RSU Placement Method Considering Road Elements for Information Dissemination

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Abstract—**In Intelligent Transportation System (ITS), communication with RoadSide Unit (RSU) is expected that weak connectivity of vehicle-to-vehicle communication can be improved since the power average of RSU is large. However, to deploy and maintain RSUs is costly. Therefore, it is necessary to effectively place RSUs within limited cost. Many opportunities to communicate with vehicles are at intersections with a lot of traffic volume. However, it is necessary to consider not only the traffic volume but also a connection relation of the road network because buildings prevent radio waves. In this paper, we propose an RSU placement method considering road elements that affect radio wave spreading. This method consists of two actions: calculation of RSU placement priority with considering road elements affecting radio wave spreading and operation of updating RSU placement priority. As a result of simulation, our proposal is particularly effective in a scenario considering information relay because the communication performance of this method was higher than or equivalent to that of other RSU placements. Further, it is found that our proposal was possible to suppress redundant RSU placement by updating operation of RSU placement priority in a scenario which is not considering information relay.**

Keywords–VANET; RSU; Road elements; Priority

I. INTRODUCTION

Recently, research on Intelligent Transportation Systems (ITS) that improves the traffic safety and traffic efficiency by making vehicles communicate with each other has been actively conducted. In ITS, vehicle communication is classified into vehicle-to-vehicle and road-to-vehicle communication. Vehicle-to-vehicle communication can be extended ad hoc networks easily because ad hoc communication is possible if only vehicles are equipped with in-vehicle devices dedicated to communication individually. In particular, ad hoc networks composed of vehicles are called Vehicular Ad-hoc NETworks (VANETs), and various applications using this VANET are being studied in the field of ITS.

In ITS, road-to-vehicle communication is expected to have high connectivity. Propagation radio waves are blocked by buildings in the city and connection of VANET is unstable because vehicles move at high speed. Therefore, the connectivity of the VANET is weak, and there arises problems such that vehicles can not communicate satisfactorily. On the other hand, road-to-vehicle communication is expected that weak connectivity of vehicle-to-vehicle communication can be improved by base station participating in communication. The Electronic Toll Collection system (ETC) [1] and the optical detector [2] that only the vehicles nearest to the RoadSide Unit (RSU) can communicate are currently being put to practical use, but in the future, it is expected that it will be possible to form networks with farther vehicles and RSUs, because a more robust ad hoc network will be formed by vehicles and RSUs relaying information.

An effective RSU placement within a limited cost is necessary since to deploy and maintain RSUs are costly. Various methods have been proposed for placement of RSUs. For the purpose of increasing communication opportunities between the vehicle and the RSUs, particularly many methods for placement the RSU based on the vehicle traffic volume have been proposed. Specifically, it is a method of placing RSUs preferentially at intersections with high traffic volume [3]. However, in order to achieve effective RSU placement, RSUs have to be deployed with the metric considering the other elements as well as the traffic volume. This is because when assuming information spreading by relaying information, in order to deploy RSU effectively, it is important to consider not only the traffic volume but also the other elements of the road network.

In this paper, we propose an RSU placement method considering road elements that affects radio signal spreading. This method consists of two actions: calculation of RSU placement priority for each intersection with considering road elements affecting radio wave spreading and operation of updating RSU placement priority. Evaluation of our proposal is performed by simulation of information dissemination by RSUs. We assumed two scenarios, which are assumed packet relay and not assumed packet relay.

In Section 2, we explain the existing methods of RSU placement. In Section 3, we describe the proposed method. In Section 4, we evaluate proposed method using simulation. We will conclude with Section 5.

II. RELATED WORK

This section explains related research on spreading information and background on RSU placement. In ITS, vehicles exchange various information, thereby improving traffic efficiency and improving safety. Various information to be exchanged here is assumed in vehicle information, such as speed and position of surrounding vehicle and itself, safety information such as where accidents occurred, entertainment information such as videos. By using this information, the vehicle can avoid the road where traffic congestion is expected and avoiding entering the area where the accident occurred.

The vehicle sends and receives these information by communication technology. Especially, ad hoc networks constituted by only vehicles are called VANETs, and various applications using VANET are assumed.

However, vehicles can not relay packets unless each vehicle are in a range of communication of each other. So, if density of vehicles is small or buildings locate where they disturb radio wave propagation, it is difficult to spread information by vehicle to vehicle. This is mentioned in papers [4], [5], [6], [7]. In a specific road structure, information spreading among vehicle to vehicle has limits because information doesn't spread wide enough by relay using Flooding. For this reason, a connectivity of vehicle to vehicle has a weak point. Then, RSU which improves the weak point of vehicle to vehicle communication are attention has been paid.

RSU is an infrastructure for telecommunication in ITS. Generally, RSU is placed on roads, and send information to vehicle and receive information from vehicle. It is assumed the situation that RSU processes information, further communicate to vehicle at local area. Furthermore, it is assumed the situation that information received by RSU are processed by server through backbone network, and RSU sends surround vehicles the packet which are processed by server. RSU is convenient but deployment cost is high. Also, it is known that cost is increased because power is frequently used for maintaining RSU once deployed. Therefore, it is not realistic to deploy infinitely many RSUs. It is necessary to effectively arrange a limited number of RSUs so that they can communicate with more vehicles.

In order to effectively utilize limited RSU, many methods of RSU placement are researched. H. Zheng et al. proposes an algorithm to set up RSU based on traffic volume to distribute advertisements at stores [8]. For each intersection, calculate the RSU placement priority high in the order of the traffic volume, and place RSUs in the place where the vehicle has many opportunities to receive the information. Similarly, J. Chi et al. also proposes an algorithm that calculates RSU placement priority at a high value based on traffic volume [3]. In addition, control is exercised not to deploy an additional RSU around the intersection where the RSU is deployed. This is an operation for preventing intersections with high RSU priority from concentrating in one place. Also, some RSU placement methods focus on deploying RSUs at highways [9], [10], [11]. Although these are references related to the placement of RSU, basically there is no constraint to deploy RSU at intersections like urban areas, so the concept of RSU placement priorities for intersections is not mentioned.

There are some analyzing methods of road network structures [12], [13], [14]. However, they don't analyze road networks from the viewpoint of radio wave diffusion. For this reason, in order to effectively deploy this RSU, we considered that it is necessary to consider the influence of static road elements in the road network on radio wave diffusion in addition to the traffic volume.

III. PROPOSED METHOD

This section proposes the RSU placement method based on road elements for information distribution. This method enables effective RSU placement suppression of redundant placement of RSU while considering the influence on radio wave diffusion by road elements. This method performs RSU placement by two operations. The first is the calculation of the RSU placement priority and the second is the update of the RSU placement priority. By calculating the priority of RSU by considering various road elements including traffic volume in the placement priority calculation of RSU, it is possible to select intersections where packets are likely to be spread as high priority intersections. Road elements are weighted based on the magnitude of influence on radio wave spread. In the update operation of the RSU placement priority, it is an operation to lower the RSU placement priority of the surrounding intersection based on the position of the existing RSU. By this operation, the redundant placement of the RSU can be suppressed, and as a result overlap of the communication range can be reduced. The p_i which express the placement priority of RSU at intersection i is expressed by the following equation:

$$p_i = w_1 \frac{1}{t_{max}} t_i + w_2 \frac{1}{s_{max}} s_i + w_3 \frac{1}{I_{max}} I_i \tag{1}$$

where t_i is a value of traffic volume at intersection i. s_i is a number of connected straight road segments at intersection i. I_i is a number of connections of the road segment at the intersection i where the connected road segment has four intersections at the other end. w_1, w_2 and w_3 are coefficients for weighting, and we set to be all $1/3$. Also, p_i is calculated between 0 and 1. The method of determining (1) is shown below.

First, in calculating the RSU placement priority, we define intersections that should be prioritized. Since information to be distributed by the RSU needs to be received by many vehicles, it is necessary to set intersections where information spreads in a wide range. Therefore, road elements that affect the spread of information to a wide range are adopted as elements for calculating the RSU placement priority. In order to spread information extensively, the information transmitted by the RSU at the intersection have to be extended over long distances and many roads. The number of road segments connected to intersections increases, information spreading tends to be effective. In addition, a straight road works favorably by spreading information because radio wave spreading is difficult to block in straight roads. Furthermore, when spreading information over a wide range with multiple hops, traffic volume becomes important because it is necessary to gather a lot of vehicles for relaying. In addition, it is conceivable that the angle of the road segments greatly influences the transmitted information to diffuse far without being blocked by buildings.

In this paper, we analyzed the correlation between road elements and the number of received cars. The road elements to be analyzed are summarized in Table. I. These road elements are classified into fields such as the number of road segments connected to the intersection, the length of the road segment, the angle formed by the road segments connected to the intersection, the angle of the connected road segment itself, the position of the intersection. For example, n_Seg denotes the number of connected road segments, d_A denotes a connection angle between road segments, and ABS 90 which is the sum of differences of each connection angle of road segments and 90°. The road map to be used this time is the map of Manhattan,

TABLE I. ROAD ELEMENTS.

classification	element
Traffic Volume	$traffic$
Number of road segment	n_Seg
	n_Inter4
	p_Inter4
Length of road segment	ave_Len_Seg
	$total\_Len\_Seg$
	d_Seg
Angle of Connection	$ABS90$
	$ABS90+$
	$ABS90+\_no\_overlap$
	$ABS180$
	$ABS180\_pair$
	$ABS180\_pair\_even$
	d_A
Angle of road segment	$n\_u-deg10$
	n_u-deg5
	n_Straight
	$p\_u-deg10$
	p_u-deg5
	p_straight
Position	$center$

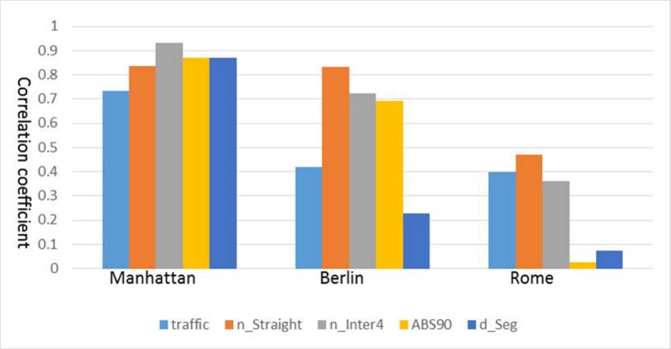

Figure 1. Correlation Coefficient between Number of Packet Received and Traffic Volume.

Berlin, Rome, $1500m$ square areas. Using these areas, we analyze road elements that affect information diffusion.

Figure. 1 represents a part of the correlation coefficient between 21 road elements and transitions of reception numbers for each intersection in each road map. In this paper, the minimum correlation coefficient to judge is 0.3. From Figure. 1, since road elements traffic, $n\_Straight$, n_Inter4 are correlated with the number of received on all road maps, these road elements are used for calculating the priority. Traffic is the traffic volume, $n\_Straight$ is the number of connected straight road segments, and n_Inter4 is the number of road segments connected with the connected road segment at the other end of the four intersections. Also, if different road elements in the same classification are duplicated for RSU priority calculation, similar road elements may duplicate and affect the RSU placement priority. Therefore, even if the correlation coefficient exceeds 0.3, only road elements with the highest correlation coefficient in the same classification shall be used for RSU placement priority calculation. Also, from the Figure. 1, even if the road elements are the same, it can be seen that the magnitude of the correlation coefficient differs depending on the road map. In addition, it can be seen that the magnitude relation with different correlation coefficients also differs depending on the road map. From these facts, it is assumed that the magnitude of the weight and the magnitude of relation between the three road elements are all equal because they change according to the road map.

The purpose of each operation is to spread the RSU widely. RSUs should be placed at intersections that are advantageous for information spreading that can distribute information to many vehicles, but if one RSU is deployed, the surrounding intersections can be covered by the RSU. In other words, if RSUs are simply placed at the intersections which are advantageous for information spreading, the RSUs are concentrated in part, the RSUs are concentrated in part and the vehicles receive duplicate and identical information from the multiple RSUs. This is called redundant RSU placement, which causes redundant information transmission. In order to perform RSU placement that uniformly transmits information to the vehicle, it is necessary to suppress the redundant RSU placement while taking advantage of the RSU placement priority. As a concrete method, it is an operation to prevent concentrating placement of the RSUs to be deployed thereafter by lowering the RSU placement priority of the intersection within the communication range of the existing RSU. Updated RSU placement priority p_{i_new} is done using (2):

$$p_{i\_new} = p_i \times \frac{dis_{RSU}}{dis_{transmit}} \tag{2}$$

where dis_{RSU} is a distance between the intersection i and the RSU deployed immediately before. $dis_{transmit}$ is the distance at which the attenuation of the priority begins to start. Since $dis_{transmit}$ plays a role of a threshold, this priority attenuation Equation is applied when the distance between the intersection i and the immediately preceding RSU is smaller than $dis_{transmit}$. In other words, it applies when this Equation $dis_{transmit}$ is above dis_{RSU}. As the value of the distance $dis_{transmit}$ at which attenuation of the priority is started this time, a value of 700 experimentally obtained is used.

A value of $dis_{istransmit}$ actually deployed the RSU in the simulation and experimentally observed and adopted a value that maximizes the number of reception. In this paper, the value of the simulation is made to conform to the reference[15] in the case where there is no specific mention. The transmission power of the radio waves of the RSU and the vehicle was set to 20 dBm, and the maximum hop number was set to 3. In the set simulation environment, the information reaches about 350 m from sender with 1 hop at 20 dBm radio field intensity. Since the maximum number of hops this time is set to 3 hops, the radio waves transmitted from the RSU can reach up to 1050 m. Therefore, we changed the hop number between 1 and 3 this time, that means $dis_{transmit}$ was 350, 700, 1050 respectively.

IV. SIMULATION EVALUATION

We evaluated the performance of our proposal by simulation. To verify the effectiveness of the proposed method, we compared our proposal with the existing methods that with existing method of RSU placement methods.

A. Simulation Set up

Here, we explain the simulation environment. In the simulation, we used two methods of RSU placement to compare with proposed method.

- Traffic 1 [8]
  An RSU placement method to calculate the placement priority of RSU at intersection based on traffic volume. There is no operation to prevent the redundant arrangement of the RSU, and simply arrange the RSU in the intersection where the traffic volume is large.
- Traffic 2 [3]
  An RSU placement method to calculate the placement priority of RSU at intersection based on traffic volume. Perform operations to prevent redundant placement of RSUs. As a specific operation, set the placement priority of RSU to a fixed distance around the already deployed RSU to 0. In this example, the distance to set the allocation priority of RSU to 0 m is set to 350 m which is the transmission range of 1 hop.

Distance operation to prevent redundant arrangement of RSUs adopted in proposed method and Traffic 2 does not necessarily work in the expected direction. This is because there is a risk that RSU placement at an intersection at which information spreading to many vehicles originally could be hindered by these distance operations.

Next, we explain about simulation scenario that we used. Place N RSUs in the simulation area. The placement of the RSU is different for each comparison target. Record simulation results when N RSUs are deployed respectively. RSUs deployed N in the area transmit packets at the same time. In the area, 500 vehicles are running at a speed of 15 to 30 km/h. 500 vehicles process received packets based on scenarios 1 and 2. In scenario 1, 500 vehicles do not relay packets received from the RSU. It is possible to receive packets only for vehicles travelling in front of RSUs. The simulation time is 600 seconds, and the RSUs in the area simultaneously transmit information 600 times in total, once a second, from simulation start to simulation end. N varies between 1 and 10. In scenario 2, 500 vehicles relay the packets received from the RSU. Even without travelling in front of the RSU, the vehicle can receive packets from the RSU within the transmission range and surrounding vehicles' relay. All vehicles participate in relaying and relay up to 3 hops. The simulation time is 130 seconds, and the RSUs in the area simultaneously transmit the information once at the time of the simulation start of 120 seconds. N varies between 1 and 20.

Finally, we explain about the simulation map that we used. The simulation area uses 1500 $m \times$ 1500 m of San Francisco. It is shown in Figures. 2. In addition, circles marks indicate RSU placement by proposed method, triangle marks indicate RSU placement by Traffic 1, and crossing marks indicate RSU placement by Traffic 2. Simulator uses Scenargie [16] and map data is acquired from OSM [17]. The packet size is 128 KB, and the radio wave propagation model uses ITU-R_P.1411 [18] which reflects the influence such as radio wave shielding by buildings. Detailed parameters are shown in the Table. II.

B. Simulation Results

Here, the results of the simulation are presented. In scenario 1, there is no packet relay by the vehicles, and it is a scenario that receives information only for vehicles passing in front of the RSU. Therefore, in scenario 1, in order to improve the reception rate, it is important to deploy RSUs at intersections where traffic volume is simply high, regardless of the radio wave spreading range.

The result is shown in Figure. 3. In San Francisco, the proposed method is the highest reception rate despite the weight of the traffic volume in the RSU calculation Equation being lower than Traffic 1 and Traffic 2. Specifically, on average, our proposal was 7.3 points higher than Traffic 2 and 27 points higher than Traffic 1. This is because San Francisco is a grid road network structure and every intersection has a similar road element. Therefore, in San Francisco, the static

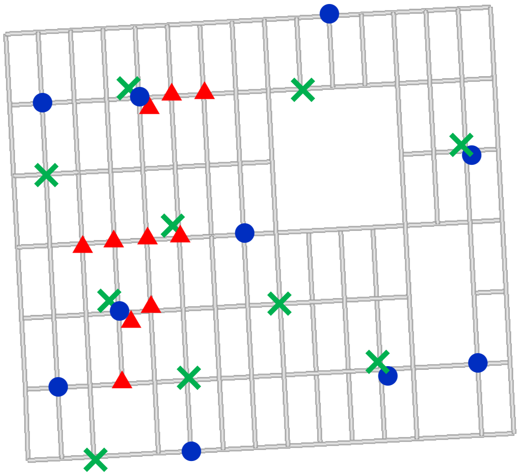

Figure 2. Simulation Area and RSU Placement in San Francisco.

TABLE II. PARAMETERS FOR EVALUATION.

Common Parameters	
Simulator	Scenargie2.0[16]
Number of vehicles	500
Velocity of vehicles	15∼30 km/h[19]
Propagation Model	ITU-R_P.1411[18]
Frequency	5.9 GHz
Bandwidth	10 MHz
Communication standard	IEEE 802.11p
Mobility Model	Random Way Point
Parameters of Scenario 1	
Simulation Time	600 s
Number of N	1 $\sim$ 10
Number of Packet sent	600
Max Hop Count	1
Transmission Power	20 dBm
Parameters of Scenario 2	
Simulation Time	130
Number of N	1 $\sim$ 20
Number of Packet sent	1
Max Hop Count	3
Transmission Power	20 dBm

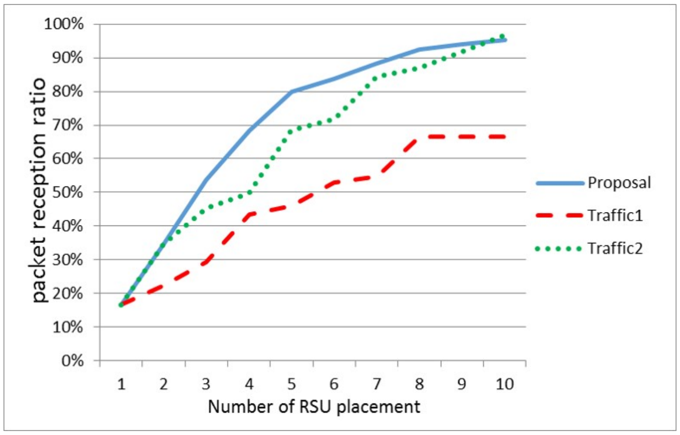

Figure 3. Reception Ratio in Scenario 1.

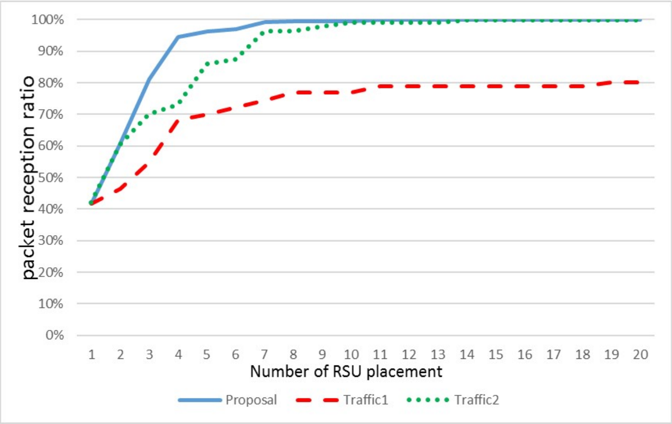

Figure 4. Reception Ratio in Scenario 2.

road elements of the road network such as n_Inter4 and $n\_Straight$ are nearly equal at every intersection, and as a result the RSU placement priority calculated in our proposal is depending on traffic volume which is a remaining element of the Equation of calculation of RSU placement. Therefore, the weights of the road elements used for the RSU placement priority calculation in the three comparison targets in San Francisco are approximately equal, and the difference in the reception ratio in this graph generated is the performance of the RSU placement priority update operation for preventing redundant RSU placement. In other words, in San Francisco the weight of the considered road element is equal for all comparison targets, so here, the performance of the updating operation of the RSU placement priority can be evaluated.

Traffic 1 that has no updating operation of the RSU placement priority has the lowest reception ratio among the comparison targets. The reception rate of Traffic 1 was about 55% even when the RSU was 10 pieces. This is thought to be due to the concentrated RSU placement because intersections whose traffic volume is high concentrate in one place. Traffic 2 suppresses redundant RSU placement by the operation of uniformly setting the priority of intersection within the communication range of RSU to 0. However, the opportunity to receive information depends on the distance from the RSU. If it ignores the distance and uniformly set the priority of the intersection within the communication range to 0 for the reason because it is within the communication range of RSU, RSU placement priority of an intersection with high possibility of working for good will is removed from candidates. Therefore, Traffic 2 has an average reception rate of 7.3 points lower than that of our proposal which linearly controls the RSU placement priority according to the distance.

In scenario 2, information relaying by the vehicle is performed. Therefore, it is important to consider the change of the radio wave spread range by the road network structure in order to increase the reception ratio. Since proposed method considers road elements related to the road network structure such as n_Inter4 and $n\_Straight$ in addition to the traffic volume to calculate the RSU placement priority, the reception rate becomes higher than Traffic 1 and Traffic 2 which consider only the traffic volume.

The result is shown in Figure. 4. As mentioned in Scenario 1, San Francisco has a regular road network structure, so there is no big difference in the road elements of each intersection. For this reason, the three comparison targets determine the RSU placement priority based on the traffic volume and RSU placement priority updating operation. The RSU placement priority updating operation works when RSUs is placed 2 or more. Therefore, when the number of RSUs is one, the three comparison targets have the same reception rate. When the number of RSUs placed is two or more, the reception ratio varies depending on the performance of the update operation of the RSU placement priority. Traffic 1 without updating the RSU placement priority is the lowest throughout the simulation graph in San Francisco. Traffic 1 converges with a difference of 20 points compared with Traffic2 and proposed method. This is thought to be due to redundant RSU placement occurring by concentrating the RSU at intersections whose traffic volume are high. Traffic 2 is an RSU placement priority updating operation of uniformly setting the priority within the communication range to 0, so the RSU placement priority updating operation does not perform corresponding to the distance between RSUs. As a result, the RSU placement priority updating operation of Traffic 1 is lower than that of proposed method, and the reception rate of traffic 1 is lower than that of the proposed method. When the number of deployed RSUs is 4, our proposal already has a reception rate of 95%, which shows that the highest reception rate is obtained throughout the graph about proposed method.

V. CONCLUSION

In this paper, we proposed an RSU placement method considering road elements for information distribution. This method consists of calculating operation of RSU placement priority considering road elements that affected radio wave spreading and updating RSU placement priority in response to the distance between the intersection and RSU deployed. In order to determine an operation of calculation RSU placement priority considering the road elements that influence the radio wave spreading, we analyzed the correlation with the number of 21 road elements received for the three cities of different road network structure. As the result, the number of straight road segments, the number of neighbor intersections which have 4 connected road segments and traffic volume were related to communication performance. In the simulation evaluation, we compared our proposal with existing method of RSU placement methods. In the simulation results, our proposal was the highest of the comparison targets of equivalent to the highest about the reception ratio in both scenarios with and without relay. From this result, our proposal is effective as an RSU placement method.

In the future work, we will research the value of w in (1). We use 1/3 in the equation, but we have to use accurate value to evaluate. We think w is variable in using map. So, we will research the weight of road elements in each maps.

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