# Simulation based Optimal RSU location Technique: Intersection and crossroad perspective

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***ABSTRACT*: The most essential component of a vehicular ad hoc network(VANET), apart from VANET enabled vehicles, is roadside units (RSUs).The power of a VANET largely depends on the location and density of these stationary units. Before complete implementation of VANET anywhere installation of RSUs is mandatory. Deployment cost of RSUs and less market penetration of VANET enabled vehicles makes it expensive to deploy a large number of RSUs. Therefore there is a need to optimally place a restricted number of RSUs on the roadside in order to achieve maximum performance. This paper presents comparative analysis for crossroad and intersection placement of a limited number of RSUs in an urban, rural and highway region. Evaluations show that placement of RSU's on crossroads and intersections gives better performance in terms of scalability and computational cost. Analysis of solution in different types of roadways with real traffic data to find optimal positions and number of RSUs in these areas has been done.**

**Every year about a million people die due to traffic accidents caused by bad road conditions. This means that traffic accidents are one of the main causes of mortality in the world. Therefore, car manufacturers and several governments are investing money and time on research and development in order to improve road conditions and passenger safety. This work present an application framework for application to monitor road conditions with a view to optimally place the RSU's within particular rural, urban and highway scenarios.**

***Keywords*: VANET, RSU, optimal localization**

## I. INTRODUCTION

Future of connected devices is the next boom in technology and vehicles are not an exception. A lot of research and applications building scope is seen in this vehicular ad hoc area. A VANET considers three types of communication as a part of it; Vehicle to vehicle communication (V2V), vehicle to infrastructure communication (V2I) and infrastructure to infrastructure (I2I) communication. All VANET applications use one or more of these communication types [1]. V2V communication depends on the location and number of nodes or vehicles, V2I communication depends on the number and location of roadside units (RSUs) and I2I communication depends on the presence of interconnecting network between RSUs. As implementation of VANETs is in its initial stages there will be very less number of vehicles and road side units due to the low market penetration of VANET enabled vehicles or due to the high cost of RSUs. So considering small number of RSUs to be used it is necessary to optimally place these RSUs in a given region or scenario in order to achieve maximum performance. Data flow in most VANET applications in either from Vehicle to RSU or from RSU to vehicle. This paper considers applications that depend on information flow from vehicle to infrastructure (V2I) such as collection of information from vehicles about traffic or road conditions or traffic accidents, etc.

Optimal location of RSU does vary depending on the kind of scenario under consideration. This paper considers a model which presents an application scenario to monitor condition of roads by capturing road images. All over the world total 25% of road accidents are caused due to bad road conditions [2]. Rural roads specially suffer from improper attention. Prior information regarding such road conditions can stop these accidents. Exact information of such road conditions can help authorities take appropriate and timely action to improve the road condition. Data thus collected can work as a great resource for researchers in intelligent transport field.

This paper presents an approach to find out optimal number of road side units for area under consideration and criteria's to decide effective location of these road side units for designing an ambient road condition monitoring system. The total system has been simulated and experimental results have been analyzed. RSU being an important unit of VANET, work discussed in this paper will help faster further research in this vehicular ad hoc network area.

## II. LITERATURE SURVEY

For collecting and analyzing traffic data, RSU is an essential infrastructural stationary unit in VANET. For an economical VANET solution efficient RSU placement for getting optimal vehicular network connectivity is most essential. RSUs play an important role for providing instant communication between VANET elements in real time traffic conditions. Some of the techniques presented so far for optimal placement of RSU's are being discussed.

Lee et al.[3] proposed optimal placement of RSUs technique to provide efficient connectivity. Each point in the map is considered as a potential RSU location. The decided optimal locations are organized based on number of vehicle within communication range of each RSU. The optimal placement scheme basically considers vehicle location reports and does not consider density or speed of all vehicles. Li et al. [4] consider the optimal placement of gateways, which connects stationary road side units to the Internet, while minimizing the average number of nodes (vehicles) from RSUs to gateways. They consider pervasive RSUs by taking care of the fact that every vehicle is connected to an RSU. They do not bother about vehicle movement pattern, speed, density. Zhao et al. [5] optimize placement of RSUs that behave as relays, to increase contact and data-rate or throughput within context of a DTN. Their goal is to improve V-2-V communication and not the V-2-I communication. Lochert et al. [6] perform optimal RSU placement by using genetic algorithm for a VANET traffic information scenario. The optimal placement is to reduce travel for predefined land marks and may not be that useful for travel between any 2 arbitrary points in an area.

Sun et al. [7] for optimizing the location of RSUs distance of vehicle from RSU was calculated by time constraint. Sum of an overhead time and driving time was calculated to evaluate distance of vehicle from RSU. Change in vehicle route is what this optimization technique expects which may affect local traffic condition. No local route changing condition is available; only current routes are taken into consideration. Fiore et al.[8] optimally places road side units in an urban vehicle environment in order to improve co-operative download of data among vehicles. Their goal is towards placing the RSUs at point where maximum vehicles cross each other; this helps in carrying the data from RSUs to a downloading vehicle through other vehicles. Trullols et al. [9] optimally deploy RSUs in an urban environment to increase the number of vehicles that contact the dissemination points. Malandrino et al. [10] concentrates on optimal deployment of the RSUs for maximization of the system throughput. They consider V-2-I (and I-2-V) and V-2-V communications for optimal placement of RSUs. Vehicle trajectory information such as location and time creates basis of this optimization technique assuming that this information is available which may not be the case always. Zheng et al. [11] optimally deploy RSUs to increase contact opportunity; defined as time for which a user remains in contact with an RSU. Xiong et al., [12] found optimal deployment places by studying the vehicular mobility pattern and for characterizing the observed mobility pattern proposed graph mobility model.

Most of these works are focused on maximizing the throughput and minimizing travel times by optimally deploying a limited number of RSU. This paper aims at determining the general solution for the placements of RSUs so that maximum vehicular-RSU connectivity can be achieved. For the considered scenario experiments have been conducted to determine optimal number of RSUs to be deployed.

## III. MODEL

To tackle challenging issue of monitoring bad road conditions, application framework can be developed using existing infrastructure of VANET technology. It will transfer captured road condition images free of cost using vehicle motion on roads. By leveraging existing infrastructure such as traveling vehicles in the city and using road data dissemination techniques proposed under VANET. Paper proposes a model which exploits wireless-enabled vehicles equipped with high quality cameras. Since it is impossible to directly report the sheer amount of captured data to the authority, vehicles keep captured images in mobile node storage and when it comes in contact with stationary nodes it forwards all the stored data.

It is assumed that network consisting of vehicles that travel in urban, rural and highway environment and several stationary RSU's are spread across city which does not provide full city coverage. These stationary points will collect readings from the moving vehicles and will feed data through backbone connection to the server where user applications will consume this road status data for deciding required actions. In VANET architecture vehicles can communicate with neighboring vehicles or stationary points within range.

Another assumption is that the map is preloaded with road statistics about the path network.

The map also contains the locations of the stationary point nodes. Vehicles will carry images with each image of compressed size of approx. 10KB, Vehicles have infinite buffer size and device should not consume much of a vehicles power. Model uses existing VANET architecture. Model has no control over vehicle movement, i.e., it cannot proactively modify vehicle trajectories for communication. The dispersed Camera equipped vehicles makes it harder for potential attackers to disable monitoring of road conditions.

First modeling of this application was done. Then in order to tackle challenge of exact locations for placement of RSU within the model some experiments were done using VanetMobiSim and NS2. Results are then proposed in the tabular and some in graphical form. So after establishing RSUs at their optimal locations in any one of the scenarios when camera and VANET enabled vehicles will travel over the road they will upload the gathered data to closet RSU such that throughput and packet delivery ratio of the network will be optimal.

## IV. EXPERIMENTAL PROCESS

To clear the idea about working of proposed model in real situations via VANET, Simulation has been done using combination of VanetMobiSim-1.1 /NS-2 application. Vehicular Ad Hoc Network Mobility Simulator (VanetMobiSim) is an open source user mobility simulator. The goal of VanetMobiSim is to provide a high level of realism in node mobility simulations [14]. It takes into account both micro and macro mobility features. Macro mobility considers road structure (single/multi-lane, unidirectional, bidirectional), the road characteristic (vehicle class based restrictions, speed limit) and the presence of traffic signs (traffic lights, stop, pause sigh etc.) along with road topology whereas macro mobility also considers effects of the Presence of point of interests, which can affect movement's pattern. Modeling of VanetMobiSim includes V2V and V2I relationship. Whereas NS2 first takes an object tcl programming language (OCTL) script as input for OCTL interpreter which perform all the required functions written in C++ and gives us results in the form of trace files and nam files [15]. Network animator can then be used to show graphical results. Fig. no. 1 shows the VANET simulation scheme. First it is needed to define some mobility scenario in a XML file. For this to work launching the VanetMobiSim framework is necessary in order to produce a node mobility trace file in NS2 format (node identifier, time, position, speed). This file must be incorporate to the communications definition file, implemented in Tcl language. After running NS2 a trace file which logs all routing events during simulation is generated. Eventually, AWK tool is needed to filter that events trace file extracting all significant data, allowing an evaluation of the scenario. Table no 1 explains complete workflow of simulation process. [15]

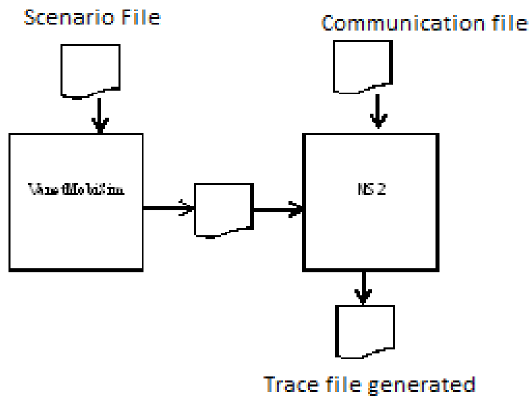



Fig no. 1: Simulation process [15]

Table no 1: Work flow

| | |
|---|---|
| Phase I: | • Installation of VanetMobiSim<br>• Preparing ".xml" file for mobility model generator<br>• Mobility model trace file generation |
| Phase II: | • Installation of NS2 on Linux platform<br>• Generating/editing 'OCTL' file for simulation<br>• Using 'cbrgen.tcl' to include in core Tcl file.<br>• Running simulation<br>• Generating NS2 trace file and NAM |
| Phase III: | • Analyze trace file to evaluate performance |

## V. SIMULATION SCENARIO AND PARAMETERS.

First type is rural roads. In this scenario the traffic frequency is low resulting into highly disconnected ad-hoc network. Moreover average speed of the vehicles is considered to be moderately low. Next type is urban roads**.** In this scenario, huge number of vehicles makes it easier to find a path between source and destination. The vehicles would run at moderately high or low speeds, depending on the specific road.one more type is highway roads**.** In this scenario the traffic pattern are different; vehicles travel at high speeds following a road without crossovers or traffic lights. One condition is new automobiles entering on the highway must be aware of those already on it.

During simulation process four scenarios have been implemented in using features that VanetMobiSim [80] offers. These scenarios are: Real rural, urban and highway scenarios extracted from TIGER/Line maps. Table.no 2 summarizes the features common for each scenario.

Table no 2: Scenario parameters

| Common Parameters | Urban/Rural /highway |
|---|---|
| **Dimension** | 1000*1000 |
| **Area** | 30km by 30 km |
| **Traffic agent** | CBR/UDP |
| **Packet length** | 512 byte |
| **Mobility Pattern** | Vehicular traces from TIGER-MAP |
| **Data rate** | 20 kbps |
| **Antenna** | Omnidirectional |
| **Mac Protocol** | IEEE802.11 |
| **Propagation model** | TwoRayGround |
| **Transmission range** | 250m |
| **Routing protocol** | AODV |
| **Queue** | PriQueue |
| **Driving Model** | Intelligent Driving model (IDM) |

In VanetMobiSim real scenarios or applications vehicle traces can be used to generate all the required experimental data. The statistics based on vehicle traces are generally reliable as daily traffic patterns and are often repeated. The real traffic data are obtained from the traffic analysis reports provided by the tiger map database. Simulations were done for various experimental such as number of RSU's, location of RSU. In order to determine the intersection priority, two traffic factors such as the visible density of vehicles and the popularity of an intersection were considered. The specifications of system used for simulation are: Processor - Intel® CoreTM 2 Quad CPU Q6700 @ 2.66 GHz, RAM - 4 GB, Hard Disk - 232 GB (200 GB free), OS – Ubuntu (Linux) 64-bit.

For Rural TIGER/Line scenario, two county's Calaveras County and Colusa County from California region were selected. On the other hand, the Highway TIGER/Line scenario corresponds to Arizona State Highway, Maricopa County And US-6 highway, California. For Urban TIGER/Line scenario, a downtown area from Alabama, Autauga County is selected. For brief and exact results four more urban areas were selected and simulation was performed with same urban using four tiger maps. Table no. 3 shows parameters specific for each scenario

Table no 3: Specific parameters

| | Rural Tiger/Line | Urban Tiger/Line | Highway Tiger/Line |
|---|---|---|---|
| **Simulation Time** | 3600s | 1000s | 1000s |
| **Base stations** | 3/4/5/6/7 | 4/5/6/7/8/9/10 | 4/5/6/7/8 |
| **Nodes** | 50 | 150 | 120 |
| **Avg. speed** | 5m/s or 18 km/hr. | 8 m/s or 28 km/hr. | 12m/s or 43km/hr. |

For each scenario following performance metrics have been measured.

[1] Overhead: It is a ratio of number of hops travelled by each packet to total number packets. Overhead is calculated as:

$$Overhead = \frac{Routing\_packets}{Data\_packet\_sent} \times 100$$

[2] Throughput: It is ratio between the total numbers of bits received to total time of simulation. Data throughput was calculated as a time function, considering intervals of 3600 seconds. Throughput is calculated as:

$$throughput(in\_kbps) = \frac{Total\_pkts\_received}{total\_time} \times 8 \times 512$$

[3] Average End-to-end delay (E2E) : It considers the time which a packet needs to go through the network from source node to destination node. Delay is calculated as:

$$E2E = \frac{\sum Time\_required\_for\_each\_packet}{Total\_packets\_received}$$

[4] Packet Delivery Ratio (PDR)

It considers the percentage of data packets received by destination node relative to data packets sent by source node. PDR is calculated as:

$$PDR = \frac{Data\_packets\_received}{Data\_packets\_sent} \times 100$$

## V. RESULTS

Work is divided in to three scenarios: rural, urban and highway region. A comparison between these scenarios was carried out, showing how their performances vary depending on the changes made in the number and location of RSU's.

In order to evaluate results better, simulations were carried on four urban areas. Overall 100 simulations have been run in order to carry out the following evaluations. Only one computer has been used to run the simulations: a PC with a processor of 1.72GHz and 512 Mb of RAM memories.

Table no. 4: percentage change with increase in RSUs at intersection

| No of RSUs at intersection | No of RSUs at Non-intersection location | Packet delivery ratio | Throughput | Overhead | Delay | Average path length |
|---|---|---|---|---|---|---|
| 1 | 3 | - | - | - | - | - |
| 2 | 3 | +3% | +35% | +20% | -20% | +2% |
| 4 | 0 | +10% | + 60% | +2% | -24% | +3% |

Table no.5: Results for various parameters with increase in RSUs

| No of RSUs | Sent | received | Dropped | Routing packets | Total sent | Total received | Received size |
|---|---|---|---|---|---|---|---|
| 3 | 113632 | 98970 | 14662 | 17736 | 202695 | 196845 | 89673650 |
| 4 | 125843 | 113727 | 12116 | 13513 | 231025 | 221134 | 117724050 |
| 5 | 130843 | 113307 | 17536 | 15659 | 244150 | 208783 | 119911424 |
| 6 | 145347 | 121327 | 24020 | 16072 | 266674 | 224957 | 121868288 |
| 7 | 144491 | 117160 | 27331 | 17879 | 261651 | 240653 | 124177408 |

Table no.6

| No of RSUs | PDR (in %) | Throughput (in kbps) | Overhead (in %) | e-2-e delay (ms) |
|---|---|---|---|---|
| 3 | 87.097671 | 199274.7778 | 08.272270 | 129.118 |
| 4 | **92.3725** | **261609.112** | **10.737983** | **135.617** |
| 5 | 86.597678 | 270495.19 | 11.057676 | 126.324 |
| 6 | 83.474031 | 273386.32 | 11.967778 | 128.612 |
| 7 | 81.084635 | 278566.22 | 12.373781 | 130.223 |

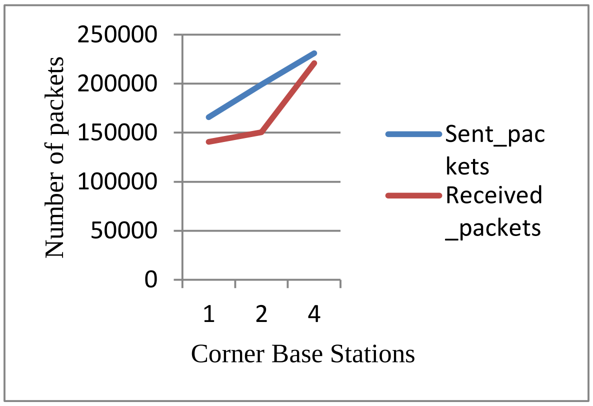
The solution was first evaluated under different road traffic conditions, OBUs were distributed over the 30 km by 30 km map ranging from 50 OBUs to 170 OBUs.

A. Rural Region Scenario

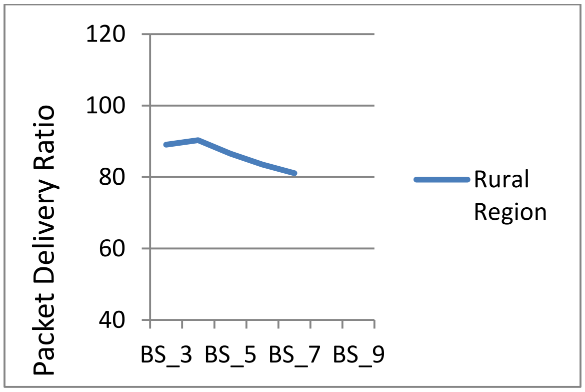
Using rural region tiger map traces evaluation of different locations of base station was done. Result showed that placement of RSU on the intersection with locating RSU alternate on the cross roads give optimal result. Table no. 4 shows detail description of one scenario where four RSU's were placed at different corner and non-corner locations. According to simulation results maximum throughput and packet delivery ratio is obtained when all the RSU's are placed at alternate corner locations. Table 5 and 6 show results for various numbers of base stations where all the base stations are placed on corners. As can be seen in table no 4 max increase of 60% in throughput and 10% in PDR has been obtained if all the RSUs are placed at the alternate sides of intersections.

According to results it can be observed that for rural region of area 30 by 30 kilometers four base stations give optimal results. When one base station was added, it means to bear cost of complete one base station including its maintenance cost. Taking this factor into consideration when 4$^{th}$ RSU was added to existing 3 RSU's very huge that is 31% increase in throughput and 6% increase in Packet delivery ratio at the cost of one RSU and 29% overhead was obtained. Whereas if one more RSU was added only 3% increase in throughput, 7% decrease in packet delivery ratio at the cost of complete one RSU was seen. Adding any more number of RSU's have proved non optimal so 4 number of RSU's give optimal results for this scenario. Here paper presents detail results of Colusa County, California. Graph no. 1 and Graph no. 2 present's graphical results of packet delivery ration and sent and received packets simultaneously of Calaveras County.

Reason behind sudden increase in throughput is due to increase in received data size which means decrease in packet dropping. When enough number of RSU's cover the area under consideration good enough that most of the packets sent by the moving vehicles are received by one of the stationary unit. Due to increase in number of RSU's nodes have to register them self every time when they enter into coverage area of particular RSU. That increases routing messages and indirectly overhead gets increased.




Graph no. 1: packet analysis (rural)




Graph no. 2: PDR for Rural Region

B. Urban region scenario

To evaluate the solution about optimal number and location of gateways for urban region simulation was performed on tiger map traces of District of Columbia. Other four scenarios have been simulated in addition to the above three scenarios in order to evaluate validity of results. Which were based on tiger map traces of SanFrancisco-Oakland, San Diego, Riverside-San Bernardino, Sacramento.

According to results it can be observed that for urban region of area 30 by 30 km 6 base stations give optimal results. Similar to rural when one base station was added it means need to bear cost of complete one base station including its maintenance cost. Taking this factor into consideration when 6$^{th}$ BS was added existing five RSU's again very huge that's is 25% increase in throughput and 5% increase in Packet delivery ratio at the cost of one RSU and 10% overhead were obtained. Increase in overhead in urban region is less as compared to 25% overhead increase in rural region. In rural region modifications in average path length are less around 0.1 to 2 %

Table no.7

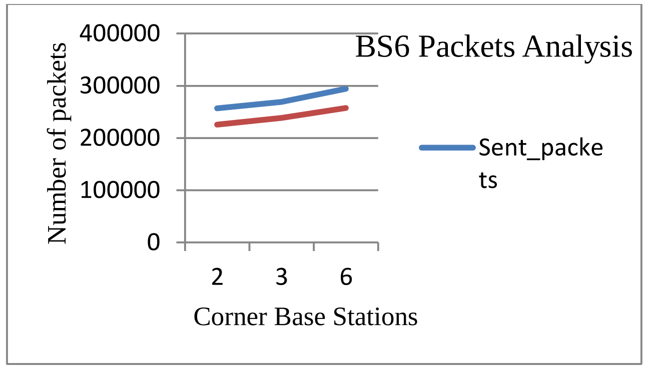
| Base Stations | Packet Delivery Ratio | Throughput | Overhead | Delay | Avg. path l |
|---|---|---|---|---|---|
| 5 | - | - | - | - | - |
| 6 | +5% | +24% | +10% | + 4% | -5% |
| 7 | -4% | +8% | +8% | -4% | +0.7% |
| 8 | -0.1% | +12% | +3% | -5% | -1% |

whereas in urban region path length changes are around up to 5%. Reason behind this is high number of roads available in urban region provides large number of alternate road options to reach same destination. But only some of them are shortest length paths. Huge number of roads demands more number of RSUs hence in rural region 4 RSUs give optimal results where as in urban region 6 RSUs provides most optimal results. Adding any more number of RSU's than six have proved non-optimal so 6 number of RSU's give optimal results.

### C. Highway Region

Highway region presents a complete different kind of environment from urban and rural area. It is basically made of long straight roads with less number of interrupting small roads. To find out optimal number and location of RSU units simulation was performed on tiger map traces of two US highways. Table no.7 show results for various numbers of base stations where all the base stations are placed on corners. According to simulation results maximum throughput and packet delivery ratio was obtained when all the RSU's are placed at corner locations. In highway region max increase of 53% in throughput and 6% in PDR has been obtained if locations of RSU's were considered. Simulation was done for tiger map traces of US-6 and US-95 number highways and results proves the concept of RSUs placed at intersection on alternate sides giving optimal results. Graph no 3 Cleary shows that in case of six base stations when all are placed at cornet or intersection gives maximum result.

After paying special attention to results another conclusion for highway region was drawn that highway region suffers from high average path length when numbers of RSU's are less than optimal or much more than optimal as only optimal number of RSU will reduce travelling of data through unwanted nodes.




Graph no. 3: Packet Analysis (highway)

## VI. CONCLUSION

VANET have opened new door to entertainment and safety applications on vehicles and these kinds of networks has been the subject of study for multiple projects around the world. This fast progress goes through lot of challenges and this paper concentrated on one such challenge of finding out optimal location of RSUs. The study showed that for all three different scenarios i.e. rural, urban and highway scenarios optimal throughput and packet delivery ratio are received when RSUs are placed at intersection on alternate sides of the road. This paper concludes that for 30 km by 30 km area represented in 1000 by 1000 pixel in NS2 four is the optimal number of RSUs for rural regions where as six is the optimal number of RSUs for urban and highway scenarios. Generalized formula for finding out optimal number of RSUs with modifications in area can be one of the future work possibility for technique presented in this paper.

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