Realistic Heterogeneous Genetic-based RSU Placement Solution for V2I Networks

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Abstract: *The main elements of a Vehicular Ad Hoc Network (VANET), besides VANET-enabled vehicles, are Roadside Units (RSUs). The effectiveness of a VANET in general depends on the density and location of these RSUs. Throughout the primary tiers of VANET, it will not be possible to install a big number of RSUs either due to the low market penetration of VANET enabled vehicles or due to the deployment fee of RSUs. There is, therefore, a need to optimally select a restricted number of RSUs in a special region in order to accomplish maximum performance. In this article, we use the well known genetic algorithm primarily based on RSU region to locate the most appropriate or near optimal solution. We supply the fundamental simulation environment of this work by OpenStreetMap (OSM) to download actual map data, Grupo de Arquitectura y Tecnología de COMputadores (Gatcom) to generate car mobility, Software Update Monitor (SUMO) to simulate street traffic, Veins model framework for walking vehicular network simulation, OMNET++ to simulate practical network and Matlab to build the algorithm in order to analyze the results. The simulation scenario is primarily based on Hamra district of Beirut, Lebanon. Based on the genetic algorithm, our proposed RSU placement model demonstrates that a most appropriate RSU position that can enhance the reception of Basic Safety Message (BSM) delivered from the vehicles, can be performed in a exact roadmap layout.*

Keywords: *Vehicular model, RSU, genetic algorithm, optimization.*

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1. Introduction

Vehicular Ad Hoc Networks (VANETs) have attracted extremely good interest in both industry and academia. It assists in enhancing street safety, traffic manage and many other commercial applications. A VANET consists of two kinds of nodes, On-Board Units (OBUs) and RoadSide Units (RSUs). OBUs are equipped with vehicles and RSUs are placed along the aspect of the roads. VANETs remember on two kinds of wifi communications for interconnection, Vehicle-Vehicle verbal exchange (V2V) and Vehicle-RSU communication (V2R).

All RSUs immediately connect to the Internet via cable. Most of the applications in VANETs collect/disseminate facts from/to vehicles via RSUs. An essential software is the speedy and reliable broadcast of emergency messages to all vehicles in the area. An important issue is to region RSUs accurately to assist this kind of message dissemination operations. Information flow in most VANET purposes is either from vehicles to infrastructure or from infrastructure to vehicles. Our focus, in this paper, is on purposes that depend on data flow from vehicles to infrastructure (or RSUs), such as collection of data from vehicles about traffic/road conditions, traffic accidents, etc., RSU performs a necessary personality in vehicular correspondences because of its potential of:

- Delivering critical data to vehicles.
- Forwarding received messages to definite recipients.
- Providing Internet access to vehicles.

RSUs are conveyed to stretch out vehicle inclusion and to enhance execution in vehicular systems. Vehicles' correspondence skills depend upon the quantity of RSUs sent and their inclusion. In this way, there is a change between full inclusion through RSU and their organization cost. In this manner, specialists tend to bind the extent of RSU, specifically in rural areas and less populated territories, making RSU a constrained asset in vehicular conditions. We consider that it is crucial to ideally ship a predetermined number of RSUs in the most gorgeous areas (i.e., those spots that unmistakably enable RSU to stretch out inclusion and to enhance the popular device execution). Therefore, it is important to find an automated strategy to achieve the best areas for the RSU to be conveyed in any situation, because of the massive distinction of urban street designs.

The purpose of the paper is twofold; first we suggest a model for the communication between the OBUs and the RSUs by proposing new simulation surrounding that integrates heterogeneous simulators. Second we apply the well-known Genetic Algorithm (GA) to decide the best number of RSUs in an city environment.

The rest of this paper is organized as follows: section 2 presents a literature review to show some current studies related to the RSU location problem, section 3 presents the simulation environment, section 4 provides the system model of GA-based RSU location. The simulation results and analysis are introduced in section 5, section 6 concludes our work.

2. Literature Review

This section describes RSU positioning. In masking area issues, the goal is to discover the ideal positions that consist of each one of the customers (vehicles), while bringing few boundaries into records. A plenty of work is proposed to include the region of RSU more desirable position. Researchers have been reading the allocation of RSUs in vehicular networks via numerous factors of view.

In [1, 7, 8, 10], the authors have proposed to locate the RSUs in the best way. They consider crossing factors as greatest positions in city place then thickness in convergences is generally increased.

In [1], the author's objective is to create facts propagation in a city region. They exhibit the role difficulty as a Maximum Coverage with Time Threshold Problems (MCTTP). To ideally send RSU to serve the most severe vehicles in the street, they make use of a hereditary heuristic to determine the MCTTP and flip into the best RSU location.

In [10], the point is to discover the best areas for RSU to include the vehicles in city streets and decline the postponement of security messages spread. The authors consider crossing point areas as manageable positions to ship RSU. They numerically demonstrate the issue and utilize two approaches to deal with:

1. Analytical Binary Integer Programming (BIP) [4] to discover the biggest transmission time in the whole zone.
2. Balloon Expansion Heuristics (BEH) method to discover the best time over every course.

In [8], the authors recommend a price-proficient RSU organization framework. The goal is to refresh safety in the urban territory. In this framework, they anticipate that each vehicle can communicate with RSU in limited time. They show the difficulty as a set-casing difficulty and make use of the polynomial-time estimation calculation called "Greed Set Cover" [6] to decide it.

In [8], the authors have proposed an RSU scenario method for document downloading on account of the city situation. The principal goal is to assure report downloading with the most minimal scenario cost. They make use of crossing points as RSU beginning area and think about simply Vehicular-to-Infrastructure (V2I) interchanges.

In [2], the authors have proposed to supply the required inclusion whilst limiting the organization price in the city territory. They define the issue as a Maximum Coverage Problem (MCP) [12]. They partition the pondered zone into uniform zones and check the number of vehicles toward within and leaving each and every location for every time unit to get the unfold of trade probability between two zones. At long last, they build up their personal heuristic calculation called "MobGDeploy" to find the best entryways positions. The authors endeavor to cowl the most extreme customers by way of deciding on to area portals in the zones with high thickness; so the goals do not consider the defer condition particularly in low-thickness cases. Such a goal is additionally not good to transmit health messages for instance.

In [13], the authors have improved the movement time between neighbor's tourist spots. They endeavor to ideally find the best RSU areas in the urban region with a specific end goal. They utilize a hereditary calculation to find the best areas. For every emphasis of the hereditary calculation, they utilize the Network Simulator (NS2) test system to assess the present arrangements and to appraise the required travel time by reproduction. They select an arbitrary applicant's sending areas, which increment the nature of the arrangement and does not consider thickness data.

In [11], the authors point is to examine the measure of the holes between RSU to create information social occasion and conveyance proportion in an interstate situation. They at first disperse RSUs close to the street and detail the separation among RSUs. At that point, they utilize OMNET++ test system to assess the considered strategy under practical situations to discover the greatest hole between each two progressive RSU.

In [3], the authors point is to limit the normal announcing time of data to a predetermined RSU. To viably assemble information in parkway situation, they propose utilizing a uniform introductory RSU conveyance. To diminish the arrangement price and secure the greatest RSU area, they enhance a heuristic in light of inflatable development strategy.

However, the authors in [3, 11] recommend their outcome just for a solitary street. Furthermore, the uniform dispersion is not the best introductory appropriation, as it does not consider the thickness in the street and increment the conveyance postponement of data.

In [5], the authors have shown the system availability utilizing a liquid ideal and a stochastic ideal. They suggest RSU task as a use of their model. The liquid model is utilized to register the system thickness. The stochastic ideal considers the vehicles' arbitrary conduct. This ideal is not the same as the Poisson-Arrival-Location Model (PALM) depicted in [9]. It is intended for urban situations; it considers activity light and communications between vehicles. It licenses deciding the level of network in a predefined street. At that point, it doles out the RSU to improve the availability where the quantity of associated hubs is lesser than an edge. The authors find the best areas to put RSU in spite of the fact that they do not advance the number of RSUs.

In our study, we deal with optimal RSU placement in urban scenarios to maximize the number of messages received from vehicles. We use V2I communication to improve the network connectivity and reduce needless infrastructures. The novelty of this work relies on the realistic representation of the simulation model that integrates several heterogeneous simulation environments.

3. Simulation Environment

The simulation of VANET is increasingly needed. However, this is not easy to achieve it because the road traffic and the network communication simulators are complex and often hybrid frameworks are required. These extensions allow for easy traffic simulation on Veins using maps imported from OSM. We present guidelines for VANET simulation with the combined use of OSM, GatcomSUMO, Matlab, SUMO, OMNET++, and Veins as illustrated in Figure 1.

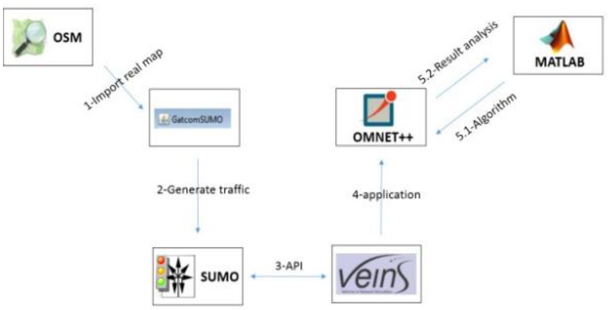

Figure 1. Guidelines for VANET simulation.

From OSM we import the map of the city of Hamra in Lebanon, which conducted the study as an area of urban through GatcomSUMO. It is approved by Sumo and also generated to specified traffic to visualize the map. Veins is the framework work in the heart of the OMNET++ where it contains large libraries and simulated networks, in addition to the fact that is considered an API between the OMNET++ and Sumo. Through the OMNET++ program we have monitored the transfer of data from the vehicle to RSU and vice versa and demonstrated the results and read them Matlab with the application of our proposed algorithm.

3.1. OMNET++

OMNET++ is a simulation surrounding emphasizing on simulation of verbal exchange networks. It presents an issue sketch for models. Components as modules are programmed in C++. It has a rich GUI as shown in Figure 2. Diverse simulation fashions can be built-in into OMNET++ for one-of-a-kind duties.

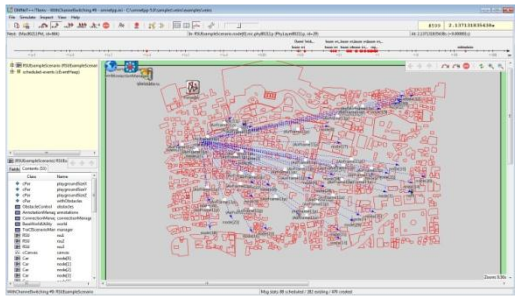

Figure 2. Modelling process.

3.2. SUMO

SUMO is a very good traffic simulator which is open source as well. SUMO has been used in a diversity of VANET missions. The road network, vehicle types, and vehicle routes are all greatly configurable. Furthermore, TraCI permits SUMO to communicate bidirectionally with any network simulator executing TraCI. This permits the results of traffic simulator to affect the network simulator and vice versa. By default, SUMO uses the Stefan Krau car following model to realistically model the acceleration and deceleration of each vehicle. The quantity of traffic can be controlled with the aid of generating more or fewer routes in a given time period. For example, Figure 3 illustrates Tampere map in SUMO.

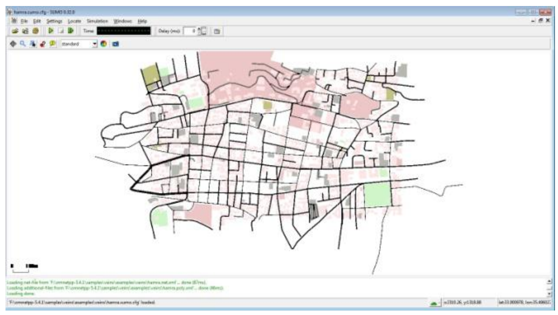

Figure 3. Hamra map in SUMO.

3.3. OSM

OpenStreetMap, or OSM in short, is an open source assignment. The map data of this task has been built from floor survey result initially, however, now there are contributions from both the authorities such as the United States and the United Kingdom and business corporations such as Automotive Navigation Data and Yahoo aside from private contributors. The data from this task is presently beneath Creative Commons license but the venture is moving on to the Open Database License, both allow the records to be used freely via the public. In this paper, we exported a small area in Hamra as shown in Figure 4.

Figure 4. Using the “Export” tab in OpenStreetMap to Get the Map of an Area in Lebanon.

3.4. GatcomSUMO

GatcomSUMO was born with the alike easy concept as TrafficModeler and SUMOPy, that is, to simplify the use of the SUMO traffic simulator, in particular with network and traffic demand generation. Individually, GatcomSUMO shapes instructions and representatives its work to the SUMO utilities (e.g., netconvert, duarouter, etc.,). However, SUMO is not the only tool used when occupied with VANETs environments. The researcher wishes a community simulator like OMNET++ together with some frameworks extensions (e.g., Veins, INET, etc.,) for the simulation of wireless networks. The enhancement of GatcomSUMO represents an effort to simplify every challenge concerned with this complicated software toolchain. The mastering curve of SUMO is hard, and carrying out a basic community simulation ought to take a long time and be frustrating. Even for an expert, doing a new scan in which both the network and the routes of the automobiles alternate can be exasperating. The graphical interface is structured in various major tabs in accordance to the steps to comply with all through the setup of a simulation with SUMO and OMNeT++ as illustrated in Figure 5. Each important tab might also include a number of secondary tabs to cover all the supplied functionalities.

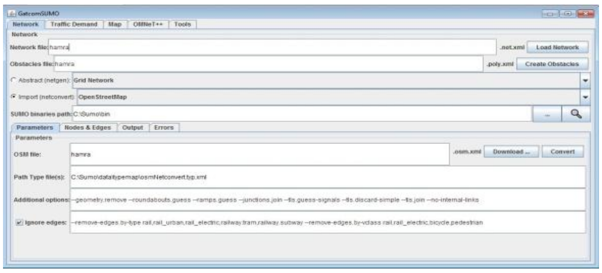

Figure 5. Network tab.

3.5. Veins

The simulation framework is joined of two simulators: OMNET++ for network simulation along with MiXim model which runs in the physical layer and SUMO for road traffic simulation. The main benefit of the Veins simulation framework is that it supports bidirectional coupling between network simulation and road traffic microsimulation. Figure 6 describes the Veins simulation framework which works on top of the MiXiM simulation model.

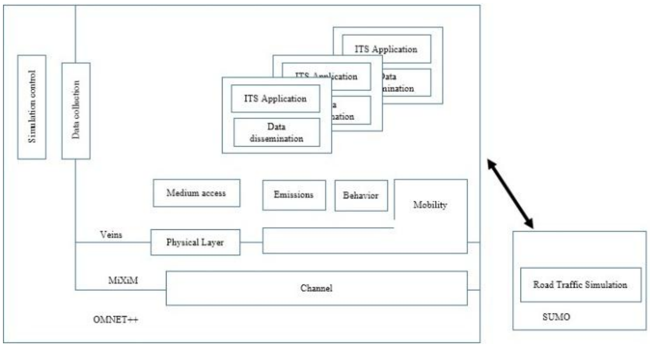

Figure 6. Veins simulation framework.

3.6. Matlab

It integrates computing, programming, signal processing and graphics in relaxed to use environment, in which problems and solutions can be expressed with mathematical notation. A simple data element is an array, which permits for computing difficult mathematical formulas, which can be found mostly in linear algebra. But Matlab is not only about math problems. It can be widely used to analyze data, modeling, simulation, and statistics.

4. Proposed Method

GAs named after the natural development method and its hereditary sub-atomic premise, lead a populace of humans to advance by subjecting such a populace to irregular procedures like those existing in natural development- i.e., transformations and hereditary re-blends- and additionally a desire as indicated by criteria to discern out which people are extra adjusted to survive. The fittest humans are chosen and advanced to ensuing ages, furthermore, those much less match humans are released.

4.1. Representation of Individuals

Each feasible reply for the issue wants to be classified into a genotype earlier than applying the hereditary administrators. Possible answers for the RSU situation issue would incorporate the location of the majority of the on hand RSUs, which turns into the phenotype.

1. *Chromosomes Encoding*: to provide a basic, rich and viable stream of GA, Holland utilized a string of paired unravel chromosomes, instead several exclusive plans are suggested alongside them separate focal points.
2. *Phenotype and Genotype*: this is fantastically notable chicken and egg issue. Actually, in GA the encoded objects are known as genotype and authentic protest is known as phenotype, anything can be encoded in light of the fact that diverse methodologies are accessible in the writing. The fundamental distinction is ability of these qualities, that in GA characteristics are not kept in sets while

in the ordinary technique are sets speaking to them guardians' investment.

3. *Chromosome Evaluation*: the objective feature to be expanded, otherwise referred to as the health function, as per Davis, haphazardly produced populace is the greater section of the occasions to a outstanding degree unfit. The wellbeing works that aides GA based RSU position is gotten BSM message from vehicle to roadside unit. Figure 7 represents the means pursued by GA primarily based RSU sending. As an initial step, it makes an underlying arbitrary RSU sending; also, it recreates this particular situation by using an altered adaptation of the OMNET++ test system, which allows us to verify the arrangement wellness. From that factor onward, it plays out the parent choice, the hybrid, and the transformation activities on Matlab. At long last, it assesses the wellbeing of the new arrangement, makes the fractional substitution and assessments whether or not the end condition is comfortable (for our situation, a most extreme number of completed ages). If not, it plays out the mum or dad choice process once more also, rehashes the ensuing activities.
4. *Basic Operators*: after preliminary populace the algorithm describes following functions: Selection, Crossover and Mutation.
5. *Parent Selection*: this stage selects the fittest individuals of the current populace to transmit their genetic information to the subsequent generation. in which okay random individuals in the population are compared, and the one with the absolute best fitness value becomes a conceivable mum or dad of new individuals.
6. *Crossover Operator*: the crossover, also recognized as recombination, operative combines two dad and mom to generate a third new individual. GA makes use of the default re-combination operator in genetic algorithms, i.e.
7. *Mutation operator*: the mutation operator introduces variety into the population, thereby averting local minimal solutions. GA makes use of probabilistic mutation for each gene, meaning that a gene can also range its fee using a constant probability. The mutation likelihood is adapted to the size of the genotype to make one change in each man or woman on average.

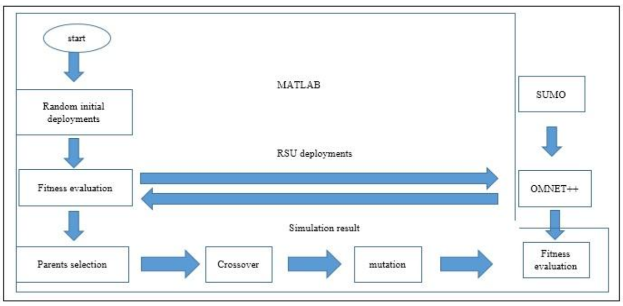

Figure 7. GA algorithm.

5. Simulation Results

In this section, we provide simulation effects of our RSU location optimization based on GA. The simulation situation is based totally on Hamra district of Beirut, Lebanon. We examined our RSU location optimization for different quantity of RSUs.

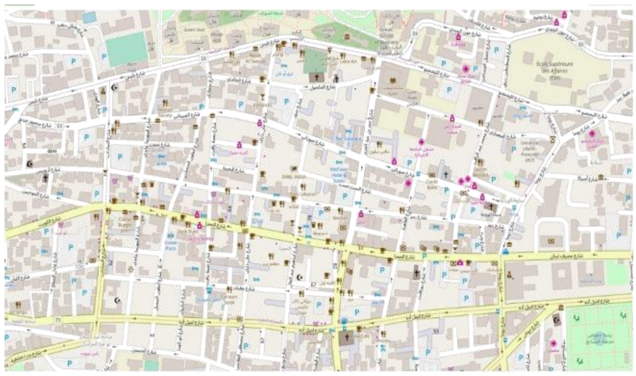

Figure 8. Hamra district of Beirut, Lebanon.

5.1. Scenario

The chosen situation is Hamra district of Beirut proven in Figure 8. Using SUMO, we organized a simulated traffic flow of forty cars with randomly generated trip routes. We ran the RSU placement optimization for exceptional variety of RSUs. The fitness function chosen for the genetic algorithm is the total number of BSMs acquired by way of RSU from vehicles. The simulation situation concerned forty cars with the following properties:

- The trip routes are chosen randomly by Gatcom-SUMO GUI.
- Departure time is 1.2s.
- Increment between vehicles is 0.01s.

Finally the candidate position is special as GA assigns a unique number to every feasible place in the RSUs, and the genotype of every answer incorporates a sequence of numbers representing the place selected for every RSU, as depicted in Figure 9.

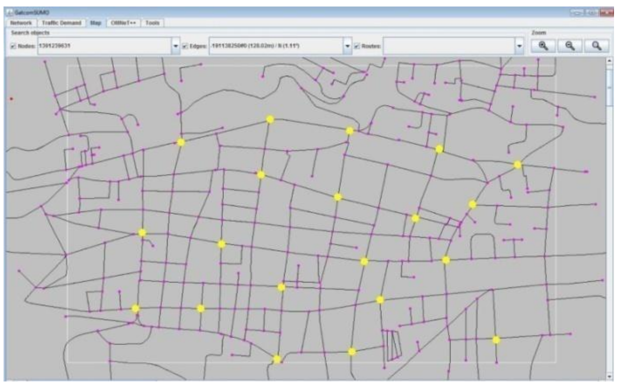

Figure 9. Each possible location for RSU appears as yellow circles on the map layout.

5.2. Results

We examined the RSU location optimization for three feasible numbers of RSUs. For every preference of RSU values, we ran the optimization three ones. Based on the dimension of Hamra district size, the chosen candidate RSU quantities are three, four and five.

1. *Case* 1: three RSUs, Table 1 shows the chosen RSU positions and acquired BSM by means of the RSU for each optimization run of the three RSU cases. The total acquired BSM for all the runs used to be ninety-two messages. This shows that the optimized positions are no longer sensitive to the performance of the GA on every run. Figure 10 shows the optimized RSU positions on the Hamra map. As shown in the figure, the optimized RSU positions lie along routes of high car density.

Table 1. The RSUs for each optimization run of the three RSUs case.

RSUs nb	X-position	Y-position	received BSM
RSU [0]	1343	869	28.0
RSU [1]	1546	740	30.0
RSU [2]	845	684	34.0

2. *Case* 2*:* four RSUs, Table 2 shows the chosen RSU location and received BSM by the RSUs for each optimization run of the 4 RSU cases. The total acquired BSM for run 1 is one hundred and one for run 2 is 104 and for run 3 is 105, which indicates the optimized RSU positions on the Hamra map for every run. The optimized RSU positions for three of the RSU are consistently chosen to be at the same positions. The fourth RSU position, however, varies slightly between runs.

Table 2. The RSUs for each optimization run of the Four RSUs case.

RSUs nb	X-position	Y-position	received BSM
		RUN 1	
RSU [0]	845	684	35.0
RSU [1]	1546	740	29.0
RSU [2]	1039	825	30.0
RSU [3]	970	469	7.0
		RUN 2	
RSU [0]	1039	825	31.0
RSU [1]	845	684	34.0
RSU [2]	1546	740	29.0
RSU [3]	1212	542	10.0
		Run 3	
RSU [0]	1039	825	31.0
RSU [1]	845	684	32.0
RSU [2]	1546	740	31.0
RSU [3]	1297	745	11.0

3. *Case* 3: five RSUs, Table 3 suggests the chosen RSU positions and acquired BSM by way of the RSU for every optimization run of the 5 RSU case. As the total acquired BSM for run 1 is 120 for run 2 is 128 and for run 3 is 113 as proven in the table, one RSU continually receives little or no BSM. This ability that the greater fifth RSU is now not needed, which suggests the optimized RSU positions on the Hamra map for every run.

5.3. Result Analysis

The results proven in this section exhibit that the GA-based RSU region optimization correctly selects RSU placements at dense car flow locations. The case of three RSUs shows that there are three dominant candidate positions. This dominance was clear from the consistent resolution of these places by the optimization. The case of 4 RSUs, on the different hand, indicates that a fourth RSU adds to the performance of the different three; however, the role of the fourth RSUs can be selected at numerous candidate positions with similar performance. The case of 5 RSUs show that, for this scenario, a fifth RSU is redundant considering the fact that the optimized RSU positions in this case persistently resulted in one RSU received little or no BSM.

Table 3. Run 1-the RSUs for each optimization run of the five RSUs case.

RSUs nb	X-position	Y-position	received BSM
		Run 1	
RSU [0]	845	684	34.0
RSU [1]	1039	825	31.0
RSU [2]	1546	740	30.0
RSU [3]	1709	990	0.0
RSU [4]	1534	390	25.0
		Run 2	
RSU [0]	845	684	32.0
RSU [1]	1546	740	31.0
RSU [2]	1039	825	31.0
RSU [3]	1343	869	28.0
RSU [4]	996	295	6.0
		Run 3	
RSU [0]	1343	869	31.0
RSU [1]	845	684	32.0
RSU [2]	1039	825	31.0
RSU [3]	1634	564	11.0
RSU [4]	1246	323	7.0

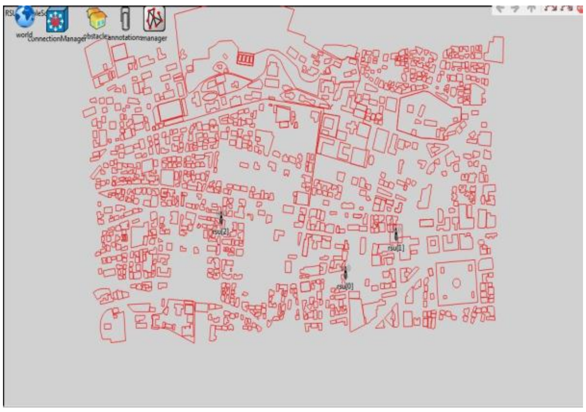

Figure 10. Tthe optimized Three RSU positions on Hamra map.

6. Conclusions

In this paper, we proposed a GA-based RSU position strategy, which is finished by a way of mechanically determining the best RSU position to increase the number of received BSM message delivery from vehicle in any specific roadmap, ranging from regular to tough city map layouts. Simulation results, based on realistic traces and map layouts, prove that GA-based RSU is capable to maximize the BSM messages in special map layouts, including complex scenarios, under different vehicular densities, as when a different number of RSUs wants to be deployed. This should exhibit that the GA-based RSU region optimization efficaciously selects RSU locations at dense vehicle flow locations.

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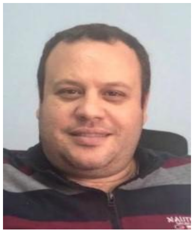

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