Shadowing-Fading-based Intersection Geographic Opportunistic Routing Protocol for Urban VANETs

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Abstract:

In vehicle ad hoc networks (VANETs) in urban environments, the presence of many obstacles causes shadowing and interference with radio wave propagation. Despite this, most of the existing opportunistic routing protocols do not consider shadowing in their simulations. In this study, we propose a new opportunistic routing protocol that minimizes the effect of shadowing by actively selecting street intersection nodes as relay nodes. Additionally, we propose a new opportunistic recovery strategy when the local optimum situation occurs. Simulation results show that the proposed scheme improves the packet delivery ratio and overhead.

Keywords: VANET, opportunistic routing, geographic routing, local optimum problem, shadowing

Classification: XYZ (choose one from the list in Sect. **??**)

References

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1 Introduction

In recent years, Opportunistic routing (OR) [1] has been attracting attention. OR does not select one relay node as in traditional geographic routing [2], but selects multiple relay nodes and broadcasts the data packet. In addition, OR by giving priority to relay nodes, makes the highest priority node among the relay nodes that received the packet rebroadcast. This has improved communication performance. LSGO [3] has been proposed as a typical OR for VANETs. In LSGO, the ETX value and distance from the destination are used to determine the priority, improving communication performance. However, many existing ORs do not consider the effects of shadowing in their performance evaluation. These studies do not clarify the effect of shadowing on routing performance. In addition, in Geographic opportunistic routing such as LSGO, the transmitting node selects relay candidate nodes from the neighbor nodes closer to the destination than itself, which causes the local optimum problem [2]. Therefore, a recovery strategy is required when the local optimum situation occurs. Many existing recovery strategies do not estimate link quality and select only one relay node, which increases the packet loss rate. Also, many recovery strategies for urban scenarios, such as JBR [4], are designed to assume that the building completely blocks radio waves. This assumption is not realistic. To solve these problems, in this study, we propose a new OR and recovery strategy that considers shadowing and evaluates using the Obstacle shadowing model [5], which is the shadowing model of network simulator ns3.

2 The proposed scheme

In this study, we propose a new OR named SIGO that considers street intersections. In SIGO, the priority of relay nodes is determined based on three metrics: distance to destination, link quality, and a street intersection relay index (IRI), which gives priority to nodes in the intersection. To deliver the packets to the destination node, the transmitting node(relay node i or the source node) selects several relay candidate nodes among the neighboring nodes based on the information in the hello packets. It broadcasts the data packets containing the priority information of each relay candidate node. The hello packet contains the ID and location information of the generating node. The data packet contains source node id, destination node id, destination location information, the relay candidate node ID with priority i (i = 1,2, 3, ... highest to lowest priority), and data payload. Because SIGO does not use control packets, the priority information assigned to each relay candidate node is included in the data packet.

2.1 Link quality estimation

In SIGO, each node estimates the link quality(ETX) using the information in a hello packet. To calculate the ETX of a link, each node should record t_0, which is the time when the first hello packet is received and the number of packets it receives from the neighbor during the last w seconds. Then, according to the interval between t_0 and the current time t and window

w, the expected probability of successful transmission $r(t)$ is calculated by Equation (1)

$$r(t) = \begin{cases} count(t, t_0), & 0 < t - t_0 < 1, \\ \frac{count(t,t_0)}{(t-t_0)/\tau}, & 1 \leq t - t_0 \leq w \\ \frac{count(t-w,t)}{w/\tau}, & t - t_0 \geq w \end{cases} \quad (1)$$

The denominator is the number of hello packets that should have been received during the window, and τ represents the broadcast interval of the hello packets. $count(t, t_0)$ is the number of hello packets received during t-t_0.

In SIGO, the asymmetry of the link is not considered, and only the expected probability of one-way transmission is used to calculate the link ETX. Assuming that the expected probability of a one-way transmission is $r(t)$, then the link ETX is calculated using Equation (2).

$$ETX = \frac{1}{r(t)^2} \quad (2)$$

2.2 Intersection Relay Index (IRI_i)

In SIGO, we add a metric(IRI_i) that preferentially selects the intersection node as a relay node to minimize the effect of shadowing by the building. To calculate IRI_i, the transmitting node selects one of the road segments closest to the destination node among the road segments where relay candidate nodes exist. The center coordinate of each road segment was used to calculate the distance between the destination node and the road segment. An example is shown in Figure **1** (a). Next, the transmitting node calculates the packet reachability probability R_p such that a packet reaches at least one relay candidate node located in the closest road segment, using Equation 3.

$$R_p = 1 - \prod_{r=1}^{N} (1 - r_p(t)) \quad (3)$$

where $r_p(t)$ is the expected transmission probability of the relay candidate node p ($1 \leq p \leq N$) in the road segment closest to the destination node. N represents the number of candidate nodes in the road segment closest to the destination node. Using the R_p, the street intersection relay index IRI_i of neighbor intersection node i is calculated using Equation 4.

$$IRI_i = \alpha \frac{\theta_i}{R_p}, \theta_i \geq 45 \quad (4)$$

where θ_i is the angle between the lines connecting the transmitting node to the destination node and connecting the transmitting node and the intersection node i (Figure **1**(a)). The higher θ_i and the lower R_p, the higher the IRI_i. As IRI_i increases, the transmitting node selects the intersection node as a relay node with a higher probability. The proposed scheme prioritizes the intersection node as the relay node when R_p is small. The node in the selected road segment can receive the packet highly probability by the intersection node's relaying. In addition, IRI_i is applied only when θ_i of intersection node i is 45 degrees or more. Therefore, in Equation 5 described later, IRI_i is not added when θ_i is less than 45 degrees. The maximum value of θ_i is 90, and 45 is exactly half the value.

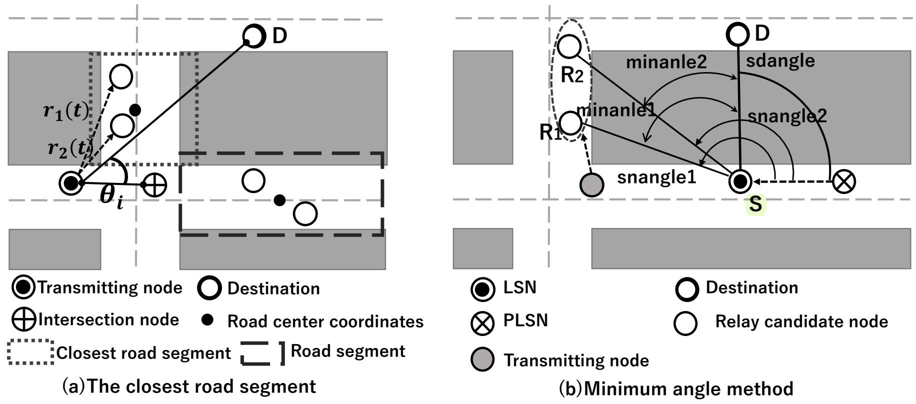

Fig. 1. closest road segment and minimum angle method

2.3 Priority scheduling algorithm

In SIGO, a timer-based priority scheduling algorithm is used. In this algorithm, the node with the highest priority rebroadcasts the data packet first. When other relay candidate nodes overhear packets from nodes with a higher priority, they discard their pending packets. Each relay candidate node rebroadcasts the packet only when it has not received any packet from the node with a higher priority than itself until its timer expires. In SIGO, the priority of node i is calculated by the following equations (5) and (6).

$$Priority = \frac{D_{sd} - D_{id}}{ETX_i^2} + IRI, D_{id} < D_{sd} \tag{5}$$

$$Priority = \frac{D_{sd} - D_{id}}{ETX_i^2}, D_{id} < D_{sd} \tag{6}$$

D_{sd} is the distance from the transmitting node to the destination node, and D_{id} is the distance from the relay candidate node i to the destination node. If the condition $Did < D_{sd}$ is not satisfied, the node is excluded from the relay candidate nodes without calculating the priority. Equation (5) is applied when node i is a street intersection node, and equation (6) is applied when node i is located outside the intersection. The larger the value calculated by equation (5) or (6), the higher the priority is assigned to node i.

2.4 Opportunistic recovery strategy(ORS)

Our proposed OR occasionally falls into the local optimum situations, i.e., when the current node cannot find a neighbor node closer to the destination than itself. A recovery strategy is necessary in order to solve this local optimum problem. Unlike the traditional unicast type recovery strategy, we propose a broadcast type recovery strategy, that is, opportunistic recovery strategy (ORS) that broadcasts packets toward the relay candidate nodes set. Similar to the operations of OR, in ORS, a relay candidate node with a higher priority rebroadcasts the receiving packet. It cancels its rebroadcast when it receives a rebroadcast packet from a relay candidate node with a higher priority than itself. In the proposed ORS, the priority is determined using the link quality and the minimum angle method proposed in JBR[]. The node that reaches the local optimum at the beginning is called the LSN, and the node one hop before the LSN is called the PLSN(the node that sent the packet toward the LSN). When the local optimum situation occurs, the reaching node (LSN) adds its position information to the packet and rebroadcasts it. If the packet arrives at a node closer to the destination than the LSN, it reverts to the normal relay strategy. Since the ORS uses the minimum angle method described later, the position information of the LSN and PLSN is continuously described in the packet until the recovery strategy is completed.

Conditions for Relay candidate nodes in ORS. In ORS, only neighbor nodes that satisfy Condition 7 are relay candidate nodes.

$$(nldis > cldis)\, AND\, (nldis > mndis\_i) \tag{7}$$

where *cldis* is the distance between the previous and transmitting node, *nldis* is the distance between the previous node and the node under consideration(a relay candidate node), and *mndis_i* is the distance between the transmitting node and the relay candidate node i.

minimum angle method. Initially, as we can see in Fig??(b), each transmitting node or LSN calculate *sdangle*. The angle between the lines connecting the LSN to the destination node and connecting the LSN and PLSN. The next step, each transmitting node or LSN calcu-late *snagle_i*. The angle between the lines connecting the LSN to the relay candidate node i and connecting the LSN and PLSN. The last step is the calculation of the absolute difference of the *sdangle* and *snagle_i*, which is *minangle* (Equation 8).

$$minangle\_i = \mid sdangle - snangle\_i \mid \tag{8}$$

ORS priority scheduling algorithm. ORS uses a timer-based scheduling algorithm similar to OR. The priority of relay candidate node i is calculated by the following equations 9 and 10.

$$Priority = \frac{360 - minangle}{ETX_i^2} + mndis \tag{9}$$

$$Priority = \frac{360 - minangle}{ETX_i^2} \tag{10}$$

Equation 9 is applied when relay candidate node i exists in the same road segment as the transmitting node or relay candidate node is intersection node. Otherwise, equation 10 is applied.

3 Evaluation

To evaluate the usefulness of the proposed OR, we compared it with the LSGO protocol for two evaluation items: packet delivery ratio (PDR) and overhead. In addition, to evaluation the usefulness of the proposed ORS, JBR and ORS were incorporated into SIGO and compared. Figure **2**(a) shows the simulation scenario, Table **I** shows the simulation parameter. Simulator uses ns3, The simulation topology scenario was created using SUMO. In addition, We used the obstacle shadowing model as the propagation model to consider the effects of shadowing. There are two parameters in the obstacle shadowing model. The first parameter is the attenuation per wall (dB) and the second is the attenuation per meter(dB). We evaluated the performance by varying the number of the attenuation per meter parameter this time. Figure **2**(b) show the PDR. The PDR is the ratio of the total number of packets received by the destination node to the total number of packets sent by the source node. As shown the figure, the communication performance of SIGO is improved compared to LSGO as the shadowing parameter increases for both PDR and overhead. This is because SIGO does not increase the number of packets compared to LSGO, but forms a route that is less susceptible to shadowing, which increases the number of packets that reach the destination node. Next, when comparing the recovery strategies, the figure shows the proposed ORS has improved communication performance compared to JBR. As shown in the figure, the ORS succeeded in recovering 4 % on average. JBR has hardly succeeded in recovery. This is because JBR's recovery strategy determines one relay node (Unicast), does not consider link quality, and the algorithm is designed assuming that radio waves are completely blocked in the building.

Table I. Simulation parameters

Simulation area	1000m × 1000m
Number of vehicles	400
Radio propagation model	obstacle shadowing model [5]
Window size w	10 s
Number of relay candidate nodes	5
shadowing parameter	10db ∼ 30db

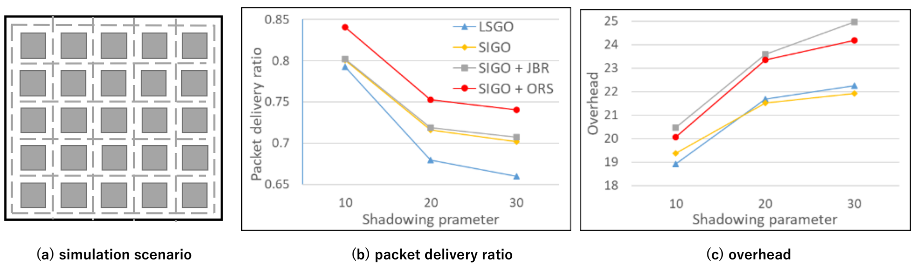

Fig. 2. simulation scenario and PDR and overhead

4 Conclusion

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