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 don't 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 is reached. 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, by giving priority to relay nodes, the highest priority node among the relay nodes that received the packet will be 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 is used as a metric to determine the priority, which improves communication performance. However, many existing OR do not consider the effects of shadowing in their performance evaluation, and may not be OR that consider the effects of shadowing. In addition, in Geographic opportunistic routing such as LSGO, the transmitting node selects relay candidate nodes from the neighbor nodes ~~that are~~ closer to the destination than itself, which causes the local optimum problem [2]. Therefore, a recovery strategy is required when the local optimum is reached. Many existing recovery strategies do not estimate link quality and relay only one relay node, which increases the packet loss rate. Also, many recovery strategies designed for urban scernario , such as JBR [4], are designed on the assumption that radio waves are completely blocked by the building. 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 opportunistic routing protocol 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 is used to give 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 and broadcasts the data packets containing the priority information of each relay candidate node.

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)

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

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).

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

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 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.

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

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.

$$IRI_i = \alpha \frac{90 \left(\frac{\theta_I}{90}\right)^{\frac{1}{\gamma}}}{R_p} \tag{4}$$

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. We also add a gamma correction to prevent the intersection node from being given too much priority when θ_I is small. where γ is the gamma correction value.

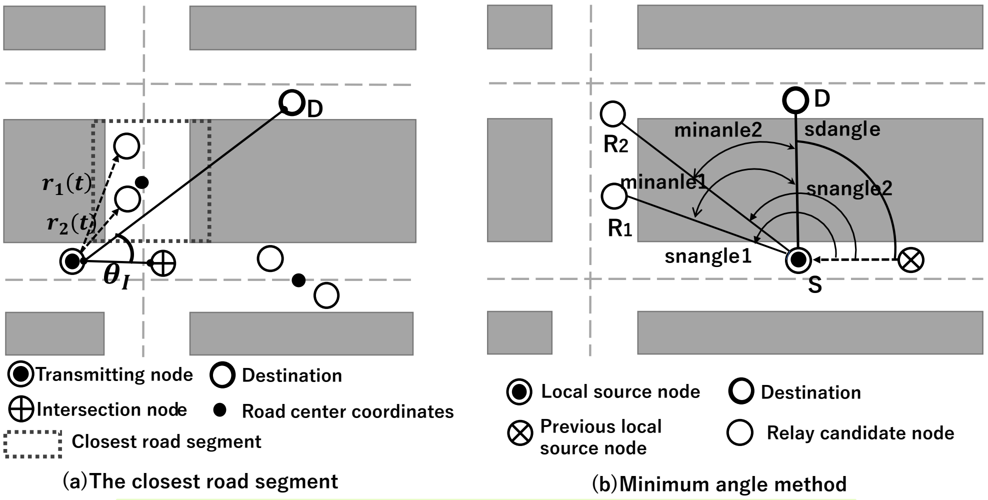


Fig. 1. closest road segment and minimum angle method

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).

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

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

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)

As above, it is possible to reach the local optimum even with the algorithm that prioritizes intersection nodes. In this case, it is necessary to use a recovery strategy different from the above relay strategy(OR). In this study, unlike the traditional unicast type recovery strategy, we propose an opportunistic recovery strategy (ORS) that broadcasts packets toward the relay candidate nodes set. Similar to the flow of OR, ORS rebroadcasts from a relay candidate node with a higher priority and cancels its own rebroadcast when it receives a rebroadcast 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 as a metric. Like the traditional RS, the ORS starts the ORS when the node that reaches the local optimum (Local source node) describes its position information in the packet. If the packet then arrives at a node closer to the destination than the Local source node, it reverts to the normal relay strategy (OR).

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

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

where cldis is the distance between the previous and transmitting node, nldis is the distance between the previous node and the node under consideration (relay candidate nodes), and mndis is the distance between the transmitting node and the relay candidate node.

minimum angle method. Initially, as we can see in Fig∼, we calculate *sdangle*. The angle between the lines connecting the local source node to the destination node and connecting the local source node and previous local source node. The next step, we calculate *snagle*. The angle between the lines connecting the local source node to the relay candidate node i and connecting the local source node and previous local source node. The last step is the calculation of the absolute difference of the *sdangle* and *snagle*, which is *minangle* (Equation 8).

$$(nldis > cldis)\,AND\,(nldis > mndis) \tag{8}$$

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.

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

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

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

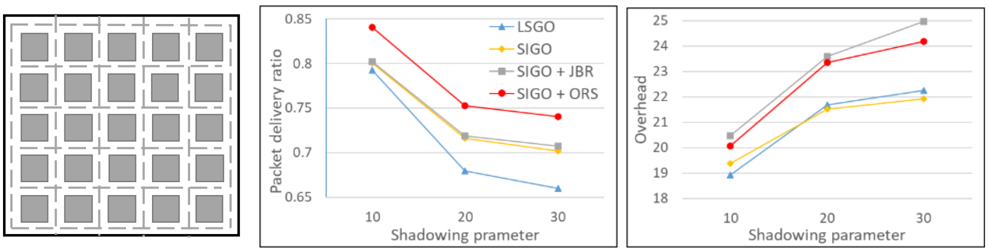
3 Evaluation

提案したSIGOの有効性を示すため,packet delivery ratio(PDR),overheadの2つの項目でLSGOと比較した．また, ORSの有効性を示すために, SIGOに提案したORSとJBRをrecovery strategyとして組み込み比較した．simulation scenarioを図**2**, simulation parameterを表**I**に示す．simulationはnetwork simulatorであるNS3と交通流シミュレータであるSUMOを用いた． さらにシャドウイングの影響を考慮するためpropagation modelとしてobstacle shadowing modelを使用した．obstacle shadowing modelには2つのparameterが存在し, 今回の評価では∼のparameterを変化させてsimulationを行った．PDRの結果を**2**(b)(c)に示す．パケット到達率は, 送信ノードが送信した合計

パケット数に対する, 宛先ノードが受信したパケット数の合計の比率, オーバーヘッドは全ノードが送信した合計パケット数に対する宛先ノードが受信したパケット数の合計の比率として定義する. 図が示す通り, SIGO と LSGO を比較すると PDR, overhead ともに shadowing parameter が増加するほど通信性能が向上していることがわかる. これは SIGO が LSGO と比較してパケット数を増大させずに, shadowing の影響を受けにくいルートを形成することで, 宛先ノードに届いたパケット数が増えたからだと推測される. 続いて, recovery strategy を比較すると提案した ORS が JBR に比べて通信性能が向上していることがわかる. 図が示す通り, ORS は平均して 4%の recovery に成功しているのに対して, JBR はほとんど recovery に成功していない. これは JBR の recovery strategy が relay node を一つに決定すること (Unicast), link quality を考慮していないこと, 建物で完全に電波が遮断されることを想定してアルゴリズムが設計されていることが原因だと推測される.

Table I. Simulation parameter

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



(a) simulation scenario (b) packet delivery ratio (c) overhead

Fig. 2. simulation scenario and PDR and overhead

4 Conclusion

conclusion