time and the number of retransmissions compared to the previous solution.

Keywords: VANETs, Broadcasting, Genetic Algorithm, Smart Flooding, Network Coverage, Information Retransmission

I. INTRODUCTION

Commuting is an important part of everyday life due to increase in both population as well as the growth of cities. Traffic jams and congestions are a constant headache for modern commuters. Traffic and road safety organizations are constantly looking toward innovative ideas to solve these issues. An important innovation is on-board wireless communication systems in vehicles that gave way to a new type of mobile ad hoc networks known as Vehicular Ad hoc Network (VANET) [2]. VANETs are distributed, self-organizing communication networks built up by moving vehicles, and are thus characterized by very high mobility of vehicles and limited degrees of freedom in vehicle movement patterns [3]. Broadcasting plays an important role in vehicular ad-hoc networks (VANETs) to disseminate time-sensitive and critical safety applications messages within the entire network. Broadcasting in VANETs is defined as the dissemination of information from a vehicle to all the neighbouring vehicles in the network for some specific purposes such as advertising, safety or security [4]. In broadcasting, there is no single destination vehicle compared to the traditional vehicle-to-vehicle or vehicle-to-infrastructure communication. Instead, the information is broadcasted from a single source to all the vehicles inside a certain geographic region. Due to the limited

range of radio communication, in a specific VANET scenario, all vehicles may not be able to receive the broadcasted data in a single hop. Hence, in most of the cases a source vehicle may not be able to cover the entire network without using multi-hop communication as shown in Figure 1. Primarily in a multi-hop environment, a process of relaying original information, also known as retransmission, is relay by multiple vehicles, which are called relay vehicles, in the same neighbourhood to achieve network coverage. Uncontrolled or blind retransmissions will cause congestion and delays in a network. This problem is referred as broadcasting storm problem [5], [6]. For a stringent network such as VANET, the broadcasting storm is considered to be an NP-hard problem.

Reducing the number of retransmissions can help avoid broadcasting storm [7]. However a blind reduction in retransmissions may cause network coverage problem. If a transmission intended for all the vehicles in a network is not achieved, then this will be articulated as network coverage problem. Hence there is a need for reducing the number of retransmissions to avoid broadcasting storm, but also achieve the network coverage in a timely manner so that the information does not become irrelevant. To solve broadcasting storm as well as network coverage, we have relied on genetic algorithm by proposing a novel and improved fitness function, which uses analytical engine to produce optimised results and increase number of generation.

A. Main Contributions

In particular, this paper has the following main contributions:

- To devise a new mechanism for the reduction of number of retransmissions in broadcasting scenarios for VANET environment.
- To develop efficient information propagation strategies for VANET broadcasting.
- To formulate an analytical solution for the fitness function in order to increase the rate of evolution for genetic algorithm that can enhance the selection of better optimised solutions for broadcasting in VANETs.

B. Paper Organization

The rest of the paper is organized as follows. In Section II, we discuss previous research and related results. In Section III, system model, proposed algorithm is described in detail, which

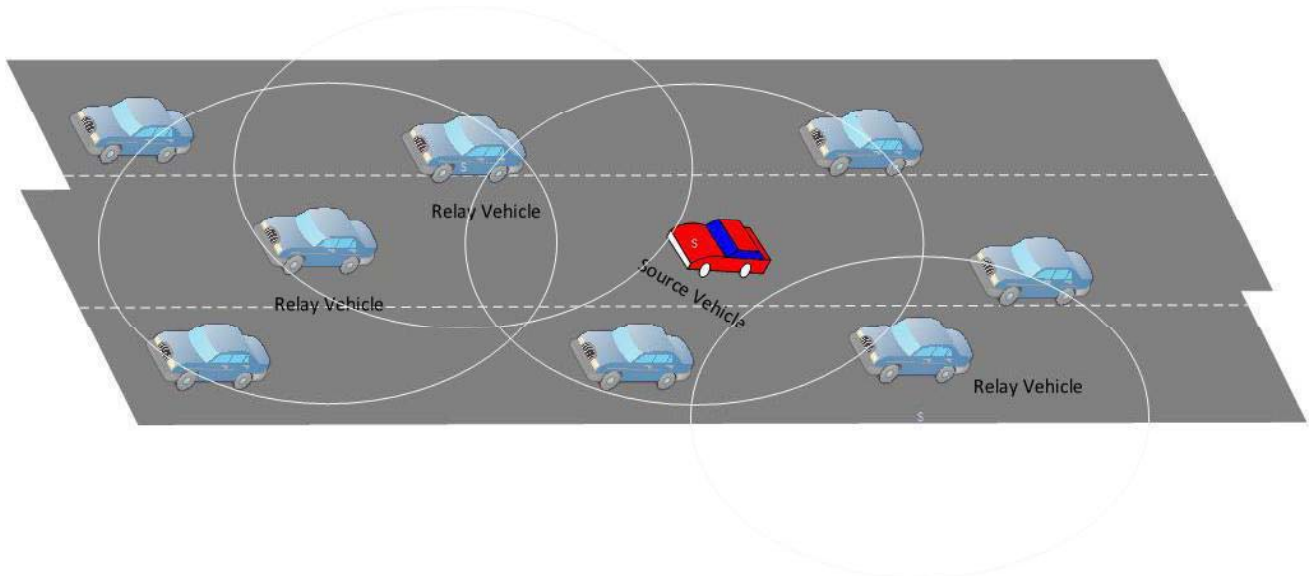


Fig. 1: Packet dissemination in a vehicular network

is used in our research. In Section IV we discuss the results, while in Section V we present conclusion.

II. RELATED WORK

Research solutions of broadcasting storm problem in VANETs fall in the two distinct areas of sender and receiver driven relay selection broadcasting techniques [8], [9]. In receiver driven relay selection broadcasting techniques, each receiving vehicle is a contender of becoming a relay vehicle [8]. All vehicles contain an independent selection criteria to assess their feasibility of being a relay vehicle. Researchers have come up with many different parameters to help facilitate this selection criteria [1], [10]–[12]. On the other hand, transmitting vehicle selects next relay vehicle from its neighbourhood in sender driven relay selection broadcasting techniques [9].

The sender driven relay selection broadcasting techniques such as [8], [9], [13]–[15] are not suited for the highly dynamic urban environment. In a highly dynamic urban environment, neighbourhood set of a vehicle changes in a rapid and dynamic manner. Hence selected relay vehicle may no longer be a part of neighbourhood set of transmitting vehicle during the process of transmission. Although our initial research does not reflect highly dynamic scenario, but our final objectives include handling of these environments. Our future aims does not facilitate research work related to sender driven relay selection broadcasting techniques.

In [9], an argument was presented that receiver driven relay selection broadcasting techniques does not consider the node density and therefore is unable to deal with most of the scenarios. We believe that this argument is not valid, particularly considering the research conducted in [16]. Although, at this point of time vehicle density in a network is not in the scope of our initial research. Researchers in receiver-

driven relay selection broadcasting techniques have either used search heuristic algorithms or tried to bypass them by using some other techniques such as [11], [12]. Literature review of receiver driven relay selection is divided into following two sub-sections:

A. Non - Optimization Techniques

This section contains previous research studies that do not consider optimization techniques to solved the broadcasting problem. Authors of [11] selected relay vehicles in special forwarding zones. This study dealt with the highly dynamic urban environment. However, the study lacks in presenting enough data to collaborate efficient retransmission of packets. [12] dealt with weather reports. To acquire minimum retransmissions, when a vehicle will receive a traffic report it enters a priority competition process to calculate waiting time according to the priority index. When similar traffic reports are received by a vehicle, it's priority index decreases and the waiting time increases accordingly. This study is focused only on traffic report and retransmission of packets is not that efficient. Furthermore, traffic density factor is also not discussed in the paper, hence it is difficult to know the exact impact of this study in terms of vehicle density.

In [17], authors proposed a modified layer architecture solution for range estimation. The proposed solution allows vehicles to dynamically estimate their transmission range which then is used to effectively broadcast the information with as few hops as possible. The farthest vehicle from the source or the last relay vehicle is selected as a next relay vehicle. Any candidate relay vehicle has to figure out whether a vehicle is the farthest in the transmission range and assign it a wait time. Relay vehicle will transmit the packet if this wait time expires. This paper lacks in presenting enough data to suggest efficient retransmission as well as propagation time for different traffic

densities.

B. State-of-the-Art in VANET Broadcasting (Optimization Techniques)

Heuristic searches, such as genetic algorithm, is categorised as a optimization technique that has been used in different studies to achieve the network coverage with minimum re-transmissions. Authors in [1] used a technique called Smart Flooding (SF), that consists of multi-objective genetic algorithm. They implemented SF using NS-2 to search the best possible solutions for multiple vehicle densities. The algorithm is slow and their results are based on fewer generations [10]. We have based our research on the studies conducted in [1]. This research proposes improving in fitness function of the algorithm so that more generations can be produced and efficient results can be obtained. To the best of our knowledge, there is no other research available related to heuristic search algorithms in VANET broadcasting.

III. SYSTEM MODEL

We consider a VANET model comprising of V number of vehicles such that $v = 1, \dots, V$, and they are communication with each other. We consider a highway scenario where multiple vehicles are moving with the same speed and in the same direction. However, in order to reduce the simulation complexity for this investigation, we consider each vehicle as static with respect to each other. This assumption corresponds well with the argument that vehicle are running with a constant speed with respect to each other. We also assume that vehicles in VANETs have on board units (OBUs) containing wireless communication system [2]. Embedded wireless communication system in OBUs aids a vehicle to establish communication with other vehicles or roadside units in immediate vicinity due to limited radio signal. The radio range of a vehicle in VANET is approximate about around 1000m [18]. Dedicated Short-Range Communication (DSRC) technology is explicitly designed to support limited range of radio communication networks containing dynamic nodes like VANETs. As dedicated wireless communication channels are required to implement DSRC, hence authorities governing communication infrastructure have started to issue special and dedicated spectrum to support establishing the vehicular network. In US, the Federal Communication Commission (FCC) has allocated 75 MHz of spectrum in the 5.9 GHz band for VANETs which is further sub divided into seven channels [18].

Furthermore, there are many standard protocols governing DSRC that are being used for the implementation of VANET such as IEEE-WAVE, CALIM and C2CNet [19]. IEEE 802.11 family contains set of protocol suites for implementation of different types of wireless communication. This family also includes IEEE 802.11p, which is designed to support Wireless Access in Vehicular Environment (WAVE) [20], [21]. IEEE 802.11p contains many salient features that have given it an edge over other protocols and has become the de facto protocol for VANET communication framework governing

both Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications. In this paper we assume that all the vehicles use IEEE802.11p for inter vehicle communication and we are only considering V2V communication.

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) as well as beaconing system are some of the salient features of IEEE802.11p that are important with respect to this research [22]. The functionality of collision management, which helps in avoiding data packet collisions, is performed by CSMA/CA. Data packet collisions may transpire in the system when more than one vehicle in the same neighbourhood attempts to transmit at the same time. In a system under CSMA/CA, when a vehicle decides to transmit something it has to check the channel for the possibility of any other transmission being carried out currently. If there is a transmission, the vehicle will assign it a random wait time after which it will check again to see if the channel is free to transmit. On the other hand, if there is no transmission, a vehicle may go ahead and transmit information. However, this situation may cause collision due to multiple vehicles following the same process with a desire to transmit some information. Hence, CSMA/CA allocates random wait time (also known as backoff interval) to each of the prospective vehicles. The random wait time is inside a contention window already defined in IEEE 802.11p. Additionally, packet acknowledgement (ACK) is also used by CSMA/CA to help in reducing collision. The ACK is sent by the receiver to notify the source about successful transmission of information. If the source does not receive ACK, it retransmit the original information. The lack of packet acknowledgement may be due to information not received by the receiver or ACK was not received intact [23]. We will take advantage of IEEE 802.11p protocol in our proposed system to implement the network packet collision avoidance and will not consider any other collision avoidance system.

One of the main implementation of our proposed system is that each vehicle must have an updated database of its neighbouring vehicles. This information can be shared between vehicles by inter-vehicle communication. In order to obtain the identities of neighbouring vehicles within the transmission range of a given vehicle, we use the beaconing mechanism as defined in IEEE 802.11p protocol [24], [25]. Upon receiving the transmitted beacon from various vehicles, the database of each vehicle is updated to include those particular vehicles.

A. Smart Flooding (SF)

Smart flooding technique, which is improved in initial phase, consists of three distinct components: evolutionary algorithm, real time simulator and log analyzer [1], [10]. The evolutionary algorithm creates a random initial population, which is forward to fitness evaluation process. Fitness evaluation is a two step process, where the first step is composed of real time simulator known as NS-2 [26] which will evaluate each individual of the population and create log files. In the second step, log analyzer extracts information from these files to assign a fitness value to each individual and report back the

TABLE I: Symbol and notations

Symbol	Description
I	Information
R_v	Relay Vehicle
N_R	Number of Retransmissions
T_P	Propagation Time
N_v	Number of Vehicles initiating transmission Packets
N_C	Network Coverage
$\mathbf{f}(x)$	Fitness Function
$z(x)$	Reproduction Function
$t(x)$	Terminal Function
$c(x)$	Cross-Over Function
$m(x)$	Mutation Function
T_{wr}	Wait Time
TTL	Time To Live
P_{NC}	Probability of Neighborhood Coverage
N_{np}	Number of vehicles that have received the transmitted packet
N_{vh}	Number of neighbouring vehicles in the neighborhood.
G_n	Generation.
TI	Time Interval
$P(x)$	Local Fitness Value
G_{gn}	Best Local Fitness Value
G_x	Best Global Fitness Value
V	All vehicles in the network
v	Single Vehicle
x	Fitness value of a individual
SF	Smart Flooding
$MOGA$	Multi Objective Genetic Algorithm
L_v	Set of Neighborhood Vehicles
T_{act}	$TTL - TI$

information to the evolutionary algorithm.

The evolutionary algorithm selects pairs of individuals for reproduction process based on fitness values to generate next generation. Reproduction process is made up of two distinct operations known as crossover and mutation. Each of the pair of individuals selected to reproduce takes part in a 10 point-cross operation to produce an individual while a newborn individual may be selected for uniform mutation. This process is revisited many time unit a stop criteria is invoked. Smart flooding flow chart is shown in figure 2.

B. Proposed Genetic Algorithm

The broadcasting storm problem is a non-deterministic problem that is not solvable by any computable equation currently known [5], [6]. Therefore, we had to look towards the domain of Non-Deterministic Polynomial hard (NP-hard) problems [1], [10]. We will use a Multi Objective Genetic Algorithm (MOGA) in this paper to solve the problem. MOGA is a heuristic based search algorithm which is used to search for optimal solutions in the search domain. Our focus will be to look for metrics such as number of retransmissions, N_R , propagation time, T_P , and network coverage, N_C . MOGA consists of three compulsory functions, similar to any other type of genetic algorithm. These functions are defined as *fitness*, *reproduction* and *termination* functions and denoted by $\mathbf{f}(x)$, $z(x)$ and $t(x)$ respectively. The symbols and notations used to describe this model are given in Table I.

A solution in the search domain consists of wait time, T_{wr} , and Time to Live, TTL . T_{wr} is the time a vehicle v should wait before retransmitting packets. While TTL is the time after

which vehicle will dispose off the packet. Both T_{wr} and TTL are based upon the probability of neighbourhood coverage, P_{nc} . This probability can be determined by using the total number of vehicles, N_{np} , that has received the transmitted packet, and total number of neighbouring vehicles, N_{vh} in the neighbourhood. Mathematically, this probability can be represented as follows:

$$P_{nc} := \begin{cases} 0, & \text{if } N_{np} = 0 \\ 1, & \text{if } N_{vh} = 0 \\ \frac{N_{np}}{N_{vh}}, & \text{otherwise} \end{cases} \quad (1)$$

An individual of the population in MOGA will be a solution that will have a fitness value x based on the fitness function $\mathbf{f}(x)$. The fitness value x of an individual is defined as the quality of that individual for the purpose of determining its worth as a possible parent of next generation G_n . The fitness function $\mathbf{f}(x)$ has been determined through NS-2 simulator in previous studies [1], [10]. However, we have proposed an analytical approach determine the fitness value x of an individual. This approach helps in iterative evaluation of packet transmission on a highway scenario against a certain number of vehicles v . The fitness function $\mathbf{f}(x)$ equation is represented as following:

$$\mathbf{f}(x) := [N_R \quad T_P], \quad (2)$$

where

$$N_R := \sum_{i=1}^{N_v} \alpha_i, \quad (3)$$

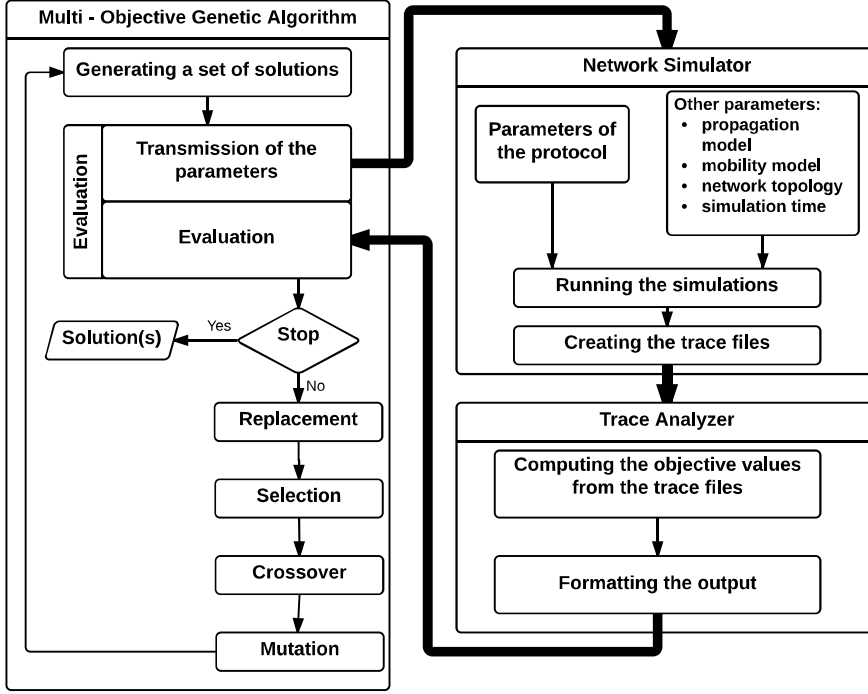


Fig. 2: Flow chart of Smart Flooding [1], [10]

and

$$\alpha := \begin{cases} \sum_{i=1}^{N_{vh}} \alpha_i, & \text{if } TTL - TI > 0 \\ N_R, & \text{if } TTL - TI = 0 \end{cases} \quad (4)$$

where $\alpha = V(N_R, P_{nc}, T_{wr}, TTL, TI, L_v)$.

The fitness function $\mathbf{f}(x)$ is a vector containing retransmissions (N_R) and propagation time (T_P) parameters that are to be optimized. Hence, best fitness values are the ones that will have minimum possible values of N_R and T_P . Initial population is created randomly, while the population of next generations (G_n) is created by the reproduction of individuals from the previous generation, exhibiting the best fitness value of x . These individuals are referred as parents for the next generation.

A reproduction function $z(x)$ is based on the crossover function, $c(x)$, and mutation function, $m(x)$. A crossover is a process of exchanging genetic materials between two individuals in the hope of creating enhanced optimized children. When two individuals from previous generations are selected as parents, the crossover function, $c(x)$, will swap arbitrary bits from various unique locations of each parent to create two new individuals for the next generation. Mutation is used to create genetic diversity. Mutation function, $m(x)$, is performed on every multiple of 10^{th} generation. Mutation function, $m(x)$, selects 10% of population randomly and changes 48 bits from random locations. The rationale behind selecting this mutation rate in our experiment is that a value of mutation rate lower than the selected value slows down

TABLE II: An example of chromosome information

P_{nc}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
T_{wr}	1	2	3	4	5	6	7	8	9

the rate of evolution, whereas higher value do not provide any extra benefit. The selected value of the mutation rate created acceptable individuals. A chromosome consists of P_{nc} and T_{wr} . Time Interval, TI , is a counter that a vehicle v starts when it receives the packet. TI is a factor that will be subtracted from TTL . This subtracted time denoted as T_{act} , has two purposes: (i) A vehicle v disposes off any packet that has $T_{act} = 0$, and (ii) it also forwards T_{act} while transmitting the packet. T_{act} serves as TTL of the packet for receiving vehicles.

Chromosomes are encoded in binary number, similar to the previous studies [1], [10]. Two cases of P_{nc} , where P_{nc} is 0 and 1, are not encoded in chromosomes. In these cases of P_{nc} , we believe there is no requirement to find an optimal value because of the reason explained ahead. When $P_{nc} = 0$, then a vehicle v initiates the retransmission process immediately, whereas the packet is not transmitted if $P_{nc} = 1$. Table II presents a typical information that is encoded in the chromosome. To further explain the encoding of a chromosome in Table II, 0.1 and 1 are collectively represented as 1 in chromosome and are encoded as 00000001 in binary. Each column in Table II is encoded with individual 8 bits pattern. The binary representation of Table

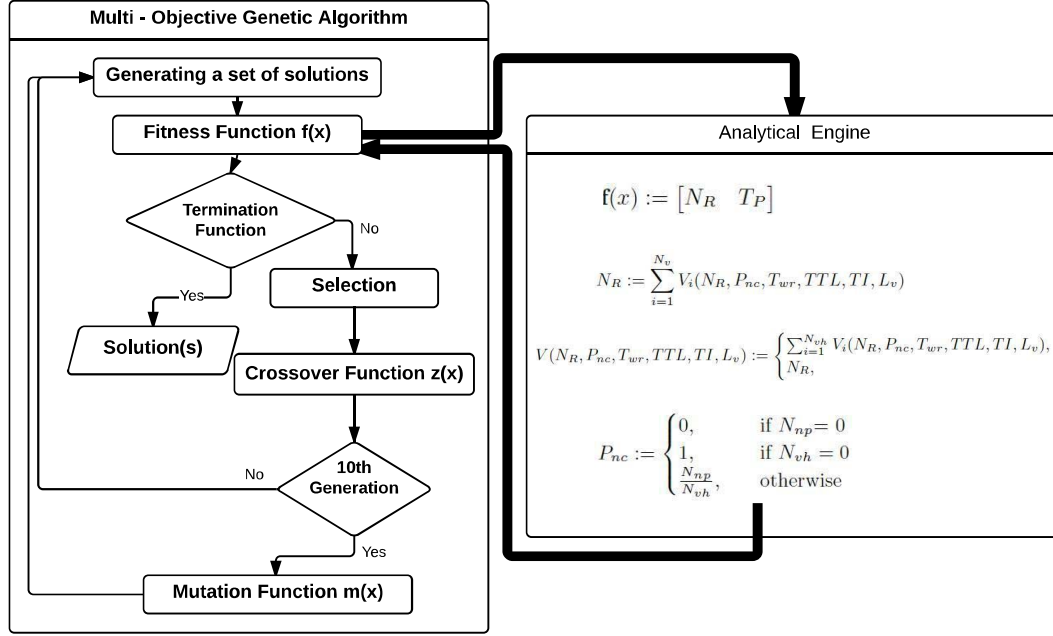


Fig. 3: Flow chart of MOGA

II information is encoded as follows:

00000001, 00000001, 00000010, 00000010, 00000011,
 00000011, 00000100, 00000100, 00000101, 00000101,
 00000110, 00000110, 00000111, 00000111, 00001000,
 00001000, 00001001, 00001001

Furthermore, an individual having the best fitness value, x , among all individuals of generations will be the best optimized. This fitness value, x , is denoted by $G(x)$ and is known as a global solution. A fitness value $P(x)$ of an individual is the best fitness among local current 500 generations. MOGA is terminated when the condition of termination function $t(x)$ is full filled. Termination function, $t(x)$, can be written as follows

$$t(x) := \begin{cases} True, & \text{if } G_{gn} = 500, P(x) > G(x) \\ False, & \text{otherwise} \end{cases} \quad (5)$$

whereas,

$$G_{gn} := \begin{cases} G_{gn}, & \text{if } G_{gn} \leq 500 \\ 1, & \text{if } G_{gn} > 500 \end{cases} \quad (6)$$

IV. RESULTS AND DISCUSSIONS

This section describes the results obtained through implementation of our proposed algorithm by developing our own library of code. It is important to note that all the individuals of the population, whose simulation results illustrate T_P to be greater than TTL , are ignored in the process of parent selection for the next generation. We assume that any solution depicting this scenario does not

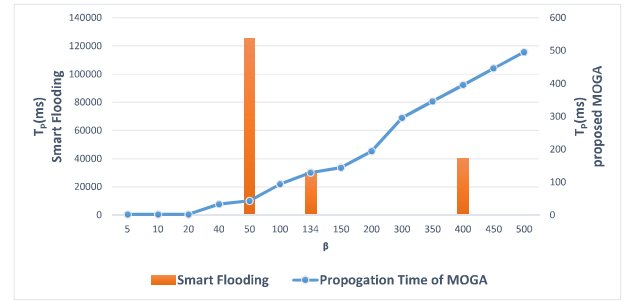


Fig. 4: Propagation time

achieve network coverage. All simulation parameters are listed in Table III and are compared with the state-of-the-art smart flooding statistics. Furthermore, we have utilised three different vehicle densities in a highway setup similar to the previous studies [1], [10] to observe deeper understanding of the results.

Figure 4 shows a comparison of propagation time between proposed MOGA and smart flooding technique for varied vehicle density. SF lacks IEEE 802.11p which has an in built CSMA/CA to avoid collision pre-emptively. Due to high collision rate, SF requires more time to propagate information as compare to our purposed MOGA. The low density scenario takes more time to propagate information as compared to medium density scenario in the case of SF. Due to lack of knowledge about the neighbourhood, a vehicle, in the smart flooding, continues to retransmit information until it receives back same packet from multiple other vehicles. This helps

TABLE III: Simulation parameters

Simulation Area	100 X 100 m
Frequency	5.9 GHz
Parameters	Values
Type of Road	Highway with multiple lanes
High Density	400 vehicles
Medium Density	134 vehicles
Low Density	50 vehicles
Protocol	IEEE 802.11p
Transmission Range	1000m
Mutation Rate	10%
Mutating Bits	48
Mutation Period	10 th generation

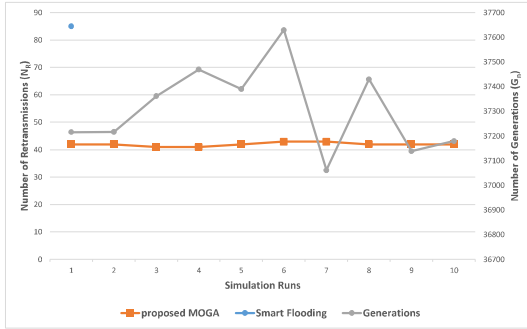


Fig. 5: Low density retransmissions and generations

in checking reliable propagation of the information in the network. Furthermore, in the low density a vehicle may not receive back enough information packets to stop retransmitting causing an increase in cases of collision with the neighbouring relay vehicles. This will cause an increase in propagation time. Hence lower the density, higher the tendency of vehicles to retransmit same information multiple times to achieve the network coverage causing an increase in propagation time.

To further explore the adaptation of our proposed approach, we study the average wait time of neighbourhood probability in case of both low and medium density scenarios as shown in Figure 7. The average wait time is calculated from the solutions containing wait time alongside different neighbourhood probability obtained through multiple simulations.

The smart flooding requires 85 and 80 retransmissions for network coverage in case of low and medium vehicle density respectively [10]. On the other hand, our proposed approach requires an average of 42.2 and 24.7 retransmissions for network coverage, respectively, as shown in Figures 5 and 6. This decrease in the number of retransmission, as opposed to SF, is due to availability of up-to-date neighbourhood information provided by the IEEE802.11p beaconing system that helps in avoiding redundant retransmissions.

Evolution is a slow but a very successful process, hence it takes a lot of generations to come up with the best suited individuals for the prevailing environmental conditions. The same rule is valid for the evolutionary algorithms derived from the natural evolution. Due to complexity of fitness criteria of the smart flooding caused by the usage of real-time simulator,

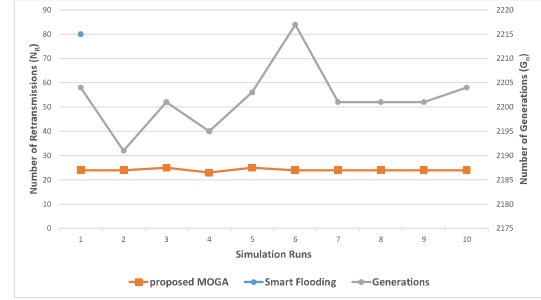


Fig. 6: Medium density retransmissions and generations

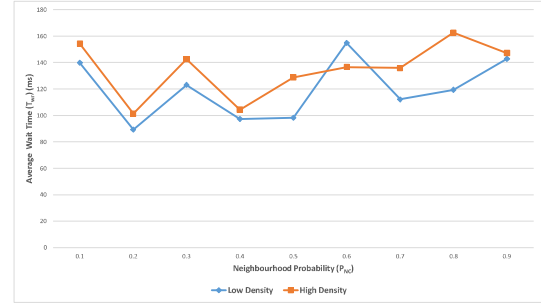


Fig. 7: Average wait time and neighbourhood probability

the given results were assembled after only 15 generations [10]. In the proposed MOGA, we improved this fitness criteria by using analytical approach, as show in Figure 3, to eliminate the need for the real-time simulator. This helps in reducing the complexity of the algorithm causing it to run for longer time and generate greater numbers of generations to obtain better optimized solutions as shown in Figures 5 and 6.

V. CONCLUSION

In this paper, we have presented a novel fitness criteria, based on analytical approach to solve the issues of broadcasting storm in VANETs. The analytical approach helps in reducing the complexity of MOGA, increasing the rate of evolution and producing the better optimized solutions. The results showed that our approach produces better results in terms of propagation time and number of retransmissions compared to the previous approaches adopted in smart flooding technique. The future work of this study is to analyse the change in wait time and search for patterns that will help in developing an optimal solution in both urban and highway scenarios which in turn will help to generate faster calculations.

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