A Receiver-Based Forwarding Scheme to Minimize Multipath Formation in VANET

Khaleel Husain and Azlan Awang

Abstract Receiver-based data forwarding schemes are well suited for vehicular environment due to their ability of making routing decision on the fly. However, existing receiver-based schemes still face the challenges of unwanted multiple paths formation especially when contending nodes are out of transmission range of each other. In this paper, we propose an approach of the receiver-based forwarding scheme where receiving nodes decide whether to participate in contention for forwarding right based on signal-to-interference-plus-noise ratio (SINR) and forwarding zone. Upon qualifying to contend for forwarding right, the contending nodes set their waiting time based on geographical progress toward destination. We present the proposed scheme and then highlight some possible issues that require further investigation. The proposed scheme tends to minimize unnecessary formation of multiple paths toward the destination while also favors the selection of a forwarding node closer to destination.

Keywords VANET · Receiver-based forwarding · Forwarding zone · Waiting time

1 Introduction

Vehicular Ad hoc Network (VANET) is one of the emerging networking technologies aims to provide reliable communication in the road traffic environment. VANET enables Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication to allow road traffic applications relating to safety, commercial use and public services. Conventional networking technology like Mobile Ad hoc Network (MANET)

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does not perform well due to the challenges of road traffic environment such as high mobility, constrained movement pattern and frequently changing traffic density [1, 2]. In order to meet stringent Quality of Service (QoS) requirements of VANET applications, the routing must be able to deal with mobility and scalability issues while also providing satisfactory network performance in terms of end-to-end delay, packet delivery ratio and overhead. According to [3], data forwarding schemes can be classified into three categories: route-based forwarding, sender-based forwarding and receiver-based forwarding. Conventional route-based forwarding involves route establishment prior to data transmission. However, it does not work well due to high mobility and this leads to frequent changes of network topology. Routing approaches that decide the next best forwarding node toward the destination during data transmission are more suitable in vehicular environment. In sender-based forwarding approach, a sender selects the next forwarder based on the information present in a routing table. However, this approach requires periodic sharing of information among vehicles through beacon messages at the expense of high overhead. Another routing approach is the receiver-based forwarding scheme where receiving nodes are responsible for deciding whether to participate or not in the receiver-based contention. This approach offers low overhead as it does not require any periodic exchange of information for data forwarding [3, 4]. A general receiver-based data forwarding scheme has two aspects: forwarding zone and waiting time. The forwarding zone is a deciding criteria for receiving nodes to contend for a forwarding right. Once the receiving nodes satisfy the forwarding zone criteria, they contend for forwarding right by setting a waiting time determined by a certain criteria. The contending node with timer expires first become the next-hop forwarder and then broadcasts the data packet accordingly. Other contenders when overhearing the transmission cancel their timers and discard the packet.

One of the issues in the current receiver-based schemes is the unwanted multiple paths formation when two receiving nodes are out of communication range of each other. Multiple paths toward destination result in redundant packets flowing through the network which in turn lead to congestion and increasing the chances of packet collision. Hence, there is a need to define a forwarding zone to ensure the formation of only a single path toward destination. In this paper, we propose an approach of the receiver-based forwarding scheme where the eligibility criteria is based on signal-to-interference-plus-noise ratio (SINR) and forwarding zone. The forwarding zone is calculated based on forwarding angle that is set to a constant value of 60° to ensure the prevention of multipath formation. Receiving nodes that satisfy the eligibility criteria contend for forwarding right by setting a waiting time based on geographic progress toward destination. The proposed scheme tends to minimize unwanted multiple paths formation, while also reducing the number of hops by selecting the nearest forwarding node toward destination.

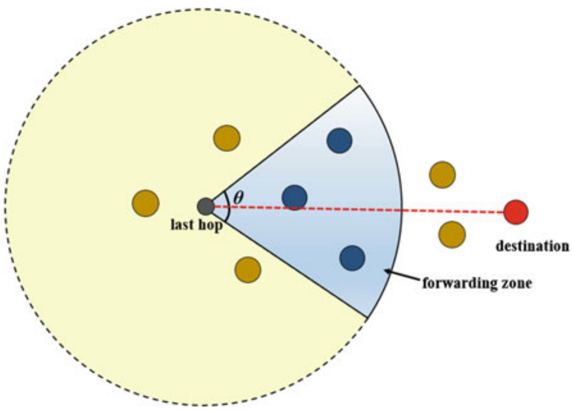
The rest of this paper is organized as follows. In Sect. 2, the existing receiver-based forwarding schemes in VANET are explained. Section 3 discusses the issue of unwanted multiple paths formation in the current receiver-based forwarding schemes. Section 4 briefly explains the existing solution to the problem mentioned in Sect. 3. Section 5 presents a detailed explanation of the proposed scheme involving the proposed model, important technical terms and its work flow. Section 6 offers a brief discussion involving the theoretical comparison of the existing and proposed scheme, while also highlighting some issues that need further investigation. Finally Sect. 7 concludes the paper with a summary of key points discussed and future perspective.

2 Related Work

There exist a few receiver-based data forwarding schemes in VANET. A reactive receiver-based solution named VIRTUS [5] was proposed to allow video streaming over VANET environment. VIRTUS enables high data rate communication among vehicles without the need for any roadside infrastructure. Here, receiving nodes participate in communication based on their current location and future location estimation. The forwarding zone of VIRTUS is in the direction of the destination as shown in Fig. 1.

The forwarding zone is set based on forwarding angle θ where maximum value is 90°. The receiving nodes compute their waiting time based on geographic progress and link stability. VIRTUS provides a satisfactory video streaming performance in vehicular networks while also reducing the number of transmission. RPBL [6] is another beaconless receiver-based routing protocol where receiving nodes set their waiting time based on their closeness toward the road intersections that lie along the path to destination. However, RPBL does not make use of forwarding zone which leads to the possibility of unwanted multiple paths formation toward the destination. LIATHON proposed in [4] is a multipath receiver-based data forwarding technique developed to enable video streaming over VANET where two paths having minimum route coupling effect are discovered by making use of location information. The receiving nodes set their waiting time based on the degree of closeness, geographic progress and link stability. LIATHON fulfills the performance requirements

Fig. 1 Definition of the forwarding zone based on forwarding angle



of video streaming by distributing the load over the two paths. LIAITHON was further upgraded to LIAITHON+ [7] where the number of multiple paths were increased to three. Also, the impact of added redundancy was analyzed in order to further enhance the routing protocol. Finally, SLBF proposed in [3] aims to improve reliability during data transmission. Here, the forwarding zone is set based on the direction and angle size of the forwarder. The forwarding angle is determined based on the time interval from previous forwarder to current forwarder and average time for single hop. Furthermore, the receiving nodes within the forwarding zone compute their waiting time based on link quality, traffic load and greedy strategy.

3 Problem Analysis

One of the major issues in receiver-based forwarding schemes as mentioned in [6] is the unwanted multipath formation when receiving nodes are out of transmission range of each other. Figure 2, adopted from our previous work [8] depicts an instance highlighting the unwanted multipath formation issue in the current receiver-based schemes.

In Fig. 2a, the source and destination are represented by the nodes S and D, respectively whereas nodes A, X, B, Y and Z represent the intermediate nodes along the path from source to destination. As shown in Fig. 2a, S broadcasts the packets in its communication range. Since nodes A and X are within the communication range of S, they receive the packet. Let us assume both nodes A and X are within the forwarding zone and hence they contend for forwarding right by setting their waiting time. Let us assume the waiting time of node A expires first resulting in broadcasting of packet. However, as shown in Fig. 2b, nodes A and X are not in the communication range of each other and hence node X will not hear node A's transmission and will broadcast the packet once its timer expires. This will result in the formation of two paths S-A-B-D and S-X-Y-Z-D as shown in Fig. 2c. Unwanted formation of multiple paths leads to redundant packets flowing throughout the network causing network congestion. Hence, there is a need to set a forwarding zone that can prevent unwanted multipath formation in receiver-based schemes. This can be achieved if

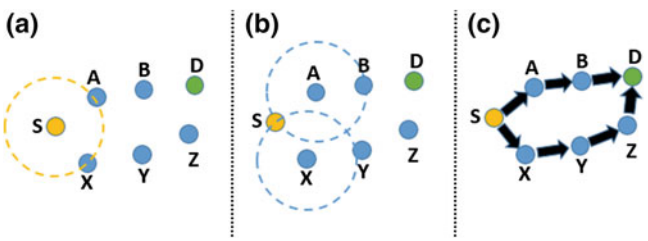


Fig. 2 Illustration of unwanted multipath formation issue in the current receiver-based schemes

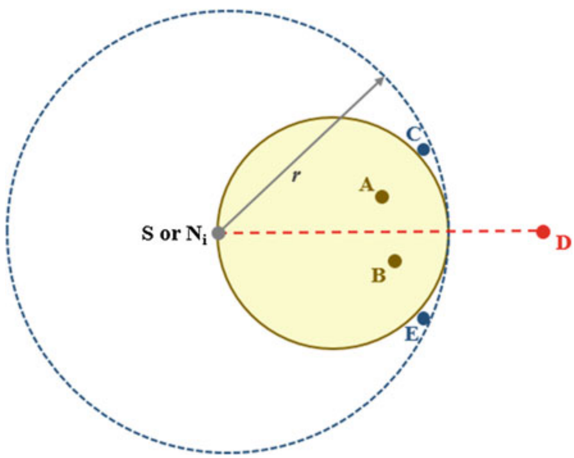
the forwarding zone is set in such away that the maximum distance between any two nodes located in the forwarding zone is less than the communication range.

4 Existing Solution

Authors in [9] proposed a receiver-based scheme based on Ad hoc On-Demand Distance Vector (AODV) routing protocol [10]. Here, prior to route establishment, receiving nodes decide whether to forward or not the route request packets based on their presence in the forwarding zone. The nodes then set their waiting time according to a competing parameter which in turn depends on the hop length and link remaining lifetime. The forwarding zone of the existing solution is shown in Fig. 3.

The yellow color area represents the forwarding zone of the source S or intermediate forwarding node N_i. r is the communication range of the node. The forwarding zone is defined as the circular field with radius $r/2$ where the line connecting node S or N_i and destination D as centerline. The zone effectively eliminates multiple paths formation since the maximum distance between any two nodes in the forwarding zone is less than the communication range of the node. As shown in Fig. 3, nodes A and B are located within the forwarding zone and hence are entitled to forward the route request packets toward D. Nodes C and E since are not located within the zone discard the route request packets. However, it can be seen from this figure that node C is closer to D when compared to A and B. Hence, it can be concluded that even though the forwarding zone of the existing solution is able to solve the unwanted multiple paths formation issue to some extent, but it is inefficient in terms of selecting the closest forwarding node toward destination.

Fig. 3 Forwarding zone of the existing solution (adopted from [9])



5 Proposed Mechanism

We propose a mechanism where receiving nodes determine whether to participate in contention to be a forwarder based on its SINR and its presence in the forwarding zone. If SINR of a receiving node is greater than a threshold and the forwarding angle is less than the angle mentioned in the packet, only then it contends for its forwarding right by setting a timer based on the geographical progress toward destination. In any other case, receiving nodes discard the packet.

5.1 VANET Model

The vehicles are assumed to be moving in a single direction with different speed. Communication model used here is the WAVE architecture [11] comprising of IEEE 802.11p standard to support both physical and MAC layer while IEEE 1609 standard is used at the higher layers. V2V communication is used from source until the last hop node while V2I communication is used between the last hop node and destination. We assume that a single source vehicle transmits data to a static destination, a Road Side Unit (RSU). The data traffic type considered here is Constant Bit Rate (CBR). Each vehicle is assumed to be equipped with a Global Positioning System (GPS) and is aware of the position of itself, the last hop node and destination. The position of the last hop node is known from the received packet. For the angle computation of the vehicles, the line connecting the vehicle and destination is considered as x-axis.

5.2 Forwarding Zone

The forwarding zone of the proposed scheme is shown in Fig. 4. The forwarding zone is a fan-shaped area in the direction of destination with a constant forwarding angle θ of 60°. Here, for the angle computation, the current forwarder A is considered as the origin of a rectangular coordinate system and the line connecting the current forwarder A and destination D is considered as x-axis. As before, r is the communication range of the node. The reason for assigning θ value as 60° is to make sure that all nodes in the forwarding zone are within communication range of each other that holds true due to the nature of equilateral triangle. As shown in Fig. 4, nodes X and Y are the farthest from each other and are separated by a distance r.

The forwarding angle θ is computed in [3] as follows

$$\theta = 2 \times \left| arccos \frac{x_r - x_{lh}}{\sqrt{(x_r - x_{lh})^2 + (y_r - y_{lh})^2}} \right| \tag{1}$$

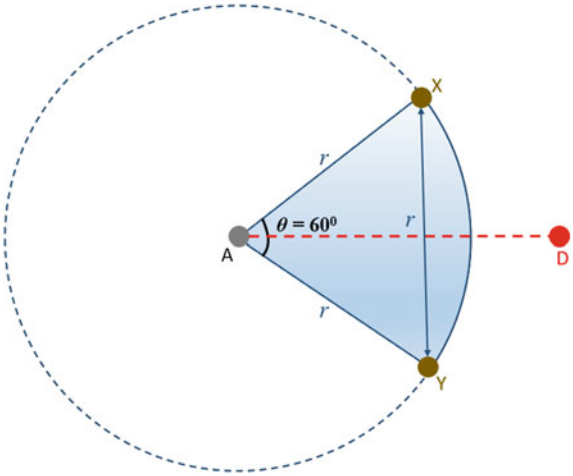


Fig. 4 Forwarding zone of the proposed scheme where θ is set to a fixed value of 60°

where (x_r, y_r) and (x_{lh}, y_{lh}) are the position coordinates of the receiving node and previous forwarding node, respectively.

5.3 Geographical Progress

The geographical progress γ_{geo} of the receiving node toward the destination is computed in [5] as follows

$$\gamma_{geo} = 1 - \frac{d(n_{lh}, n_d) - d(n_r, n_d)}{r} \tag{2}$$

where $d(n_{lh}, n_d)$ is the distance from previous forwarding node to destination, and $d(n_r, n_d)$ is the distance from receiving node to destination.

5.4 Waiting Time

Once the receiving nodes are eligible to participate in contention to be a forwarder, they contend for forwarding right by setting the waiting time which is derived from [5] as follows

$$\lambda = \gamma_{geo} \times \Gamma \tag{3}$$

where Γ is the maximum waiting time scale is the maximum waiting time scale to set the upper limit for a contending node can wait before broadcasting a packet.

5.5 Algorithm

The work flow of the proposed receiver-based scheme will be explained in two parts. Firstly, we explain the steps involved during data transmission as a source node before moving on to explain the steps involved during data transmission as an intermediate or destination node.

Source perspective Figure 5 highlights the steps involved for the source node during data transmission. Initially, source inserts its position coordinates and address in the packet. Source then sets the forwarding angle as 60° in the packet. The packet is then broadcasted and the timer is set. If the source receives the same packet or an Acknowledgment (ACK) before timeout then it discards the packet and cancels the timer. Otherwise, the source increases the forwarding angle to 180° and rebroadcasts the packet before setting the timer. In case of more than one transmission timeout, the forwarding angle is unchanged (180°) and the packet is again rebroadcasted and

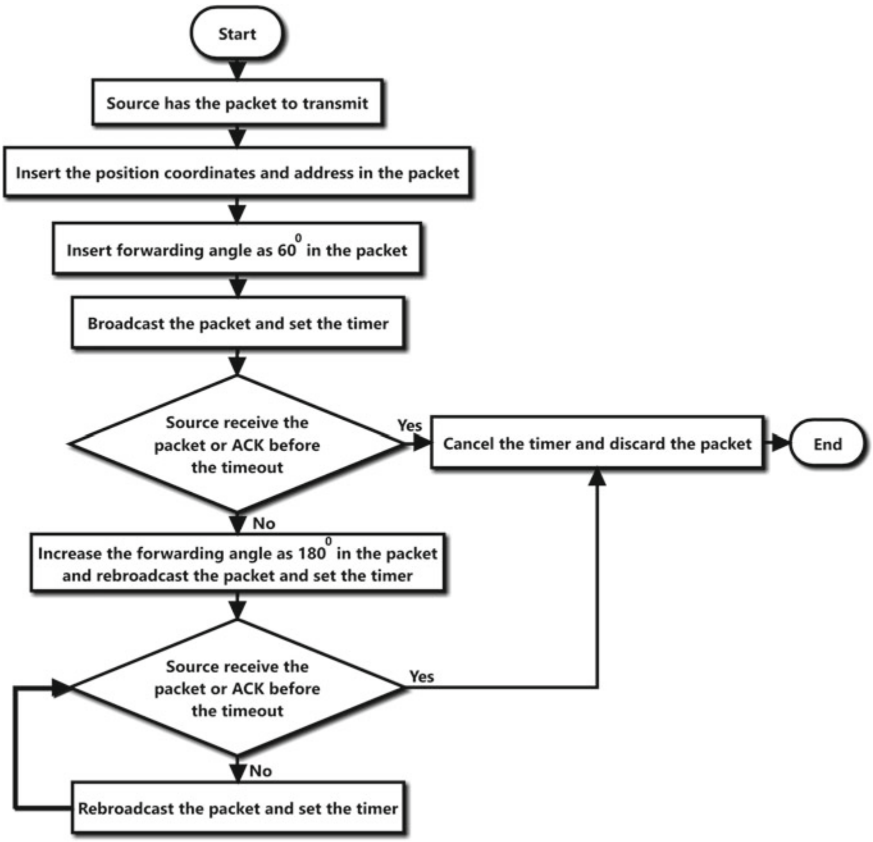


Fig. 5 Flowchart showing the steps involved for a source node during data transmission

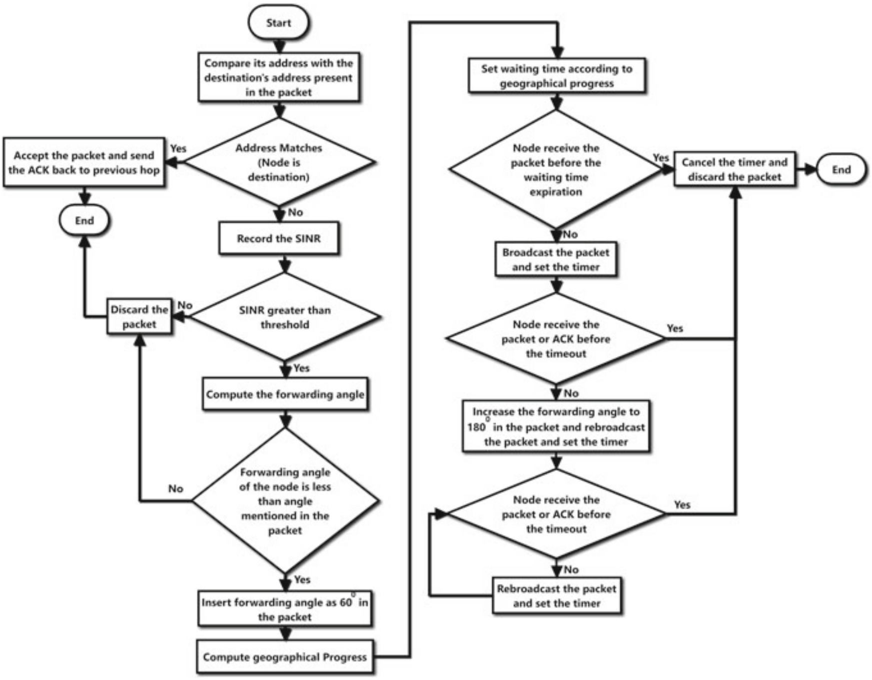


Fig. 6 Flowchart showing the steps involved for an intermediate node or destination during data transmission

the timer is set. The first transmission timeout indicate the unavailability of nodes within the forwarding zone. The intention for setting the next forwarding angle to 180° is to only select the nodes which are ahead and nearer to the destination.

Intermediate node, Destination perspective Figure 6 highlights the steps involved for an intermediate node or destination during data transmission. Once the node receives the packet it checks whether it is the destination by comparing its address with destination address present in the packet. If the receiving node is the destination then it accepts the packet and sends an ACK to previous forwarding node. If it is not the destination, it records the SINR and checks whether the recorded SINR is greater than a threshold. This threshold is the minimum signal strength required for a successful packet transmission. If the SINR is less than the threshold, that means the link does not meet the minimum signal strength requirements and the node is not eligible to participate in contention and the packet will be discarded. If it is not the case, the receiving node computes the forwarding angle and checks whether the computed forwarding angle is less than the angle retrieved from the packet. A forwarding angle less than the angle obtained from the packet implies that the receiving node is not located within the forwarding zone and similarly packet will be discarded. Otherwise, the receiving node inserts the forwarding angle as 60° in the packet, computes the geographic progress and then sets the waiting time accordingly before broadcasting the packet. In the case when the same packet or ACK is received before the timer expires, this implies that another forwarder has already been selected. The receiving node then cancels the timer and discards the packet accordingly. Otherwise, it increases the forwarding angle to 180° in the packet before broadcasting the packet and then sets the timer. In cases when more than one transmission timeout, the receiving node keeps forwarding angle unchanged before rebroadcasting the packet and sets the timer accordingly.

6 Discussion and Future Work

In addition to forwarding zone, the use of SINR parameter in the eligibility criteria for forwarding right assists in eliminating nodes that do not meet the minimum signal strength requirement and hence makes the zone more effective. Moreover, the waiting time criteria based on geographic progress favors the proposed mechanism to select a forwarding node closer to destination. Table 1 highlights the forwarding zones of the existing protocols and our proposed receiver-based forwarding scheme.

RPBL [6] does not make use of forwarding zone concept and thus have the highest chances of multiple paths formation. LIATHON [4] and LIATHON+ [7] are multi-path receiver-based schemes aim at controlling the number of multiple paths toward the destination to two and three, respectively. The forwarding zone of VIRTUS [5] is defined by the forwarding angle which is set to 90° that allows for the possibility of multiple paths formation. The forwarding angle of SLBF [3] varies between 60° to 180° based on the time interval from previous forwarder to current forwarder and average time for single hop. Receiver-based scheme in [9] although defines a forwarding zone and free from multiple paths formation but the zone is inefficient

Table 1 A summary of forwarding zones of the existing protocols and proposed scheme

Protocol	Forwarding Zone
VIRTUS [5]	Forwarding angle of 90° in the direction of destination
RPBL [6]	–
LIAITHON [4] and LIAITHON+ [7]	Forwarding angle of 90°
SLBF [3]	Varying forwarding angle (from 60° to 180°) in the direction of destination along the road
Existing solution [9]	Circular field with the radium of R/2 with the line connecting source node/intermediate node and destination as centerline
Proposed scheme	Fixed forwarding angle of 60° in the direction of destination and in case of retransmission, forwarding angle of 180° in the direction of destination

in terms of routing as it neglects more suitable forwarders nearer to destination. The receiver-based scheme proposed in our current work, in case of no transmission timeouts, ensures single path to destination. It may also improve the routing performance by favoring more forwarders nearer to destination to be selected. However, in case of transmission timeouts, there is still chance of multiple paths formation as the forwarding angle is increased to 180°. Also, excessive retransmissions may result in an increased end-to end delay. Hence, in the future work, we would like to analyze the performance of the proposed receiver-based scheme under different conditions through simulations in a realistic VANET environment. We will also include more detailed analysis that incorporate important parameters such as communication and traffic models. In addition, performance comparison with existing receiver-based schemes will be carried out to show the improvements offered by the proposed scheme. Finally, other metrics that could further improve the waiting time criteria will be investigated.

7 Conclusion

In this paper, we propose an approach of the receiver-based forwarding scheme aims to avoid unwanted multiple paths formation. In the proposed scheme, the eligibility criteria for the receiver-based contention is based on SINR and forwarding zone. Only those receiving nodes with SINR greater than a threshold and with forwarding angle less than the angle mentioned in the packet are entitled to contend for forwarding rights by setting their waiting time based on geographic progress. All other receiving nodes discard the packet. In case of a transmission timeout, the forwarding angle is increased to 180°. In case of no transmission timeouts, the proposed scheme ensures single path to the destination thereby reducing network congestion. Also, the scheme selects a forwarding node closest to destination resulting in less number of hops and thus making routing more efficient. However, chances of multiple paths formation increase in case of transmission timeouts. In addition, excessive retransmission may significantly increase the end-to-end delay. Hence, the performance of the proposed scheme will be analyzed under different conditions through simulations which have been in progress and planned as part of the future work.

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