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# A Feasible RSU Deployment Planner Using Fusion Algorithm

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**Abstract**

With day to day exponential increase in the number of vehicles, it is essential to communicate travel information for road travellers to enhance their travelling experience. One of the recent technologies that aid in real time and faster communication of information is Vehicular Ad-hoc Network (VANET). To ensure significant connectivity and continuous data flow, Road Side Units (RSU) are installed in VANET. RSUs receive the traffic information from vehicles and communicate it to other RSUs, Traffic Management Centre (TMC) or other adjacent vehicles. However, identifying the appropriate locations to deploy RSUs to maintain network connectivity and reduce cost of installation in a given area are still challenging and cannot be decided based on a single parameter. This paper proposes an Optimal RSU Distribution Planner (ORDP) using a Fusion Algorithm (FA) comprising of Evolutionary Genetic Algorithm (EGA) and D-Trimming. Further it also provides the feasibility to choose the appropriate parameter configuration based on user requirement which makes the model feasible and efficient. The scalability and efficiency of the planner are tested against simulated and realistic datasets and it is seen that ORDP has proved to deliver improved results compared with other greedy approaches.

**Keywords** VANET · Optimal RSU Distribution · Evolutionary Genetic Algorithm · Trimming Algorithm · Fusion Algorithm

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## 1 Introduction

With rapid urbanization and growing economy, the number of vehicles increases exponentially. Over time, the problem of road traffic is only going to be inevitable and becomes complicated to be handled by the existing Intelligent Transportation Systems (ITS) applications. In this paper, the problem is addressed using the Vehicular Adhoc Network (VANET) infrastructure which is the most recent, trending development in ITS. It is a promising application-oriented network which aids in managing traffic, distributing traffic related information, safety warnings and entertainment content to passengers [1]. This infrastructure is similar to wireless communication technology called Mobile Ad-hoc Network (MANET) but in contrast the wireless sensor networks are dynamic, high in processing capacity, efficiency and storage. The are three types of communication of information in VANET they are as follows: (1) Communications between Vehicles (V2V), (2) Communications between Vehicles to any road side infrastructures or Road Side Units (RSUs) (V2I) and (3) Communications between Infrastructure to Infrastructure (I2I). This infrastructure enables development of new and innovative real time applications to travellers [2].

The duration and continuous connectivity is essential to establish communication capabilities among wireless equipments. The connections over V2V cannot completely fulfil the requirement of operation in an Intelligent Transportation Systems (ITS) application. It may not provide satisfying Quality of Service (QoS) and connectivity due to its dynamic nature of the network. To overcome such challenges, Road Side Units (RSUs) are utilized to ensure the connectivity of access point, QoS to applications, mobility support and collaborate the dynamic resource management in VANET. RSUs also help in avoiding delay and loss of information during multi hop communication [1, 3–7]. However, distributing RSUs comes up with huge cost. It needs to be ensured that (1) Limited RSU's are to be deployed especially in suburbs and scarcely populated locations during a large scale deployment (2) Maximum number of road segments are under coverage (3) Transmission of information through heavy traffic and emergency conditions are handled (4) The cost involved to place RSUs to be kept minimum. Therefore, optimizing the number of RSUs in any given set of road segments is imperative. Our goal is to identify the parameters that affect the placement of RSU in a road segment and to offer an improvised and efficient planner to optimally place the RSU to enable accurate information transfer to travellers within the budget. With the following sections, the rest of the paper is structured: Section 2 illustrates few existing work similar to the proposed model. Section3 describes the function of ORDP with Sect. 3.1–3.3 describing each module in detail. Section 4 discusses the results for simulation and real world data. Future work and conclusion are presented in Sect. 5 and 6 respectively followed by References.

## 2 Related Works

The recent development of VANET based infrastructure provides an opportunity to efficiently estimate traffic related parameters that are essential for applications aiming to communicate traffic related information. Therefore, the distribution of components of VANET have to ensure an effective communications between numerous sources and receivers. Recent researchers in this area have proposed various algorithms with several parameters as an influential performance metric to reduce the number of RSU deployed, improve the coverage and overall network performance. Outline of few approaches are discussed in this section.

The problem of deployment is solved as a non-linear integer programming problem with average car density over a period of time [4]. A polynomial running time approximation algorithm that uses grid graph of the city map and Greedy Set-Cover Algorithm are proposed in [5, 8] respectively to solve the deployment problem. A centrality based approach is followed by [9] that formulates the problem as linear programming problem and solves it using 0-1 Knapsack algorithm. A cost-effective and heuristic strategy for maximizing the performance of RSU when the vehicle is within direct and indirect transmission range for highways are proposed in [6, 7]. In [10] Influencing factors such as traffic, topological and infrastructure for RSU deployment are considered using a greedy weighing method for allocation of RSU in each location. In [11] the author proposes a Branch-and-Bound method and Balloon Expansion Heuristic method to deploy RSUs in intersections. This work can be used only in simple road topology and not feasible for realistic traffic conditions. Knapsack and PageRank algorithms are used in [12] as a weighted edges graph that indicates the importance of the connection for deployment. Another proposal by [13] is *Tailor* Algorithm that aids in dissemination information at intersection with or without mobility information. The authors of [14] proposes solution based on Knapsack algorithm and Maximum Coverage with Time Threshold Problem (MCTTP) by applying divide and conquer and greedy algorithm.

There are other approaches that use evolutionary algorithm to solve the deployment problem. [15] models uses MCTTP and solves it using Genetic Algorithm and the simulation were carried out for four real world datasets which shows increased vehicle coverage. The optimal deployment problem is solved using an evolutionary mulit-objective algorithm accounting the number of vehicles and speed in [16]. It mainly concentrates only on improving the coverage of vehicles. The other recent work in [1, 3] uses genetic algorithm considering betweeness centrality and warning message delivery time as the key factor that influence the placement of RSU respectively. The coverage and connectivity has immensely improved in both the works. But other parameters such as cost of installation, accident information are not incorporated in their design.

Other approaches with different strategies were also proposed: intersection connectivity priority [17], delay in cable and wireless connectivity [18], traffic flow based probabilistic models [19], number of curves, number of on-ramps,cost limitations, weather condition and accident rate [20] and Density based Density based model in [21].

From the existing literature, the common drawback among most of the work focuses on specific scenario and very few parameters to decide the optimal placements of RSU along with simplified assumptions. Though the existing works obtain good results for simple scenario it is not feasible to be accomplished in a complex environment with multi-objective functionality and diverse parameter values. In our work, an easy to use planner is proposed that incorporates all the parameter that affects the optimal solution to the deployment problem. Also it is not possible to provide solution with a single algorithm due to the diverse nature of the parameters considered. Therefore a composite algorithms are used to easily attain the desired efficiency.

## 3 Optimal RSU Distribution Planner (ORDP)

In this paper an efficient model known as the Optimal Road side unit Distribution Planner (ORDP) is proposed that helps in finding an optimal location for RSU with the feasibility to select the combination of parameters to decide deployment. It is an evident fact that all the locations that require an RSU infrastructure will not have similar physical configuration. For example highways and urban roads does not have similar traffic density which might lead to having different transmission range of RSU. The labour or wiring cost in a busy road segment and highway road cannot be uniform. Hence it is necessary to provide an opportunity to the user decide and modify the parameters and its values that affect the decision of installing the RSU component. The major motivations to create such planner are as follows: (1) The solution to this problem entirely depend on the user's parameter values and cannot be completely automatic without user involvement and interaction. (2) At times it is not possible or not willing to collect all the necessary data that are listed. (3) It should also be noted that the deployment of RSU is a major physical task and usage of the algorithms to decide the location are used as recommendation component. The usage of such system is not as recurrent as that of any real time applications.

The distribution of RSU is a multi-factor problem for any given set of roads. To solve this challenge a three step algorithm is proposed. As an initial step the parameter combination are chosen. Next,as a pre-processing step the essential candidate location for RSU deployment are identified. Finally, the candidate location of RSU from parameter combination of D- and O- Parameters are used in Fusion Algorithm that provides resultant set of locations for RSU placement. The overall modules in the proposed ORDP is shown in Fig. 1 and the detailed descriptions are discussed below. For further understanding it is assumed that k RSU are to be optimally placed for m roads. Similarly, whenever the road segments are beyond the transmission range of the RSU the road segment are sub-divided into H sub-segments of unit distance as shown in Fig. 2. The main reason to divide the road into segments is to ensure the proposed model adhere to robustness characteristics i.e irrespective of the road segment distance which can be highway or urban or rural roads the total distance considered for evaluation becomes uniform.

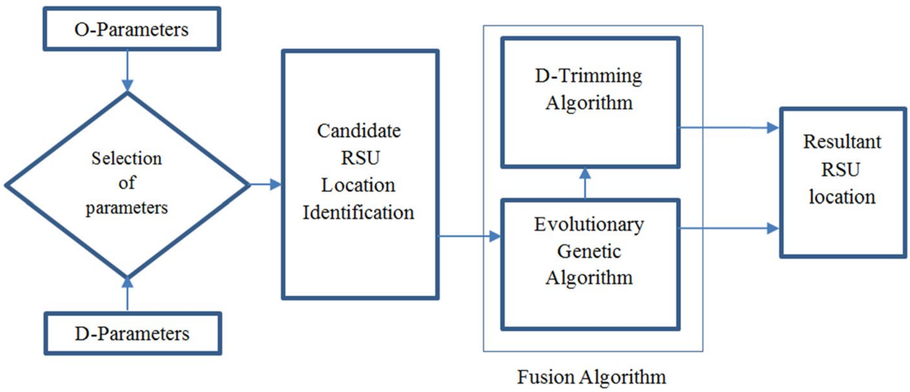



**Fig. 1** Proposed function diagram of ORDP

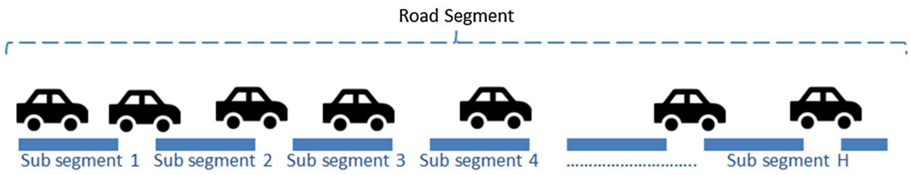



**Fig. 2** Road segments and sub-segments representation

## 3.1 Parameters for ORDP

In this work parameters that affect the installation of RSU are extensively studied. The parameters are categorised into two based on the requirements. The first set of parameters are Default Parameters (D-Parameters) that are very essential and basic requirement for decision making. The second set of parameters are the Optional Parameters (O-Parameters)which provides another lever of scrutiny in distribution when implemented.

### 3.1.1 D-Parameters

1. *Level of Service*

   For any road, factors such as maximum speed based on the road condition, density, level of maneuver, traffic interruptions, comfort and convenience can be defined collectively using a single Level of Service (LoS) term. There are six levels of service identified by Highway Capacity Manual (HCM) [22]. The labelling of LoS starts from A to F, where A is the finest operating condition and F being the least. Consequently, the LoS value is inversely proportional to the number of RSU required for the road as given in Eq. (1) [23].

$$LoS_m = \frac{\sum_{i=1}^{H} s_{f,i}}{1 + (a(v_i/c_i)^b)} \tag{1}$$

   where $s_f$ v,c are average speed at free flow, volume (vehicles per unit distance) and capacity (maximum number of vehicles per unit distance) of the $m$ roads and $H$ sub road segment respectively and a = 0.15 and b = 4. LoS helps to identify the multiple condition of the road condition within single value of LoS [24].

2. *Traffic Density using Passenger Car Unit (PCU)*

   The traffic density in a sub segment of the road is an important parameter which describes the movement of vehicles. Heterogeneous traffic can be measured using the Passenger Car Unit (PCU)as in Eq. (2). Individual vehicle class is to their equivalent PCUs based on their respective dimension and operational speed [22].

$$P_m = \frac{\sum_{i=1}^{H} \sum_{j=1}^{t} \sum_{k=1}^{c} pf_{i,j}^{c}}{t} \tag{2}$$

   where $P_m$ is the PCU value for time $t$ for $m$ road segment with H-sub segment, $pf_{i,j}^{c}$ is the PCU value of $c$ vehicle type [23].

3. *Budget or Cost of Installation*
   Placing an RSU entails installation costs depending on the segments of the road. Installation cost of RSU on m road segment is given in Eq. (3).

$$C_m = \sum_{i=1}^{H} b_i \times X_i \tag{3}$$

   where the total cost $C$ of $m$ the road segment is given by the summation of $X_i$ indicating the individual cost for H sub-segment. $b_i$ denotes the number of RSU required for $m$ road segment. The installation labor charges or specification of RSU equipment are not uniform throughout all locations [23].

The above mentioned parameters are the default requirement to identify the candidate location of RSU.

### 3.1.2 O-Parameters

The additional set of parameters or O-Parameter that establishes forms another level of scrutiny for better result apart from the above mentioned parameters are listed below.

1. *Significance of Road Segment (SoR)*
   Initial filtering is carried by removing least significant road segments from the exhaustive list. The significance of the road are calculated using number of bus stops in the road and the commercial activities carried out in a road. This parameter is calculated by considering sub-segments of a road segment with unit distance as in Fig. 2.The total number of bus stops available in a sub-segment is identified and averaged for a road segment. This will provide the list of significant roads with their respective bus stops. Since the bus stop cannot contribute completely to the significance of a road segment, the busiest component based on the commercial activities or famous area is also considered. Equation (4) provides SoR for a road segment.

$$SoR_m = \frac{\sum_{i=1}^{H} Bu_{i,m}}{H} + Com_m \tag{4}$$

   where $Bu_{i,m}$ is the number of bus stops in $H$ sub-segment of $m$ road segment and $Com_m$ is the commercial activity component ranging from 0 to 1.
2. *Accident History of a Road Segment*
   Certain road segments are highly prioritized through parameters such as Level of Service and PCU because of the worst road conditions or very high volume of traffic in such roads. This means there is high probability that road segments that do not have high traffic density and with smoother conditions are easily ignored. However, in reality, few roads with less traffic history or better road conditions might not be safe to road travelers. Highways connecting to a urban road can be an example. It is also imperative to collect data from vehicles in such accident probable roads and warn the travelers about it. Accident rates (AR) of a road segment as a parameter ensures that such road segments are not ignored but considered for RSU candidates [20].

$$AR_m = \sum_{j=1}^{T} \frac{\sum_{i=1}^{H} A_{i,j}^{m}}{T} \tag{5}$$

where $A_{i,j}^{m}$ is total accidents (including fatal and non-fatal) in a given unit time of $H$ road sub-segment and $T$ is the unit time.

3. *Transmission Range and Coverage*

   For a given area there are chances that adjacent roads are taken into consideration even though that the probability of reaching one road from the other is very high. The transmission range is primarily used to filter out unnecessary RSUs placed in adjacent road segments. Even though the road segments that are adjacent to each other are individually critical locations for RSU placement, if a single or limited RSUs within its range can cover all the adjacent road segments then all other RSUs placed in other road segments can be eliminated. Based on this concept, all the intersecting RSUs are identified and tested for redundancies. The installation of RSU at (x,y) be such that any vehicle in the road at (a,b) should satisfy the distance Eq. (6).

$$(a - x)^2 + (b - y)^2 \le R_{Cov}^2 \tag{6}$$

where $R_{Cov}^2$ is the transmission range of the RSU to be installed.

### 3.2 Candidate RSU Location Identification

To begin with the optimization algorithm the candidate locations are selected. This is done by using the Significance of a Road segment (SoR). It provides a value to a road based on the individual preference, frequent usage and popular landmarks. It is efficient to start with the descending order of significance from Eq. (4) and identify the top candidate locations as given in Eq. (7). While using only D-Parameters the value of Th is assigned as 0.

$$CS_m = \begin{cases} 1 & \text{if} SoR_m \ge \text{Th} \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

where $CS_m$ is the binary code bits for the $i$th road segment. 1 and 0 indicates the $i$th road segment to be a candidate or not respectively.

### 3.3 Fusion Algorithm

Using a novel Fusion Algorithm (FA) consisting of Evolutionary Genetic Algorithm (EGA) and D-Trimming, the ideal RSU distribution is acquired. The planner allows any combination of parameters to be used in EGA. Whenever O-Parameters are available for processing, the use of Dedicated Short Range based Trimming (D-Trimming) provides another level of scrutiny to reduce the number of RSUs required.

#### 3.3.1 Evolutionary Genetic Algorithm

The optimized solution for RSU location is obtained by using EGA. Genetic algorithm is an optimization technique that is non-traditional and mimics the process of evolution or natural behavior [1, 3, 16].

| Binary Code | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|---|
| Road Segment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | .. | *M* |

**Fig. 3** Binary code depiction for EGA

*Individual Road Segment Representation*

In EGA the number of RSU for road segments are represented equivalently using an binary code framework with m bits. The candidate bits for genetic algorithm representing the initial location of RSU are obtained from Eq. (7). The presence and absence of RSU in a road segment are represented using 0's and 1's binary bits as in Fig. 3. For example, the 1st and 4th road segments have an RSU and 2nd and 3rd road segment does not have one.

*Parent Selection*

The candidate set of location enumerated in Section acts as the first set of population. ORDP uses Tournament method to select the individual road segments in consequent generation as in [3, 8, 10].

*Crossover and Mutation*

Crossover or recombination combines the parents to provide next set of generation. ORDP uses the general one point crossover with probability of Pc. The diversity of the population is introduced using mutation. The probability mutation Pm is adapted to decide the change in the number of genotype for each segment

*Replacement*

The replacement is a survivor selection or environmental selection process, where the new offspring entirely replaces the last generation. In ORDP, the generations with highest value are assured survival. In our strategy, the percentage of substituted people in each generation is set at 50%.

*Fitness Function*

Parameters described in Sect. 3.1 are the considered in this section. Each parameter value of the road segment contribute to the RSU placement and their relationship are as follows: (1) The LoS value seems to be inversely proportional RSU required. (2) The more the number of vehicle concentrated in a location the more number of RSU is required to handle the congested communication. (3) As the budget factor increases the possibility to install RSU reduces. (4) It will also be helpful to have more number of RSUs in any accident prone location for communication during emergency situations. Using these relationships an objective function as in Eq. (8) is modelled to identify the set of locations that requires an RSU.

$$ORDB_{objfunc} = \alpha\frac{1}{LoS} + \beta P_m + \gamma\frac{1}{C_m} + \delta AR_m \tag{8}$$

where $\alpha, \beta, \gamma and \delta$ are weighing factor given to each parameter based on their relative importance.

On each iteration of EGA, the different configuration of road segment are considered as EGA population and their respective objective value is identified. This is similar to a search process finding the best combination that has minimal number RSU for the maximum fitness solution. The termination condition in our model is to exhaust all the set of combination of RSU.

### 3.3.2 Dedicated Short Range Communication Based Trimming (D-Trimming)

While planning for a complex degree of layout, the probability of adjacent road segments lying within the Dedicated Short Range Communication (DSRC) may be higher. Though the parameters of a road segment such as Los, PCU might contribute to placement of the RSU, it is possible that the adjacent road segments have similar values that make the GA to select them as an optimal location. Considering this problem, it is possible to reduce the number of RSU further by considering Algorithm 1.

**Algorithm 1** D-Trimming

**Input: Road Segments from EGA,** $N = R_1, R_2, ...R_N$
**Output: Optimal Number of Road Segments**
**Begin**
$List\_of\_connected\_roads = BFS(N)$
$\forall setofList\_of\_connected\_roads$
**if** $(a-s)^2 + (b-t)^2 \leq R_{cov}^2$ **then**
  $List\_RSU\_Intersec \leftarrow Linked\_RSU(R_i, R_j)$
**end if**
$Transitivity(List\_RSU\_Intersec)$
$List\_New\_RSU\_Intersec \leftarrow Linked\_RSU\_Item(R_i, R_j, ...R_k)$
$List\_New\_RSU\_Intersec \leftarrow Linked\_RSU\_Item(Remain(List\_RSU\_Intersec))$
**for** Item= 1 to P **do**
  $List\_Roads) \leftarrow (Road\_Segments\_CoveredbyR_m)$ $\{\forall m = 1toL\}$
  **for** each$LC_1, LC_2....LC_{L-1} combinationsofRSU$ **do**
    **if** $R_m \in List\_Roads$ **then**
      $Final\_RSU \leftarrow R_m$ {for $LC_1$ Combination}
      $Remove\_Linked\_RSU_Item(R_m)$
    **end if**
    **if** $R_m \cup R_{m+1} \in List_Roads$ **then**
      $Final\_RSU \leftarrow R_m \cup R_{m+1}$ {for $LC_2$ Combination}
      $Remove\_Linked\_RSU_Item(R_m \cup R_{m+1})$
    **end if**
    **if** $R_m \cup R_{m+1} \cup ...R_L \in List_Roads$ **then**
      $Final\_RSU \leftarrow R_m \cup R_{m+1} \cup ...R_L)$ {for $LC_{L-1}$ Combination}
      $Covered\_Roads \leftarrow Remove\_List\_Road(R_m \cup R_{m+1} \cup ...R_L)$
      $Remove\_Linked\_RSU_Item(R_m \cup R_{m+1} \cup ...R_L)$
    **else**
      $List\_Missed\_Roads \leftarrow (List\_Roads–Covered\_Roads))$
      $R_u = Max\_Parameter(List\_New\_RSU\_Intersec - Final\_RSU) \geq Threshold$
      $Final\_RSU \leftarrow R_u$
    **end if**
  **end for**
**end for**
**Return Final_RSU**

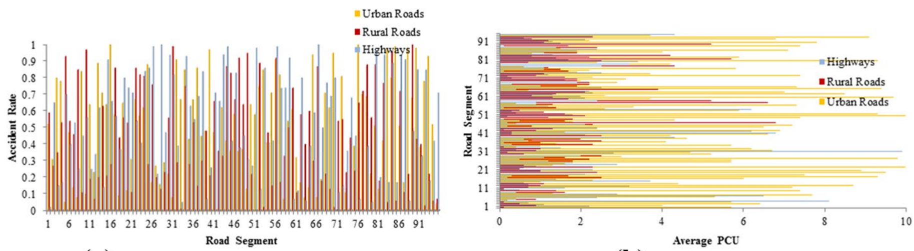
The set of road segments that are specified for RSU placement can be diverse. The connectivity of each road segment are identified using Breadth First Search technique BFS(N). The list of connected road segments and their components are separately handled to ensure coverage in unconnected road segments. The main idea in this algorithm is to initially identify the location of two adjacent RSU within each other coverage $R_{cov}$ . With (a,b)and (s,t, location coordinates of RSU $R_i, R_j$ . If they are within the coverage then the RSU pair is added to *List_RSU_intersec*. The multiple transitivity condition among the pairs is identified using *Transitivity*(*List_RSU_Intersec*) and RSUs that have intersecting coverage are added as *Linked_Roads_Item* to the *List_New_RSU_Intersec*. The remaining RSU pair in *List_RSU_intersec* are added as *Linked_RSU_Item*. The number of *Linked_Roads_Item* added and number of RSU in each Item is denoted by P and L. All the road segments covered by *Linked_RSU_Item* is added to *List_Roads*. Exhaustive combination of RSU identify the best coverage of roads in *List_Roads*. For each combination of RSU in *Linked_RSU_Item* if the respective combination covers all the roads or maximum of roads in *List_Road* then the combination of RSU are added to *Final_RSU*. Remaining other RSU and the covered road segments in *Linked_Roads_Item* and *List_Road* respectively are discarded using *Remove_Linked_RSU*$_I$*tem*() function. After all exhaustive combination of $LC_{L-1}$ RSU combination the combination the uncovered road segment are listed in *List_Missed_Roads*. From the remaining missed out RSU (N-*Final_RSU*)the corresponding parameter values in Eq. (8) are analysed and filtered using threshold and the maximum value among the filtered RSU are added to the *Final_RSU* until *List_Missed_Roads* is negligible.

To summarize the major novelty of the proposed work, ORDP provides an innovative and feasible option of choosing various combination of parameters values available with the user to decide the placement of RSU irrespective of complexity of the layout. The method of choosing the location based on the parameters is also unique and novel by means of Fusion Algorithm comprising of EGA and D-Trimming. Both algorithms are east to access and aid to place the RSU efficiently in the design of any VANET infrastructure.

## 4 Results and Discussions

The efficiency and efficacy of the proposed method to distribute RSUs are analyzed by simulating values for the parameter and real time data from roads of Tiruchirappalli city of Tamil Nadu, India. This is to ensure the feasibility of the proposed model to work for any complex layout.

The analysis is approached by optimally placing limited number of RSU's with constant installation cost. Three types of degree of traffic complexity with three different geographical characteristics of the road are considered for simulation. The three categories of complexity in traffic include complex, sparse and evenly distributed traffic density similar to Urban, Rural and Highways respectively. For each category, it is assumed that a maximum of 80 RSUs are to be placed across 95 road segments that have connectivity with road segments.




**(a)** Simulated Values for Accident Rates **(b)** Simulated Value for PCU

**Fig. 4** Simulated values

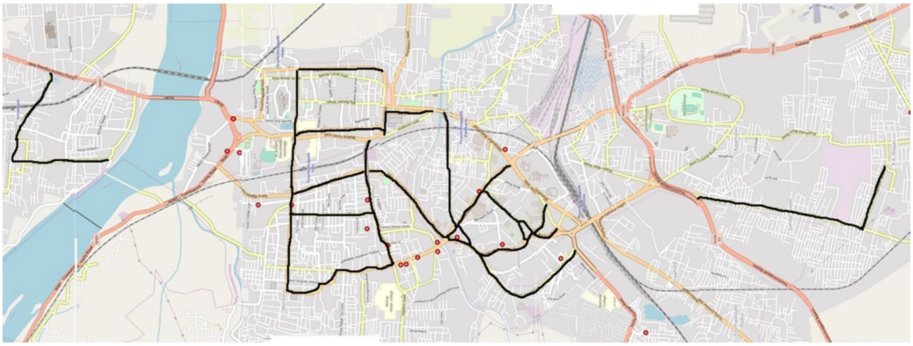
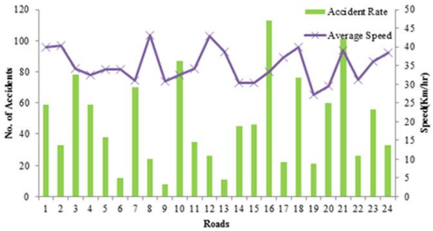
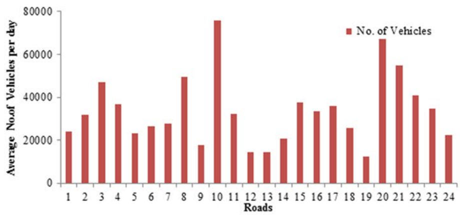


**Fig. 5** Highlighted road segments in map of Trichirappalli City




**(a)** Accident Rates and Average Speed of Tiruchirappalli City Roads




**(b)** Vehicle Density of Tiruchirappalli City Roads

**Fig. 6** Real world data of Tiruchirappalli City

As a first step, traffic density and speed are simulated using VISSIM for replicating road scenario. The simulated values of accident rates and PCU values are normalized and shown in Fig. 4a, b. Similarly the real-time data collected for 24 roads of Tiruchirappalli City that are highlighted in the Fig. 5. The accident rate data collected for span of 5 years and PCU collected over 5 days with to respective road segments are shown in Fig. 6a, b respectively.

In the second step, the initial lists of RSU candidates are filtered out from the initial set of D-parameters described in Sect. 3.1. As the third step O-parameters are utilized in Eq. (8). The SoR value for each road segment is calculated using Eq. (4) with $\mathrm{Com}_m$ value computed based on the number of bus stops, commercial value and popularity in $m$ road segments. By recommendation of experts and trial and error, values of 0.3, 0.2 and 0.1 is considered as Th from Eq. (7). In the fourth and final step, the candiate RSU location acts as the parent for the initial iteration of EGA with the population size, crossover probability, mutation probability are 30, 0.5 and 0.7 respectively. Each test set of road segments considered totally 1000 iterations for an area. The resultant optimal RSU locations are trimmed using Algorithm 1.

All the simulated values are kept consistent across other algorithms. Several works are proposed to provide an efficient RSU distribution for a scenario, but there are no enough details to replicate them for fair comparison. Therefore, greedy based deployment methods are used for comparison. Since the main advantage of the ORDP is to utilize the planner based on available parameter values. For analysis purpose the results are also compared

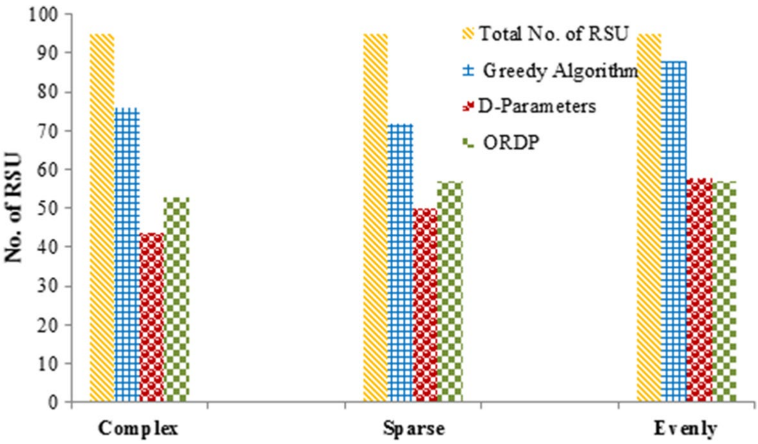



**Fig. 7** Simulation results for total number of RSU distributed

against the results obtained using only D-parameters in ORDP which is denoted as only D-Parameter in the rest of the discussion.

The results of simulation are evaluated in accordance with the following factor

*Number of RSUs*

Figure 7 shows the total number of RSU obtained using simulation of three kinds of vehicle concentration (Complex, Sparse and Even) replicating vehicle behaviour in Urban, rural and Highways. It is seen that ORDP has considerably lesser number of RSUs when compared to the other models for all types. The number of RSU for Complex and Sparse are lesser mainly because of several layers of filtering with additional parameters considered for trimming algorithm.

The number of RSU with 500 m transmission range in Tiruchirappalli city roads using ORDP, D-Parameters and Greedy Algorithm are 10,07 and 16 respectively as shown in Fig. 9. In Fig. 9a it is seen that the roads in the extreme right and left ends does not have any connectivity to the rest of the road segments while using D-Parameters.

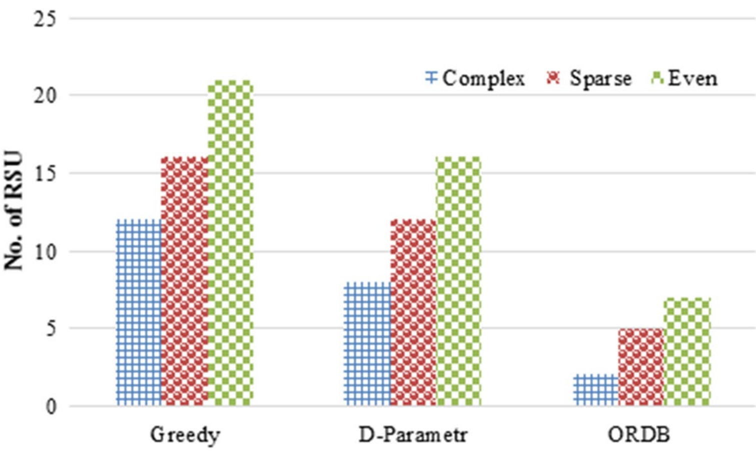
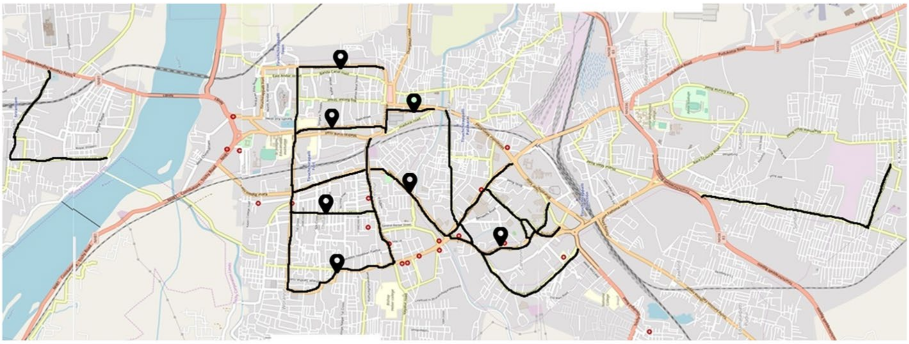
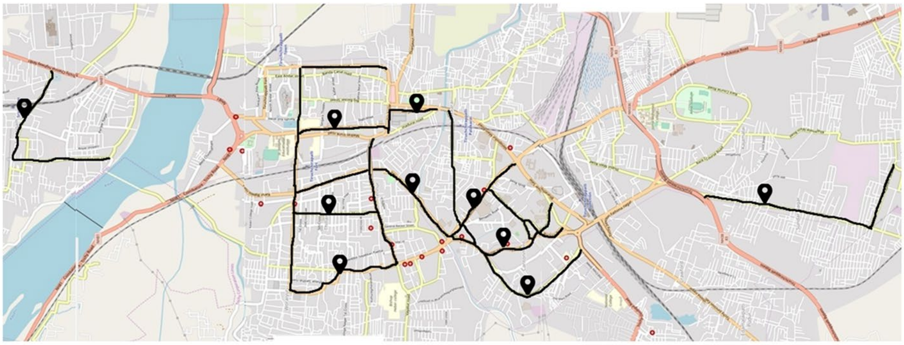


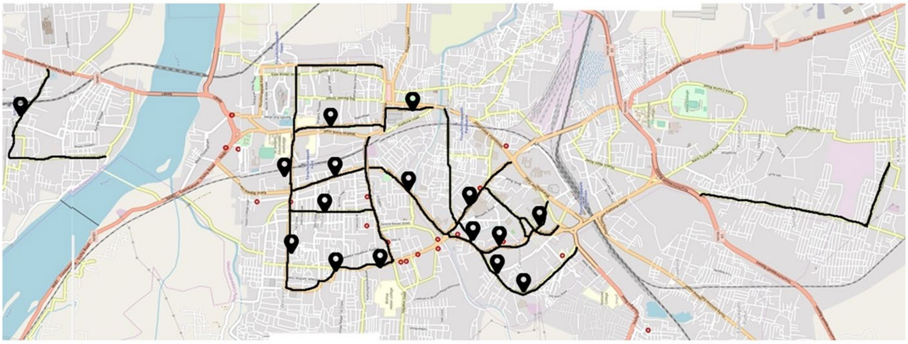

**Fig. 8** Simulation result of reduction of number of overlapping RSU



**(a)** D-Parameters



**(b)** ORDP



**(c)** Greedy Algorithm

**Fig. 9** RSU distribution in Tiruchirappalli City roads

The number of RSU has increased in ORDP than D-Parameters is due to the connectivity of the road segment which has the major role in D-Trimming Algorithm as in Fig. 9b. Whereas in Fig. 9c its seen that the total number of RSU in Greedy Algorithm appears to be visually effective but the optimal results are provided in ORDP.

*Overlapping of Coverage Area*

The influence of ORDP in reducing the number of overlapping RSUs is shown in Fig. 8. There is a high probability of RSU overlapping in greedy and using D-parameters as they

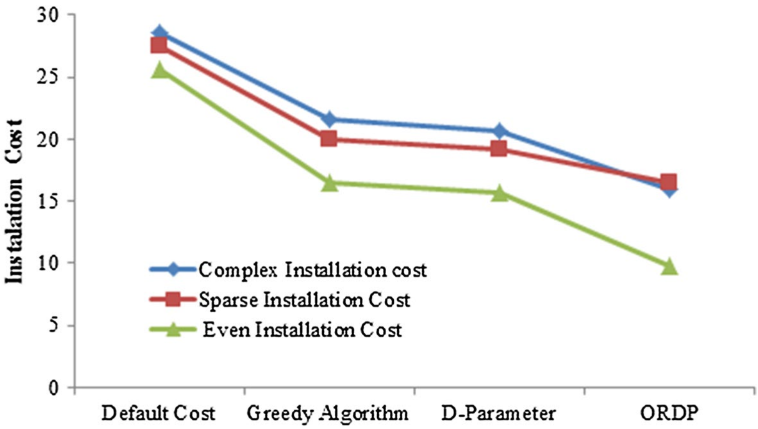



**Fig. 10** Comparison of installation cost

assign equal weightage to most of the roads. However, with ORDP there is a drastic reduction in the number of RSUs owing to the fact that more number of RSU overlapping have been identified and removed in the fourth step of based D-Trimming. The number of overlapping in Tiruchirappalli city for Greedy Algorithm is 7 and nil for D-parameter and ORDP models.

*Installation Cost* The effect of various parameter values are discussed in the consequent section. Figure 10 shows how the installation cost of RSU differs across different methods. As mentioned above the installation cost is assumed to be constant for installing single RSU in specific type of vehicle concentration but different for different vehicle concentration. The budget values assumed for single RSU installation in complex, sparse and even are 0.3, 0.29, 0.27 respectively.

*Coverage Percentage*


**Fig. 11** Comparison of coverage

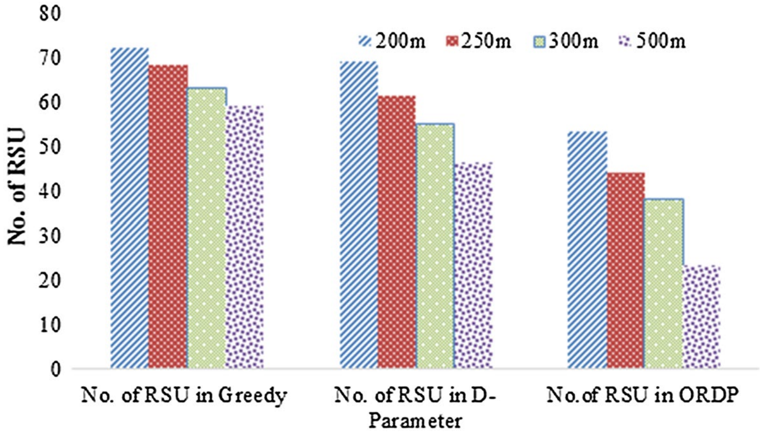



**Fig. 12** Comparison of number of RSU based on transmission range

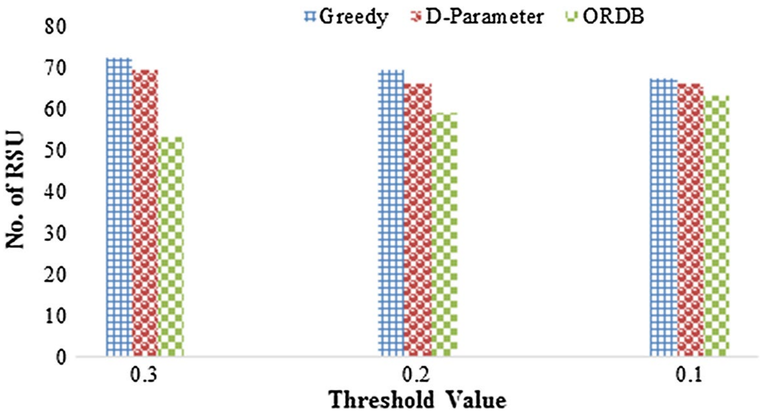



**Fig. 13** Variation in ORDP performances with Candidate Threshold limit

The capability of providing continuous coverage with minimal or no overlapping transmission range is shown in Fig. 11. It is calculated by the summation of total number of roads that come under the communication range of an RSU for the given area. It is high for ORDP because it considers wide variety of road segments not based on traffic flow. The total coverage in Tiruchirappalli road segment data is 35, 78 and 88 for D-Parameters, Greedy and ORDP models respectively. In greedy approach RSU are concentrated in locations of more density but in ORDP it is scattered in an optimal way.

*Transmission Range*

Next the outcome of using different transmission range of RSU with the radius 200 m, 250 m, 300 m and 500 m is shown in Fig. 12. It affirms that number of RSU decreases from 53 to 22 RSU in the proposed planned when the radius increases from 200 to 500 m.

*SoR Threshold*

The candidate threshold from Eq. (7) highly influences the success factor of ORDP. AS the threshold limit is decreased, the performance of the ORDP model gets closer to the other models. The variations in performance with candidate threshold limit are presented in Fig. 13.

To summarize the results obtained in different scenario, the total number of RSU required using D-parameters seems to be very less. But ORDP model have reasonable number of RSU that provide highest covering percentage. The overall coverage percentage in any type of layout or vehicle density is about 86% in ORDP which makes the model robust. The number of overlapping RSU are higher in a greedy algorithm and least in D-Parameters. Since the connectivity factor is not considered using D-Parameters overlapping is less. Optimal overlapping is achieved due to the D-Trimming Algorithm that ensures continuous. connectivity. The effectiveness and robustness of ORDP is established by providing the option to modify the value of individual parameter and threshold values of individual road segments. Therefore, ORDP based RSU deployment has optimal results in all aspect specifically in connectivity and cost.

## 5 Future Work

As the optimization of the RSU deployment depends on the parameters and their respective values therefore more elaborated discussions on the results of varying parameters value are reserved for future work. Especially the aspect of performance in data transmission and delay analysis based on D-parameters and ORDP. Other crucial parameters such as maximum delay, transmission rate etc. are to be included in the O-parameters and their results requires further analysis.

## 6 Conclusion

This paper proposes an Optimal Road side unit Distribution Planner (ORDP) to identify optimal location for placing an RSU for any given set of road segments. ORDP uses several influential parameters that are categorized as Default Parameters (D-Parameters) and Optional Parameters (O-Parameters) for a road segment to obtain an objective function that are used in Fusion Algorithm (FA) comprising of Evolutionary Genetic Algorithm (EGA) and D-Trimming Algorithm. The efficiency and robustness of FA are tested with simulated values and real world data. The simulation values are obtained using VISSIM inorder to produce complex, sparse and even vehicle concentration that replicates Urban, rural and Highway roadways. Correspondingly, The real world data is collected for 24 roads of Tiruchirappalli city and results are presented. It can be seen that an overall average coverage provided by FA are higher compared with Greedy Approaches and using D-parameter irrespective of the complexity of the layout or vehicle density and thus this holistic planner aids in an efficient, continuous and cost effective distribution of RSUs in VANET infrastructure.

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