Location optimisation for road side unit deployment and maximising communication probability in multilane highway

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Abstract: Quick advancements in wireless and mobile communications have made an outlook change in human life styles. Vehicular ad hoc network (VANET) is an emerging and challenging technology in mobile communication. Vehicle to infrastructure communication is a cornerstone for providing a wide plethora of VANET. To offer an acceptable quality of service, this work considers placing the road side unit (RSU) appropriately for efficient communication. This paper proposes to provide the desired geometry based coverage strategy using Voronoi sweep line algorithm for partitioning the target area and uses the genetic approach for optimal location identification for successful deployment of RSU. The proposed work will further extend to enabling the better connectivity using some handoff mechanisms. Simulation results illustrate that the proposed coverage protocol works surpass in highway vehicular networks.

Keywords: VANET; vehicular ad hoc network; deployment; RSU; road side unit; Voronoi sweep line algorithm; genetic algorithm; smart PC; LORDMC.

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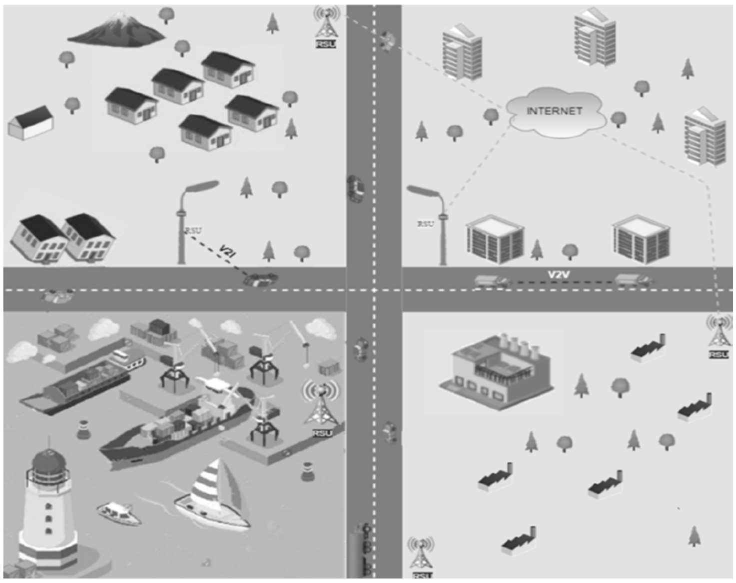
1 Introduction

Vehicular ad hoc network (VANET) is an emerging technology for shrewd transportation of vehicles. VANET permits vehicles equipped with remote specialised gadgets to form a self-organised network with the requirement of permanent infrastructures. They are highly movable wireless ad hoc networks envisioned to provide support for both safety and non-safety applications by enabling vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and infrastructure to infrastructure (I2I) communications. The system model for the vehicle to road side communication of smart PC is shown in Figure 1.

Figure 1 System model for vehicle to roadside communication in smart PC



Coverage is one of the key performance matrices to access the quality of service (QoS) (Patil and Gokhale, 2013; Naskath et al., 2011) in the VANET. It represents how well services have been provided in a network. To maintain the network connectivity, RSUs are conveyed to fulfil certain coverage quality (Wu and Dai, 2005). Road side unit (RSU) deployment problem is usually modelled as a streamlining problem under various imperatives such as severe resource limitations and classified antagonistic environmental conditions. This paper considers VANETs on a multilane highway in which the vehicles can establish their connectivity with other vehicles travelling in the same or different bearings of its motion with an allied speed limit. During this moment, we avoid some coverage barriers in the network using intermediate RSUs.

In this paper, location optimisation for road side unit deployment and maximising communication probability in multi lane highway (LORDMC), we concentrate on the issue of positioning minimum number of RSUs to achieve a complete coverage scenario. It also expands the coverage service even when the counts of vehicles get increased. For this purpose, select a multilane highway, and then partition the highway trajectories with suitable candidate locations. Finally, select the optimal locations to deploy the RSU for better communication. Extensive experiments in the synthetic and realistic scenarios are carried out to evaluate the performance of our solution. The simulation results show that our solution achieves the desired coverage performance and minimises the number of required RSUs. The main contributions of this paper are as follows:

- to partition the selected road segment using sweep line based Voronoi algorithm
- to identify the optimal positions from feasible ranges using genetic approach
- to verify the result using network simulation and compare with the recent coverage approaches.

The remaining part of this paper is structured as follows. Section 2 gives the related work done by other authors on RSU deployment and coverage related issues. Section 3 introduces the proposed methodology for partitioning the selected road area and suggestion of an optimal location. Section 4 examines the experimental setups.

2 Related work

Vehicular ad hoc networks (VANETs) (Al-Sultan, 2013) are classified as an application of mobile ad hoc network (MANET) that has the potential in improving road safety and in providing travellers' comfort. Recently, VANETs have emerged to turn the attention of researchers in the field of wireless and mobile communications. The main key objective of this sensing application is information gathering and dissemination to and from the target location. This successful transmission mainly based on the two important metrics like coverage and connectivity (Liu et al., 2013) of the network. Coverage is one of the key performance matrices to evaluate the QoS (Ammari and Mulligan, 2010) in the network. It represents how well services have been supplied over the network. Coverage of the network is mainly depending on the connectivity of the network, link availability, and consistency of the target network (Cheng et al., 2014). If the conditions are all satisfied, then network ensures to get full coverage (Liu et al., 2013). Coverage of RSU defines a set of locations within its transmission range. Connectivity of RSU described in two levels of connections called direct and indirect (Festag, 2014). Connection between two consecutive RSU or OBU is termed as direct and communication through other devices called as indirect connection.

Moreover, Kaveh et al. (Shafiee and Leung, 2011) classified the connectivity of the network based on the sparse and dense area of the network. When the network is sparse, consider the connectivity of routes in its route selection logic to maximise the chance of packet reception. If the network is dense, adequate routes are available with a minimum delay for data transmission. This connectivity pattern is diagnosed using some vehicular traffic traces. But due to lack of the realistic set of traces, various mobility models have been developed. Wantanee et al. (Viriyasitavat, 2011) proposed their ideas to overcome these coverage and connectivity problem. The dedicated RSUs are proposed to be integrated into the vehicular networks (Xiong et al., 2013). Youngping et al. described the problem of deploying the RSUs to provide the desired coverage and connectivity performance (Sou and Tonguz, 2011; Lochert, 2008; Li et al., 2007). The hot emerged research topic in VANET is the deployment of connecting units with the OBU and other devices like gateway, APs have been dealt with different objectives and methods like enhancing the coverage and connectivity of the network, minimise the power consumption, minimise the number of hops and improve the efficiency of timely communication. Miguel Rios et al. (Rios et al., 2015) defined to maintain the network connectivity, RSUs are deployed to fulfil certain coverage quality. An access point (AP) deployment problem is usually modelled as an optimisation problem under different constraints such as, severe resource limitations and assorted hostile environmental conditions (Fan and Jin, 2010).

Recently, Haung et al. proposed the problem of coverage in geocover (Cheng et al., 2014) and described an optimal deployment of RSU in urban area. Affordable and reliable RSU deployment plans over vehicular networks have been studied extensively. Generally, these plans are classified into spatial coverage, temporal coverage and spatiotemporal coverage. Li et al. (Li et al., 2007) consider the method to minimise the average number of hops from RSUs to gateways. The gateways are used in their scenario to connect RSUs to the internet. In the coverage model, each RSU is connected to both vehicles and a centre gateway, so that the optimal deployment of the gateway assists in improving the performance of communication. Other types of temporal coverage focus on the contacts of OBUs and RSUs. Trullols et al. (2010) seek to maximise the number of vehicles that make good communication with the road side infrastructures and originate their problem as a maximum coverage problem (MCP). To improve the cooperative communication among vehicles in an urban vehicular network, Fiore and Barcelo Ordinas (Fiore and Barcelo-Ordinas, 2009) devise a strategy for RSU deployment based on vehicular traffic flow analysis. The authors transfer the road topology into a graph where vertices are intersections and edges are streets. On the basis of this graph, they evaluate the average time vehicles spend to travel to each edge and redeem the calculation results as traversing volumes. They then propose that deploying RSUs at the cross-sectional area of urban roads will increase the potential for collaboration among vehicles as intermediate nodes.

3 Proposed method

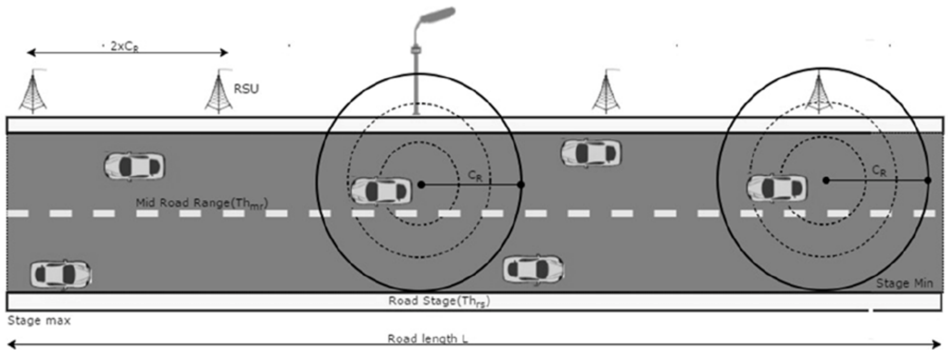
3.1 Assumption and definition

We have selected the Thoothukudi City (tagged as Smart Pearl City) from Tamilnadu (Highways Department, Demand No. 21, 2008; Thoothukudi vision 2025, 2015), India for our proposed work. It is a main port city of India. It lays in the Coromandel Coast of the Bay of Bengal and it is familiar for pearl cultivation, fishing centre and second largest producer of salt in India and important commercial ship building centre in southern states. The city has seven sub-divisions under its control for maintaining the roads of 1993.476 km in length. They are State Highways – 371.062 km, major district roads – 293.772 km and other district roads – 1328.642 km (Highways Department, Demand No. 21, 2008). National Highway 45B, 7A and State Highways SH-32, 33, 40, 44, 75, 76, 77, 93, and 176 connect to other parts of the state. We have focused on multilane highway of smart PC for our proposed work. Let us make the following assumptions:

- according to traffic information and street map structure partitioned the chosen area
- identify the optimal locations to deploy the RSU
- coverage range of a RSU is same at every site
- deploy RSU according to its transmission range
- optimise the count of RSU.

Figure 2 depicts the highway trajectory model of smart PC. RSU is an immobile unit installed at an optimal position of multilane road area. Each RSU is basically equipped with appropriate hardware devices like transmitter, storage device, etc., Transmitter for wireless communications (75 MHz of dedicated short range communication (DSRC) spectrum at 5.9 GHz is adopted for the wireless communication technology) (Tanuja et al., 2015). In addition, RSUs keep analysing local traffic situations then broadcast the analysed data periodically and disseminate abnormal events to smart vehicles, gateways and its class devices occasionally. The working model of our proposed work represented in Figure 3.

Figure 2 Highway trajectory model of smart PC



3.2 Area partitioning approach

The first phase of this proposed work is area partitioning approach using Voronoi sweep line-based algorithms. It is one of the most important applications of computational geometry. This algorithm used to partition the lane area and identified the feasible location sites. Consider the plane area *A*. Let $A = \{a_1, a_2, \ldots, a_n\}$ be a set of points in the sites and $V_c(a_i)$, is the Voronoi cell for a_i, to be the set of points S_a in the plane that are closer to a_i than to any other site. The Voronoi cell for a_i is described to be:

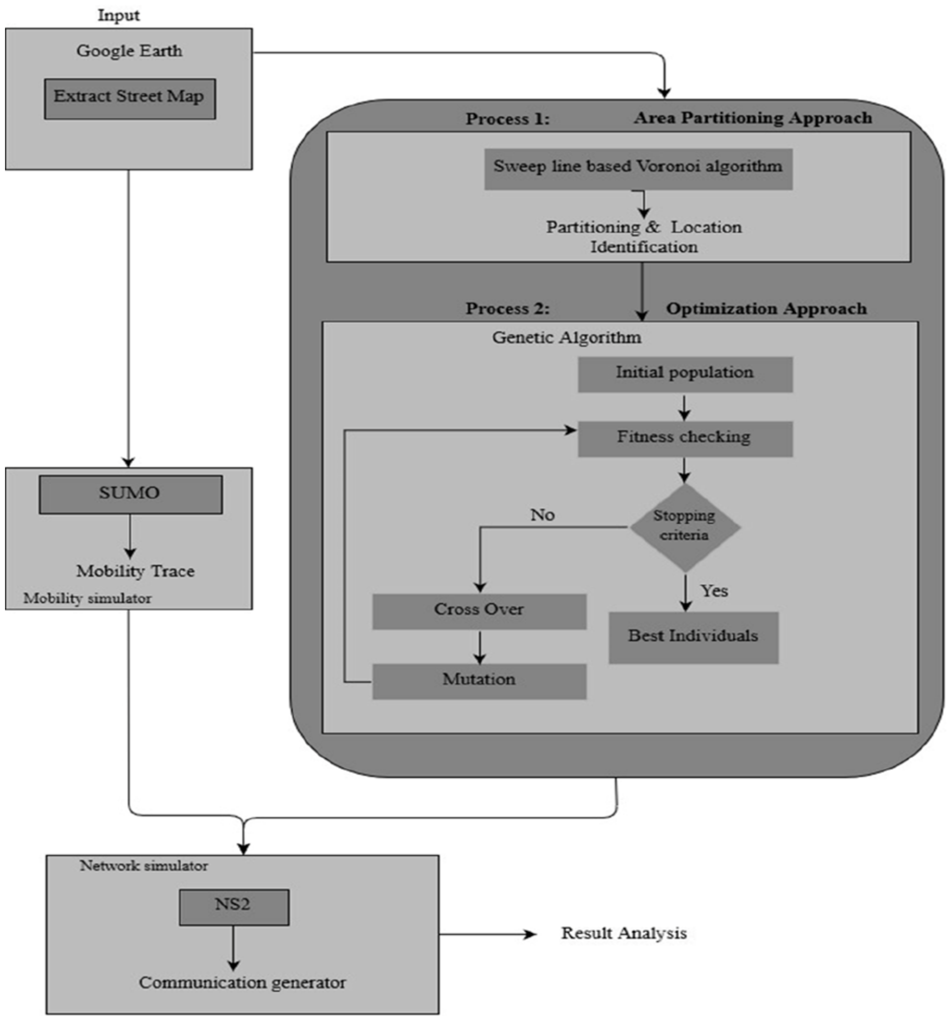
$$V_c(a_i) = \{S_a \,\|\, a_i S_a \,|< \left|a_j S_a\right|, \forall j \neq i\}.$$

Moreover, Voronoi cell $V_c(a_i)$ can be defined as

$$V_c(a_i) = hp(a_i, a_j) \text{ where } \cap j \neq i.$$

Here $V_c(a_i)$ is in terms of the intersection of half planes, the points $hp(a_i, a_j)$ that are strictly closer to a_i than to a_j is just the open half plane whose bounding line is the perpendicular bisector between a_i and a_j. The proposed Fortune's algorithm that is a plane sweep algorithm for producing a Voronoi diagram using $O(n \log n)$ time and $O(n)$ space. Figure 4(a) and (b) depicted its structure. Algorithm 1 is more efficient than various partitioning algorithms due to time complexity and additional computations. The essential parameters of this algorithm are sweep line S_L, beach line B_L, and events for partitioning purposes. Voronoi diagram constructed a horizontal line which sweeps the set of sites A from pinnacle to bottom and also maintain a curve called a beach line. The B_L splits the plane into two regions like secure region and insecure regions.

Figure 3 Working diagram of LORDMC



The motion of sweep line described as:

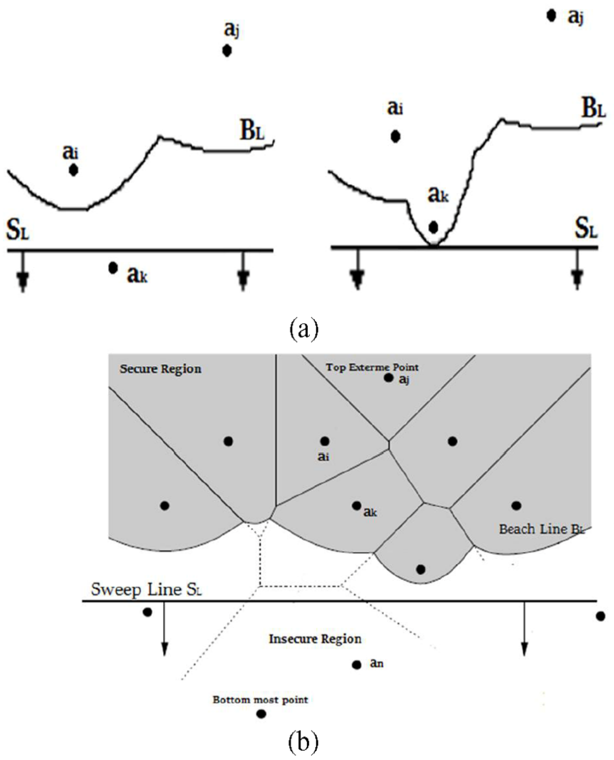
$$S_L = \begin{cases} S_{Lx}, & \text{position constant;} \\ S_{Ly}, & \text{position changed at time } t; \end{cases} \tag{1}$$

The secure region incorporates a partial Voronoi diagram with a perfectly computed structure and insecure region corresponds to an undetermined part of the Voronoi diagram that has to be computed.

$$\text{Region of Plane } A = \begin{cases} \text{points intersected by } S_{L(x,y)}, & \text{Secure region;} \\ \text{points not intersected by } S_{L(x,y)}, & \text{Insecure region;} \end{cases} \tag{2}$$

An important fact of the construction of this diagram using B_L is that it does not explicitly lay up the parabolic arcs, it is only considered for the purpose of deriving the algorithm. Instead for each parabolic arc on the current B_L cache the site point that gives rise to this arc.

Figure 4 (a) Sweep line based Voronoi approach: an initial phase and (b) sweep line based Voronoi approach: final phase



There are various types of events used; they are site event, merge event and parabolic event. At an initial period of time, site event which communicates to a point site, the B_L will move from top to bottom and start the partitioning process. When the S_L visits the site event location, it splits them into the parabola. The target area segmented into parts and then added with new parabolic segments between the divided segments and inserts a new Voronoi edge V_e in the Voronoi diagram are being constructed.

If the sweep line, moves along with the beach line and moves downward as well, but the B_L shape will depend on the location of the sites.

Algorithm 1 Area partitioning algorithm

Input : An area with set of points A **Output : Produce partitioned area**		
Initialization:	i.	Set point an area Ar If a ∈ A then ax and ay are x, y coordinates of a; Set of point n>1 with unique bottommost point ab;
	ii.	Set sweep line S_L at top of the plane;
Sweep line Event : (Primary Movement)	i.	Start to move sweep line from upwards to downward direction across the plane (S_{Lx}, S_{Ly}), as per equation 1;
	ii.	S_L Intersect the point P on the plane;
	iii.	Create x-monotone curve called Beach line B_L for each point; Generate parabolic curve;
	iv.	Point on the parabolic curves are equivalent to into 'a' and sweep line S_L;
(Next Movement)	i.	Whole plane subdivided in to 2 regions as per equation 2;
	ii.	Continue until complete the unsafe region;
	iii.	Split the previous parabolic arc into 2 arcs while reaching new point;
	iv.	Stretch an arc up to new point ;
	v.	When the S_L passes over a new point ,a new parabola arc will be inserted into the beach line
Vertex Event :	i.	If (parabolic length==0) (N point create at most 2n arcs on beach line) An arc disappear; V_v will be created.
	ii.	Continue the same up to reach the bottom most point in the plane.
	iii.	Center of the Circum circle is placed equal distance from points that center is called V_v.
Merge Event:	i.	Process of removing $B_{L(e1,e2)}$ and creating V_e. $\mathrm{B}_{\mathrm{L(e1,e2)}} = \begin{cases} \leq 1 & \text{interior to the parabolic curve ;} \\ > 1 & \text{exterior to the parabolic curve ;} \end{cases}$
	ii.	Find the B_{Le} and two connected $B_{L(e1,e2)}$ toB_{Le}. If ($B_{L(e1,e2)}$ >1) Remove B_L; Merge B_Le1, B_Le2 to make one $B_{L(e1,e2)}$ Else Join the two V_e to one; Merge left B_{Le1} and right B_{Le2} to make one $B_{L(e1,e2)}$; Remove other B_{Le}; Create one Parabolic Event;
Parabolic Event :	i.	Occurrence of Voronoi vertex V_v ; $B_{L(e1,e2)} = \begin{cases} 0 & \text{valid;} \\ 1 & \textit{invalid;} \end{cases}$
	ii.	If (B_L == 0) Connect $V_e$with B_L; Create V_v; Connect V_e with V_v; Connect other B_L edges with neighbouring B_Ln; Create arc parabolic events ; Remove the B_L; Else Continue until B_L reach 0;

After the S_L visits the locations of all events, the construction of the Voronoi diagram is completed with the perfect partitioning.

$$\text{RSrange} = \{\text{Stagem in}, \text{Stagem in}+1\ldots\ldots\text{Stagemax}) \quad (3)$$

$$\text{NRSrange} = \{\text{stagemin........Midroadmin}\} \quad (4)$$

$$\text{MRSrange} = \{\text{Midroadmin........Midroadmax}\}. \quad (5)$$

After partitioning the area, the location points are categorised as three ranges are: road stage range, RSrange; nearest to road stage range, NRrange; and mid-road range MRrange. As per equations (3)–(5), the selected locations are denoted as LosRS(i,j), LosNRS(i,j) and LosMRS(i,j), respectively. As per Algorithm 2, the locations from MRSrange are neglected. Remaining location ranges are considered for further purpose.

3.3 Location optimisation approach

The heuristics solution approaches like greedy adding, Tabu search, simulated annealing, genetic algorithms and Lagrangian relaxation-based heuristics are utilised for solving large-size location problems. Subsequent to evaluating the solution approaches in the literature, we decided to build up our solution methodology based on the genetic algorithm that is proved to be producing reliable results in large area network problems. Using Voronoi partition sweep line algorithm, we have partitioned highway avenues and identified some infeasible and feasible points. Genetic algorithms encourage the survival of the fittest among the individuals over periods for solving a problem. Each generation consists of a population character string that has described in two distinctive approaches as binary and non-binary populations. The adaptive rank selection method, it is a technique for evolving suitable locations from the location set for multimodal function optimisation. The technique is based on the concept of adaptively adjusting the location point according to the individuals' dissimilarity. The distance threshold and the location point are adaptively adjusted in keeping with the value of multiple optima. The genetic heritage is carried to an offspring by two feasible parents. We have chosen a rank selection, in which every individual possesses a part of an area according to its fitness in the selection scheme, and the higher the individual fitness, the higher the probability of that individual to for the production of offspring. Selected location populations are given as associate input for the fitness function calculation. The fitness function measures the best optimum location vs. alternative locations. There is a reproduction section that is based on both the fitness value and probability.

Considering a problem of optimising a function $F(x)$, $x \in$ Loc(i,j), where Loc(i,j) is a finite set of locations selected from area partitioning algorithm. The problem here is to find optimal location such that $F(\text{LocO}(i,j)) \geq F(x)$; for all $\in \text{Loc}(i,j)$. Selected location populations are given as associate input for the fitness function calculation. The fitness function measures the best optimum location vs. alternative locations. There is a reproduction section that is based on both the fitness value and probability. It could be carried out using two more sub phases called crossover and mutation. In the phase of crossover, two parent individuals are chosen and two new children individuals are created by combining the traits of the two parent individuals. Next, in the mutation phase, one parent individual is chosen and a mutation is completed. In the replacement phase, fitness values are evaluated and compared with the prevailing ones in the population. The worst participants of the population are replaced by the new participants if the new ones surmount the existing ones. The last phase of the genetic algorithm is termination part, in this part convergence-based stopping criterion is designed and also the algorithm terminates when observing an outlined range of iterations. Table 1 shows that notation of proposed algorithms.

Table 1 Summary notations of our proposed algorithm

Summary of notations	
Beach line	B_L
Sweep line	S_L
Euclidean distance	$EDist$
Coverage range	C_r
Road stage range	$LocRS(i,j)$
Midroad range	$LocM(i,j)$
HotSpot area	$LocH(i,j)$
Feasible location	$LocF(i,j)$
Optimal location	$LocO(i,j)$
OffSpring location	$OSLoc(i,j)$
Nearest to stage range	$LocN(i,j)$
Threshold range of road stage	Th_{rs}
Threshold range of mid road	Th_{mr}
Threshold range of hotspot	Th_{hs}

3.3.1 Fitness function calculation

A function associated with an optimisation problem which determines how the best location is obtained from the feasible location for deployment of RSU. According to its final fitness value, it can be categorised into three types. They are as follows:

$$\text{Fitness value ranges} = \begin{cases} Loc(i,j) = fvLocO(i,j) \text{Optimal Location;} \\ Loc(i,j) = fvLocF(i,j) \text{Feasible Location;} \\ Loc(i,j) = fvOtherLoc(i,j) \text{Otherwise;} \end{cases}$$

The location points are selected from the area partitioning algorithm and apply fitness function if the fitness values are calculated as per the feasible location identification methodology and optimal location identification methodology. Although some selected points may not be satisfied the both fitness value, those location points are refused as unfit to the deployment process.

Feasible location identification (*FLI*): A feasible solution is a set of values for the decision variables that satisfy the constraints in an optimisation problem. Feasible location *LocF*(*i*,*j*) is evaluated from different locations like RSrange, NRSrange and MRSrange.

Case (i): Location Loc(i,j) within the RSrange,

$$LocRS(i, j) = Loc(i, j)\ ; \quad i = 0,1,2,3\ldots m \text{ and } j = 1,2,3\ldots n.$$

If the candidate location point is selected from equation (3) then apply Euclidean distance between next road stage locations. If the distance is less than $2 \times C_r$ the location *LocRS*(i,j) is selected, as a feasible location *LocF*(i,j) may ready to apply the genetic enhancement function to convert as an optimal location otherwise it is rejected. Continue the same case operation up to reach the end value of $i = m$ and $j = n$ in the RSrange.

Case (ii): Location from NRSrange,

If the candidate location point is selected from equation (4) then select that location point to genetic enhancement for converting the nearest candidate value to optimal value for achieving our target.

Case (iii): Location within the MRSrange,

If the selected location satisfied equation (5) condition that location is considered as unfit to the deployment of the RSU, so neglect the selected points from the Voronoi sweep line algorithm.

Case *(iv)*: Location is hotspot area or RSrange,

$$EDist\ (Loc(i, j)\ , LocH(i, j)) <> 0 \,\|<> 2\times C_r\ ). \tag{6}$$

Here the hotspot location may be the pole or name board location of the highway, so calculate Euclidean distance between selected point from partitioning algorithm and hotspot area $LocH(i, j)$ satisfied equation (6). Then consider the $Loc(i, j)$ is a feasible location for genetic enhancement. Continue the same case operation up to reach the end values *m* and *n*.

Case (v): Location point from other ranges, apply feasibility testing, if possible apply the genetic enhancement to achieve target location or reject the location point. From case (i) to (iv), feasible location $LocF(i, j)$ is identified and applies the genetic enhancement for generating new offspring locations for deploying RSU. Moreover assign fitness value $fv(LocF(i, j))$ ranges from 0.5 to 0.7.

Optimal location identification (OLI): Optimal solution which is determined to be the best solution from all feasible solutions. Very few optimal solutions can be found by statistical analysis or formulae, and experimental approach. Optimal location points are identified by following cases:

Case (i): Location compare to $LocH(i, j)$, the candidate location $LocRS(i, j)$ from RSrange compare with the $LocH(i, j)$ as:

$$EDist(LocH(i, j), LocRS(i, j) == 0) \,\|\, ED\left(LocH(i, j), LocRS(i, j) == 2\times C_r.\right) \tag{7}$$

And satisfying equation (7), then the location $LocRS(i, j)$ is picked as an optimal location.

Case (ii): Conditions applied between optimal points are

$$EDist(LocO(i,j), Loco(i+1, j+1)) == 2\times C_r) \,||\, (ED\ (Loco(i,j), LocH(i,j)) == 2\times C_r) \tag{8}$$

an optimal location is identified from equation (8).

Case (iii): Offspring location $OSLoc(i,j)$ from genetic enhancement, also applied for optimality testing, if it is satisfied the optimal cases or below equations, it is considered as an optimal location. Otherwise it may apply for genetic enhancement, otherwise rejected.

$$EDist(Loco(i,j), OSLoc(i,j)) == 0 \,||{==}\, 2\times C_r) \,||\, ED(OSLocO(i,j), LocH(i,j) == 2\times C_r. \tag{9}$$

From case (i) to (iii), optimal location LocO(*i*,*j*) is identified and assigned fitness value for optimal location *fv*(LocO(*i*,*j*)) is 0.8–0.9. Remaining MRSrange, locations are valued as $fv(OtherLoc(i,j)$ is 0.0. Fitness value calculated as:

$$FV = \{ fv(LocF(i,j) \,||\, fv(LocO(i,j) \,||\, fv(OtherLoc(i,j)\} \times 100. \tag{10}$$

The algorithm will terminate its function, when the number of iterations attained or essential network coverage rate is obtained. Table 2 shows the fitness value calculation.

Table 2 Fitness value calculation

Candidate location from area partitioning algorithm	*Location identification (LI)*	*Function value (FV)*	*FV = LIx100*	*Apply genetic enhancement {Y-Yes, N-No}*
Loc(i,j)	fv(LocF(i,j)	0.6	60	Y
Loc(i+1,j+1)	fv(LocO(i,j)	0.9	90	N
Loc(i+2,j+2)	fv(OtherLoc(i,j)	0.0	0	N
…	…	….	….	…..
Loc(m,n)	fv(LocO(i,j)	0.8	80	N

3.3.2 Apply genetic enhancement

Crossover operation exchanges information between two potential strings and generates offspring for the next population. Let *Pc* be the probability that takes part in the crossover operation. If crossover probability is 100%, then all offspring is made by crossover if it is 0%, whole new generation is made from exact copies of chromosomes from the old population then the crossover operation between two axis positions. Loc(*i*,*j*) and LocRS(*i*,*j*) consider as *L* and *RL*, respectively.

$$L = \{Lm, Lm-1, ...L2, L1\} \tag{11}$$

$$RL = \{RLm, RLm-1, ...RL2, RL1\} \tag{12}$$

And is performed in the following way,

$$L' = \{Lm, Lm-1, Lpos, RLpos-1, ...L2, L1\} - \quad (13)$$

$$RL' = \{RLm, RLm-1, RLpos-1, Lpos, ...RL2, RL1\} \quad (14)$$

This crossover may apply between location points of RSrange, NRSrange area and hot spot area as per our optimal requirements. Like crossover, mutation is a genetic operator used to maintain diversity in the population. The main process of mutation is altering one or more genes values in a chromosome that maintains diversity from one generation of a population of the chromosome to next generation. The mutation occurs during evolution according to user definable mutation probability *Pm*. At the end of genetic enhancement, it has produced the lot of offspring locations like *OSLoc*(*i*,*j*), then check,

$$EDist\ (LocH(i,j), OSLoc(i,j) == 0) \parallel ED\ (LocO(i,j), OSLoc(i,j) == 0) \quad (15)$$

$$EDist(LocO(i,j), OSLoc(i,j)) == C_r \times 2) \parallel ED\left(LocH\left(i,j\right), OSLoc\left(i,j\right)\right) == C_r \times 2). \quad (16)$$

Algorithm 2 Location optimisation algorithm

Input: Candidate Locations from Algorithm 1 **Output:Optimal Locations** **Algorithm:Genetic Algorithm**	
Step 1	Choose heuristic population
Step 2	Generate population From Size N Location. Create("heuristic", Initial population); $Loc_{(i,j)}$=={$Loc_{1,1}$,$Loc_{2,2}$....$Loc_{(m,n)}$};
Step 3	Evaluate fitness of each location position; Location.Calculate Fitness(); Check optimality of each position

Step 4	While (! Location($Loc_{(m,n)}$))
	Offspring Location=Select("Rank",$Loc_{(i,j)}$)
	Genetic Enhancement()
	{

i	Location. Crossover(); Crossover with probability Lc; Generation of new offspring; Check optimality of new offspring $OSLoc_{(i,j)}$; Goto step 3;
ii	Location. Mutation(); Mutation with probability Lm; Generation of new offspring; Check optimality of new offspring $OSLoc_{(i,j)}$; Goto step 3; }
iii	Breed new offspring $OSLoc_{(i,j)}$ ion through crossover And mutation;
Step 5	Apply generalised replacement;
Step 6	Replace feasible location part by new offspring location; Update the Location;
Step 7	While(Location==$Loc_{(m,n)}$) Terminate the operation;

If the new offspring location does not satisfy equations (13) and (14) it may again apply to genetic enhancement process up to reach the terminate condition. The genetic algorithm proposed various types of mutation techniques. In this proposed work, we have used creep mutation for getting the optimal genetic diversity. In creep mutation, feasible locations are selected and its values are changed according to an optimal threshold value. At the end of these genetic diversity processes, new offspring is generated. If mutation probability is 100%, the whole chromosome is changed if it is 0%, nothing is changed in the population. Again the offspring are tested by the fitness function. If the condition is satisfied, it will be selected for deployment otherwise rejected. As per step 4 in Algorithm 2, the genetic enhancement is applied and breed the new offsprings *OSLoc*(*i*,*j*).

Algorithm 3 Calculation of fitness function

Input : Check the fitness value of each feasible points Output: Identification of an optimal location	
Fitness Function:	$Loc_{(i,j)}$=={$Loc_{1,1}$,$Loc_{2,2}$....$Loc_{(m,n)}$}; i=0,1,2….m & j=0,1,2….n Location. CalculateFitness() { Switch($Loc_{(i,j)}$) {Case 1: Position of $Loc_{(i,j)}$ in Midroad Range; MidRoad Range(); break; Case 2:Position of $Loc_{(i,j)}$ nearest or within to stage range; StageRange(); Break; Case 3:Position of $Loc_{(i,j)}$ hotspot area; Hotspot Range(); break; Case 4:Position of $Loc_{(i,j)}$ Optimal Range OptimalRange();break;}}

**Position on MidRoad Range:
MidRoad Position MidRoad (i,j) ;
Threshold Value Th_{MR};**
	If (Distance($Loc_{(i,j)}$, $LocRS_{(i,j)}$)< Th_{mr})
	Select $Loc_{(i,j)}$;
	Genetic Enhancement();
	Generate Offspring Position OSLoc(i,j);;
	Else
	Reject $Loc_{(i,j)}$;

Position on RoadStage Area: RoadStage Position $LocRS_{(i,j)}$; Threshold Value Th_{RS};	If (Distance($Loc_{(i,j)}$, $LocRS_{(i,j)}$)< Th_{rs}) Select $Loc_{(i,j)}$; Reject $LocRS_{(i,j)}$; Continue upto $LocRS_{(m,n)}$; Else Select both points; Genetic Enhancement(); Generate Offspring Position OSLoc(i,j);; Select next position up to $LocRS_{(m,n)}$; Reject $Loc_{(i,j)}$;
Position on HotSpot Area : HotSpot Position $LocH_{(i,j)}$; Threshold Value Th_{HS};	If (Distance($Loc_{(i,j)}$, $LocH_{(i,j)}$))< Th_{HS}) Select $Loc_{(i,j)}$; Genetic Enhancement(); Generate Offspring Position OSLoc(i,j);; Else Reject $Loc_{(i,j)}$
Position on Optimal Range: Distance between two points=$2C_r$ C_r -Coverage Radius of each RSU)	If (E_{dist}($Loc_{(i,j)}$, $LocRS_{(i,j)}$)==2xC_r) Select $Loc_{(i,j)}$; Else if E_{dist}($Loc_{(i,j)}$,LocH(i,j)==0) Select $Loc_{(i,j)}$ is optimal position;

4 Result analysis

This section evaluates the effectiveness of the solutions generated by our partition algorithm with an optimisation technique. We first present the experimental setup followed by the results.

4.1 Experimental setup

The proposed algorithm is evaluated using extensive simulators, since no single simulator is readily available to conduct the entire evaluations. The movement of vehicles is obtained from mobility simulator SUMO, and then it has been bridged with NS2 version 2.33 using the Tracl bridging capability for doing network simulations.

4.2 Experimental evaluation

The evaluations of our algorithm presented in this paper have been performed using extensive simulations. Table 3 shows that simulation parameters of proposed algorithm.

- *Coverage ratio*: Figure 5 shows the coverage ratio of Geocover Genetic, MCP and our proposed algorithm LORDMC. It provides a good coverage ratio as the transmission range grows from 50 m to 150 m. When the transmission range is 50 m, the coverage ratio of Geocover Genetic, MCP and LORDMC shows linear growth while increasing the number of RSU. At the range of 100 m, LORDMC also performs better than others. Though coverage ratios of three methodologies rise faster than the 50 m-transmission range, LORDMC reaches a peak value more quickly than other two and it grows the fastest augmenting from 2 RSUs to 10 RSUs. When the transmission range of an RSU reaches 100 m and 150 m, the preponderance of proposed algorithm is more obvious than Geocover Genetic and MCP. In the simulation of 150 m transmission range, the LORDMC strategy realises nearly 90% coverage with only 10 RSUs and it reaches 100% as the number of RSUs grows to 15. The growth is slower in Geocover Genetic and MCP since it only provides nearly 75% of coverage under 10 RSUs. The gap between LORDMC, MCP and Geocover Genetic also widens as transmission range rises from 50 m to 100 m and it reaches the peak in the form of a 150 m-transmission range. Through this proposed algorithm, we have achieved preeminent spatial coverage. This full coverage strategy will reduce the interconnection gap and increase the contact time between vehicles to Infrastructure.
- *Packet delivery ratio*: The PDR is defined as the number of received data packets divided by the number of generated data packets. Through this simulation setup, we have evaluated the effectiveness of three types of deployment strategies by measuring the PDR over the various number of RSU. From the simulation environment vehicles were randomly selected to send packets overutilisation. The simulation time for each run is 500 seconds. The number of RSU is varied in this scenario Figure 6. The following graph illustrates the proposed algorithm continuously retained a higher PDR of approximately 88% when the number of RSU is 10 during the transmission range of 150 m. The LORDMC showed efficient packet forwarding even though the network topology was varying over the time.

Figure 5 Number of RSU vs. coverage (%) in terms of a range of transmissions

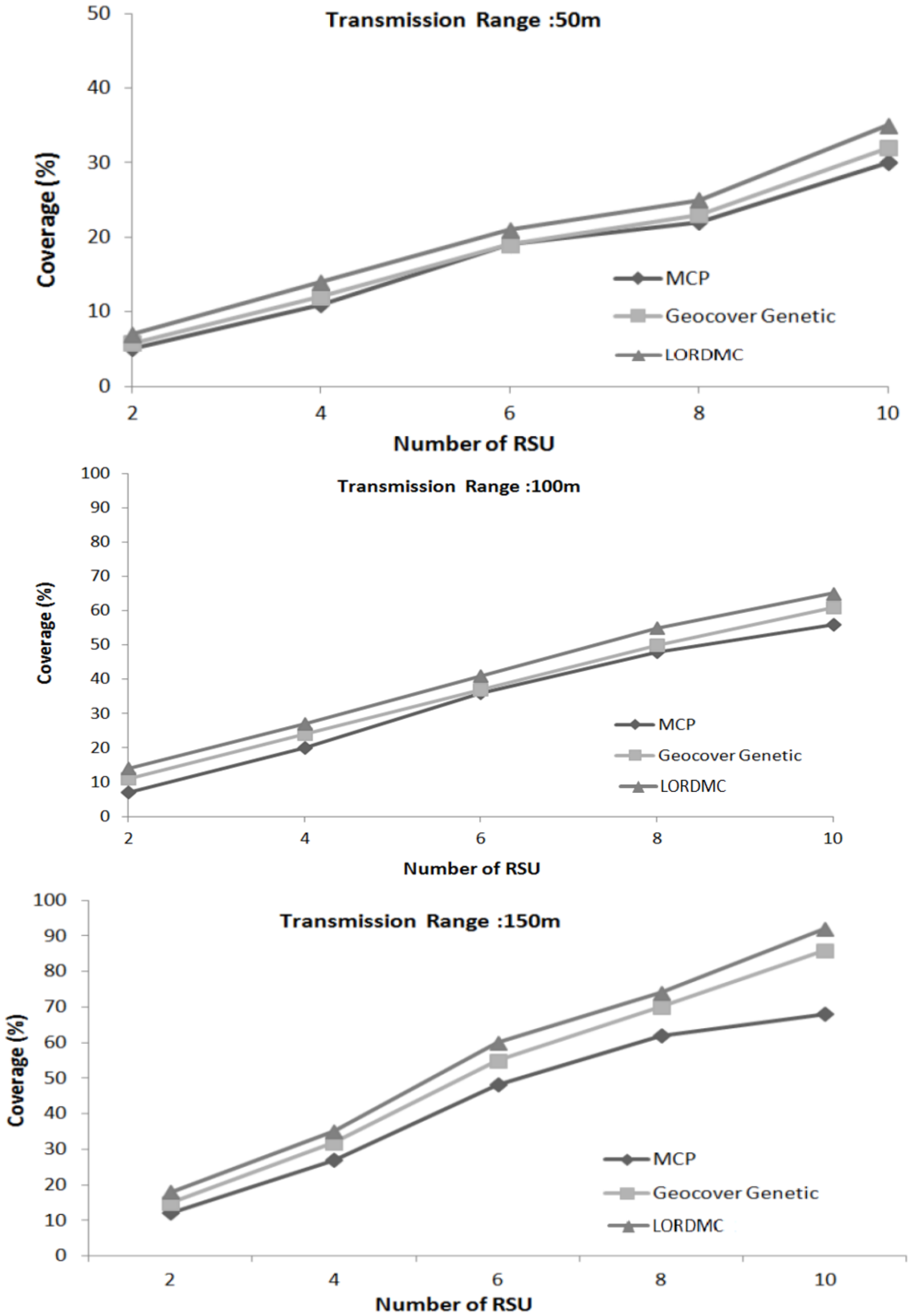


Table 3 Simulation parameters

Parameters	*Values (High way Lane)*
Simulated area	1000×500
Simulation time	500 s
Mobility simulator	SUMO
Network simulator	NS2
Area of map	Pearl City
Number of RSU	2–10
RSU height	1.5 m
RSU antenna	Omni
Number of vehicles	10,15,20...
Vehicle speed	40–60 m/s
Routing protocol	AODV
PHY/MAC protocol	IEEE 802.11p
Transmission range of RSU	50,100,150,
Network interface type	PHY/WirelessPHY
Channel type	Channel/Wireless Channel

- *End to end delay*: Delay is the total time taken by the packets to reach from the source to destination. The packet end to end delay is the average time that packets take to traverse in the network. It includes all the delays in the network such as propagation, processing, transmission, and queuing delay. The following graph in Figure 7 illustrates the end to end delay of Geocover Genetic, MCP and LORDMC. When the transmission range is 50 m, the Geocover Genetic, MCP and the LORDMC experiences the gradual decrease in the end to end delay as the number of RSU increases. Similarly, as the transmission range increases the LORDMC continuously retained a lower end to end delay of approximately 85% when the number of RSU is 10, whereas, in the case of Geocover Genetic, and MCP the end to end delay is approximately 70% when the number of RSU is 10.Thus the proposed algorithm achieved the lower end to end delay than the others. And it showed efficient packet forwarding even though the network topology was varying over the time.
- *Packet loss*: Packet loss occurs due to inadequate signal strength at the destination, natural or human-made interference, excessive system noise, hardware failure, software corruption or overburdened network nodes. Often more than one of these factors is involved. Packet loss is measured as a percentage of packets lost with respect to packets sent. In this proposed work packet loss is inferior to the compared algorithm. Figure 8 compares the packet loss ratio according to a number of RSU used in the proposed area and also with the transmission range of the each RSU. When the transmission range is 50 m, the packet loss for the LORDMC and others are less disparate.

Figure 6 Number of RSU vs. packet delivery ratio in terms of a range of transmissions

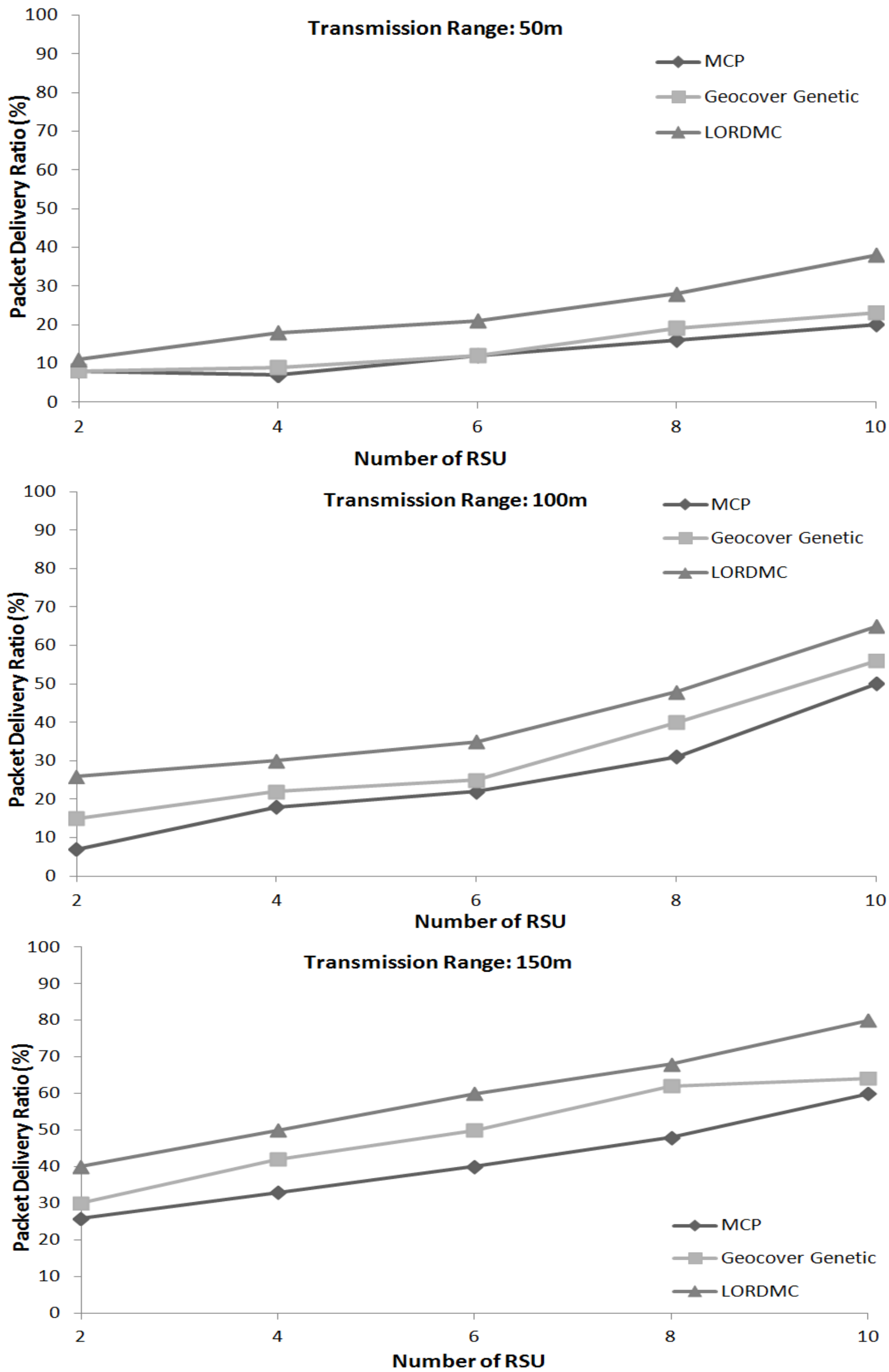


Figure 7 Number of RSU vs. end to end delay in terms of a range of transmissions

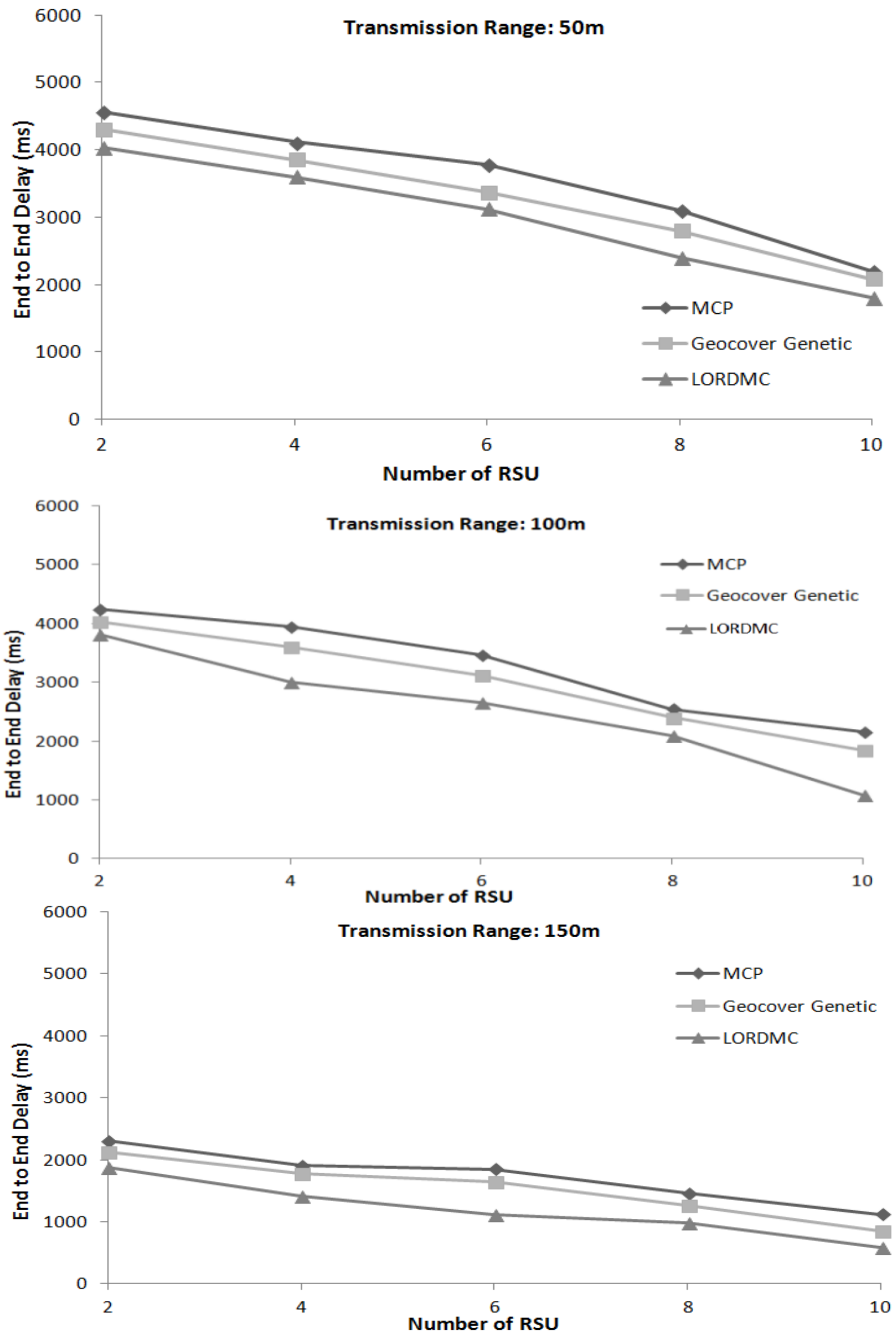
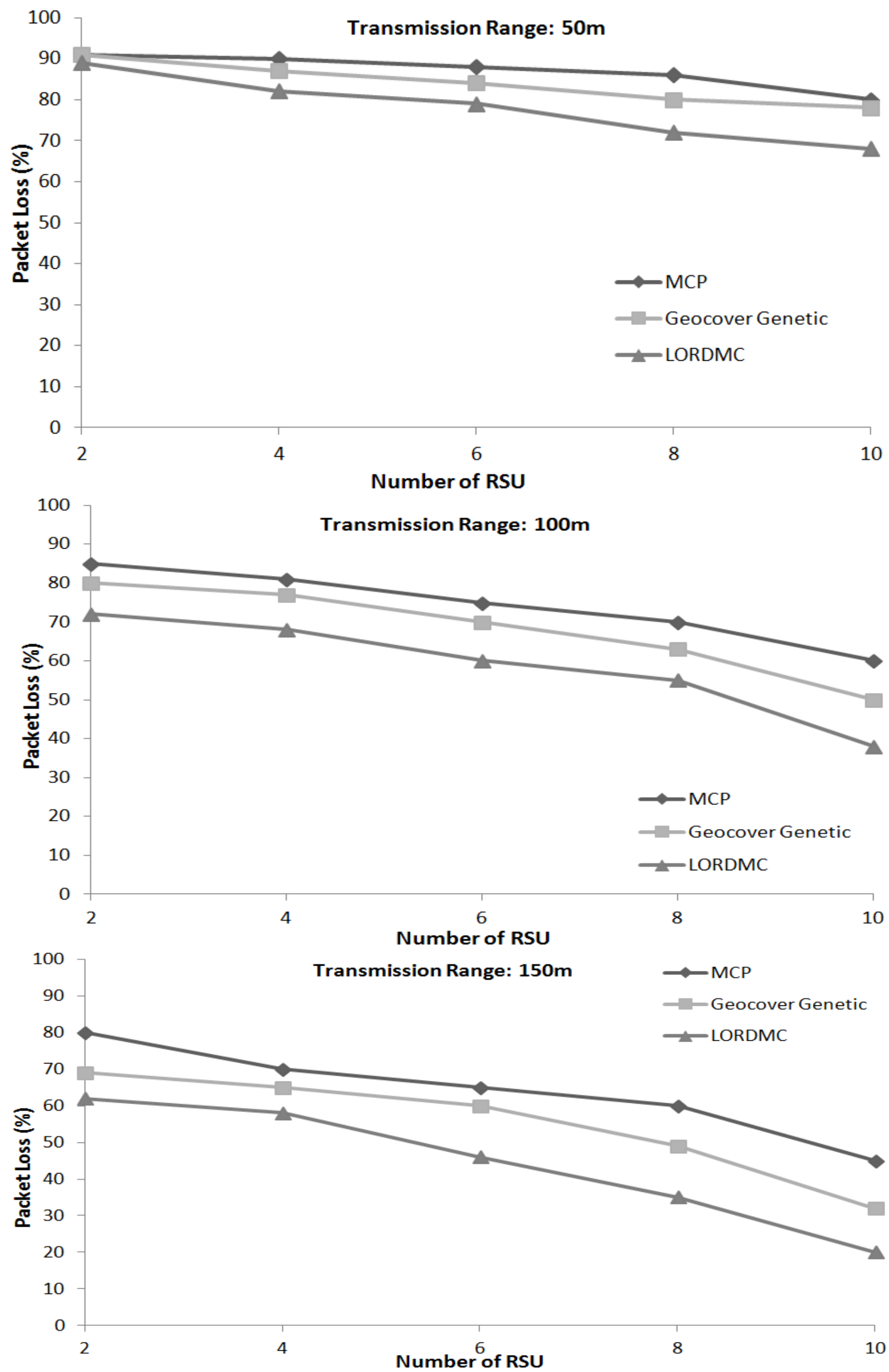


Figure 8 Number of RSU vs. packet loss in terms of a range of transmissions



The gap between the LORDMC and Geocover Genetic increases as the transmission range increases from 50 m to 100 m, which means that the packet loss for proposed algorithm is less when compared to Geocover Genetic and MCP. Compared to other two strategies, LORDMC performs better performance over the range of 150 m and the packet loss is reduced to the point of 10 RSU.

5 Conclusion and future directions

In this paper, we have addressed the problem of locating a fixed number of RSUs to maximise the coverage ratio and minimise the communication delay in smart PC highways. The proposed techniques aim at finding an optimal location for the deployment of RSU, which is essential to achieve adequate communication contingencies for vehicles. This paper describes the sweep line-based Voronoi algorithm to partitioning the target area and designs genetic algorithm to deploy the road side infrastructure in an optimal location from feasible points to maximise the quality of coverage. The simulation results validate the mobility and network-based strategies. It reveals that this proposed RSU deployment scheme will enhance and improve the performances regarding coverage ratio, end-to-end delay, packet delivery ratio and packet drop ratio in the highway environment. Our network simulator, NS2 proves that the proposed algorithms perform with better scalability and stability when compared with an existing VANET coverage algorithm.

In future, we will extend our research work for more complex road topology of smart PC to enable the better connectivity using some handoff mechanisms.

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