A Receiver-Based Routing Algorithm Using Competing Parameter for VANET in Urban Scenarios

Lujie Wang, Yiming Wang*, and Cheng Wu

School of Urban Rail Transportation, Soochow University,
Suzhou 215131, P.R. China
`ymwang@suda.edu.cn`

Abstract. This paper proposes an AODV-based routing algorithm for Vehicular Ad Hoc Network (VANET).This routing algorithm uses a routing metric, which includes the length of each hop as well as the link remaining lifetime. In addition, it can effectively reduce routing overhead by the use of receiver-based method. Furthermore, we design a new urban road scenario and a new mobility model for vehicles to describe the movement of cars. The simulation results we provide confirm the superiority of the proposed algorithm. These simulation comparisons of different ratios between both link-length and link stability also show improvements.

Keywords: VANET, routing algorithm, competing parameter, remaining lifetime.

1 Introduction

With the rapid development of urban modernization, automobile ownership surges at an average rate of 20%. Unfortunately, this leads to congestions, accidents and other traffic problems that impair urban development. Intelligent transportation system (ITS) can analyze traffic problems accurately and help travelers deal with them with the help of its powerful information processing and transmitting technology [1]. Vehicular Ad Hoc Network (VANET), as a special kind of ad-hoc network particularly designed for transport sector, plays an important part in ITS. Compared with the universal ad-hoc network, the biggest challenge posed to the VANET is the frequently changing topology resulting from the fast movement of vehicles. In spite of this, the special application still brings many advantages, such as a regular pattern of mobility model since cars always move along roads and a convenient availability of geographic information by a great deal of accessory equipment on the car [2].

Ad hoc on-demand distance vector routing (AODV) possesses the strengths of low network overhead, adaptability to dynamic routes and quick route establishment. However, fast-moving vehicles spoil its performance. A series of studies [1][3] indicate that the AODV protocol simulated in the traffic scenarios displays reducing

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[*] Corresponding author.

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routing coverage, and a serious decline of information throughput. The study [4] works out a new protocol called double-forwarding AODV considering only remaining route lifetime when selecting best path. Also,it use directional and dynamically probabilistic forwarding to restrict the propagation range of Routing Request(RREQ). In addition, to relieve the negative effects caused by flooding approach for broadcasting, some papers give several solutions as follows. 1. Choose a forwarding area [5]. Only the nodes located farther than a certain distance away from the previous node are entitled to forward route request packet (RREQ).The result shows the number of RREQs can reduce 50%. 2. Set forwarding intervals [1]. Give higher priority to the node that has a longer distance from previous one. 3. Send RREQs to the specific area using directional antennas [6].

Due to the real-time control of traffic lights, traffic on the city roads is often divided into different sections. Vehicles between two intersections move as a whole group. It can be said that vehicle groups segment by segment form the whole traffic on the road. We focus our research on one segment of them and propose a routing algorithm receiver-based AODV. For the sake of reducing network overhead, we use receiver-based forwarding method, combining the strategies of forwarding area and forwarding intervals [7]. On the other hand, both link-length and link stability are taken into account to improve link stability. The rest of paper is organized as follows. Section 2 describes how to implement receiver-based approach , and the algorithm to select optimal route with competing parameter ω. Section 3 addresses the scenario considered in the simulations. Section 4 presents experimental results achieved with the proposed receiver-based routing algorithm. Finally, some concluding remarks are given in Section 5.

2 Receiver-Based AODV Routing Protocol

2.1 Receiver-Based Route Establishments

Although the approach of flooding is simple,it introduces a large number of duplicate messages that may cause network congestion. On the other side, many routing protocols applied for VANET use sender-based method, such as: GPSR (greedy perimeter stateless routing), GSR (geographic source routing). The sender of RREQ determines one or several nodes as the next forwarders. This method needs geographic information from neighboring nodes beforehand. On the contrary, in the receiver-based method, it is the receiver who determines whether to forward RREQs according to its own status. All the nodes that decide to forward RREQs compete for this right [8]. This method can keep routing overhead under control and there is no need to exchange geographic information ahead of route discovery.

Forwarding Area. Forwarding area refers to the specific region designated by the previous node within its communication range. Nodes in this region have the right to forward RREQs, while the nodes outside have to drop them directly. In Figure 1, the shaded area indicates the forwarding area of the source S or the previous node N_i. As nodes A and B are in the forward area, they are entitled to forward RREQs directed to the destination N_d. Node C, however, has to discard RREQ as it is outside. In the receiver-based protocol, the forwarding area is designed as a circle field with the radium of R/2 (R is the radium of communication range), taking the P-D line (from the previous node to the destination node) as the centerline. In that case, the maximum distance between any two nodes in the forwarding area is no more than R. So other nodes can monitor the message and respond accordingly.

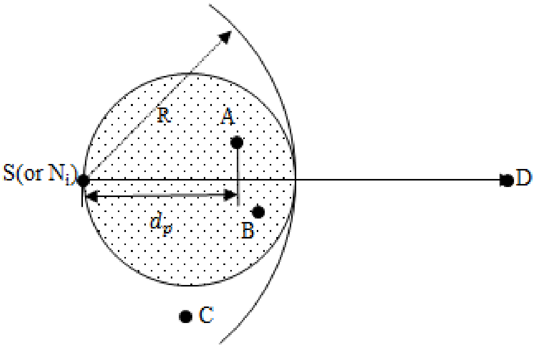


Fig. 1. Forwarding Area

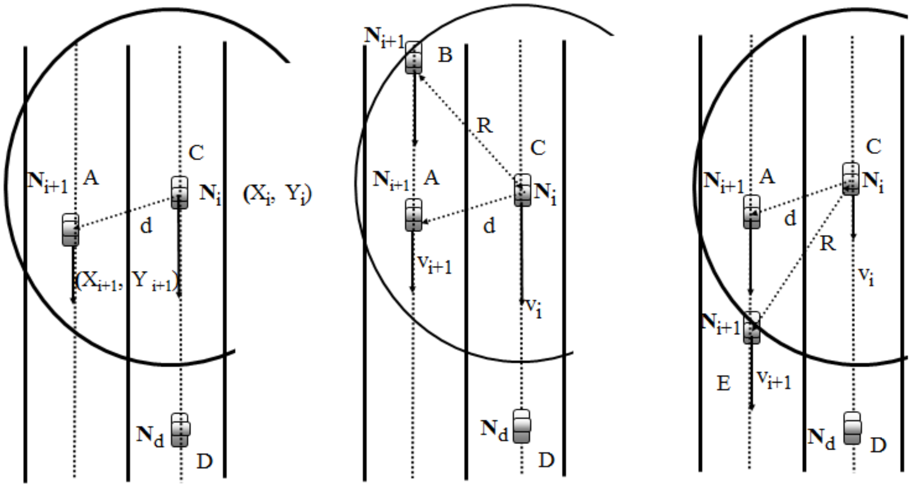
Dynamic Forwarding Delay. Any node in the forwarding area that hopes to forward RREQs has to compete with others. Each one of these competitors calculates its own forwarding delay t_d according to the equation shown as (1).

$$t_d = \max\_delay \times (1 - \omega) \tag{1}$$

Where ω is the competing parameter calculated on the basis of the routing metric hereinafter mentioned in 2.2. Max_delay is equal to node transmission time, that is, an estimate of the one-hop traversal time for a packet. It includes queuing delays, interrupt processing times and transfer times. If one node has the maximum ω among all the competitors in the forwarding area, the path between this node and the previous one is believed to be the most suitable link and is able to limit the spread of the routing control messages effectively. So this node deserves the minimum forwarding delay and finally forwards the RREQs first. When other nodes in the same forwarding area overhear the packet from this node, they cancel the scheduled timing for forwarding.

2.2 Competing Parameter ω

As mentioned above, the competing parameter ω depends on routing metric which is the key for routing establishment. In our algorithm, the best route is judged not only by its hops but also by its stability. It is a straightforward and intuitive method to assess the stability by measuring the lifetime of this route from its connection to breakage, called link remaining lifetime. The route is thought to be more stable if it has a long link remaining lifetime. We consider the interleaving affection of both link remaining lifetime and the least number of hops in the routing metric.



(a) The Initial Moment (b) $v_{i+1} < v_i$ (c) $v_{i+1} > v_i$

Fig. 2. The Calculation of Link Remaining Lifetime

Calculation of Link Remaining Lifetime. We assume that all vehicular routing nodes can obtains its own geographical information such as location, speed and direction, with the help of global positioning system (GPS). And the movement of any node is regarded to be same in a short period of time. Then the link remaining lifetime of the path between two nodes is calculated as follows. Because the designated forwarding area points to the destination node, thus all nodes that qualified are located in the area between the previous node and the destination one. In figure 2, assume that node N_i located in position C with the coordinates of (X_i,Y_i) is the previous node and node N_{i+1} at the position A is the receiver of RREQs from N_i. Its coordinates are (X_{i+1},Y_{i+1}). Destination node N_d is located in front of them. R denotes the communication range. As the Figure 2(a) shows, at the initial moment t, N_{i+1} is ahead of N_i on the right. During the short period of Δ t, assuming that N_i is static, then the relative movement of N_{i+1} to N_i is divided into two types. Each type is characterized by different speed conditions. In figure 2(b), N_i has a higher speed v_i than N_{i+1}'s speed, v_{i+1}. At the time t + Δ t, N_i moves from the location A to B relative to N_i. In this process, N_{i+1} first moves closer to N_i. Then goes far from it. On the contrary, in Figure 2 (c), the speed v_i is less than v_{i+1}, during the period Δ t, N_{i+1} gradually moves far away from N_i from location A to E. Both location B and E are at the boundary of N_i's communication area. If N_{i+1} moves beyond this boundary, the established link between two nodes breaks. So the distance between A and B (or A and E) is just the remainder distance that N_i can move before link breakage. Furthermore, T_P represents the link remaining lifetime, namely the remainder time that the communication between two nodes can maintain. The calculation is shown as (2) to (7):

$$T_P = \frac{D(A,B)}{|\Delta v|} (\text{or} \frac{D(A,E)}{|\Delta v|}) \tag{2}$$

When $v_{i+1} < v_i$,

$$D(A,B) = \sqrt{R^2 - (X_i - X_{i+1})^2} + (Y_{i+1} - Y_i) \tag{3}$$

$$T_P = \frac{\sqrt{R^2 - (X_i - X_{i+1})^2} + (Y_{i+1} - Y_i)}{v_i - v_{i+1}} \tag{4}$$

When $v_{i+1} > v_i$,

$$D(A,E) = \sqrt{R^2 - (X_i - X_{i+1})^2} - (Y_{i+1} - Y_i) \tag{5}$$

$$T_P = \frac{\sqrt{R^2 - (X_i - X_{i+1})^2} - (Y_{i+1} - Y_i)}{v_{i+1} - v_i} \tag{6}$$

Combine (4) with (2), we can get the link remaining lifetime:

$$T_P = \frac{\sqrt{(v_i - v_{i+1})^2 [R^2 - (X_i - X_{i+1})^2]} + (v_i - v_{i+1})(Y_{i+1} - Y_i)}{(v_i - v_{i+1})^2} \tag{7}$$

The Routing Metric. Our routing metric takes both link stability and hops into account. Except for link remaining lifetime, another parameter is also considered for the sake of the number of hops. That is the projection distance of the link between the node and its previous node to the P-D line. As shown in Figure 1, d_p represents the projection distance of node A and the source S (or intermediate node Ni) to the P-D line, Select a forwarding node that is further away from the source (or intermediate node) as the next-hop node N_{i+1}. Routing metric integrates these two parameters and gets the competing parameter ω, with a weight α to measure the effects of these two parameters to ω, as equation (8) shows.

$$\omega = (1 - \alpha) \frac{T_P}{T_{max}} + \alpha \frac{d_p}{R} (\mathrm{T} <= Tmax) \tag{8}$$

Where T_P is the remaining lifetime and T_{max} is the designed maximum value of remaining lifetime. R is the radius of communication range. If the value of α is set properly, an optimal route, with relatively few hops and greater stability, can be discovered. And the competing parameter ω of this link should be the maximum value.

3 Simulation Scenario and Mobility Model

One of the most common scenarios during our daily commutes looks like this: you are at the intersection. When the traffic light turns green, all waiting vehicles start to move forward, and stop at the next intersection (if the traffic light is red). Between these two intersections, all vehicles move to the same direction but at different speeds on different lanes. This constitutes a temporary mobile ad-hoc network. Each vehicle can be source or forwarder of data. We describe the scenario above on the OPNET simulation platform.

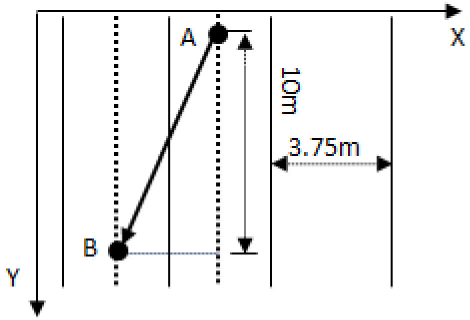


Fig. 3. Changing Lanes

In order to describe the movement of vehicles, this paper presents a new type of mobility model especially for vehicles. The detailed movement is explained as follows: before the simulation, all nodes wait at the first intersection, that is, the zero point of the y-axis. When simulation starts, every node figures out whether or not its own location is along the centerline of any lanes. If not, the nodes quickly and randomly select an alternative lane and move to its centerline. After the initialization, each one picks a goal from "go straight" and "change to another lane" randomly. If "go straight" is selected, the node needs to choose a target location alone the same lane and moves to it at a speed selected from a uniformly distributed interval. If the node chooses to "changing lanes", it then selects a changing direction (left or right), and moves as Figure 3 shows: assuming that this car changes to the right lane from point A to point B. Once this goal is achieved, the node then sets another target with another direction to move again. The movement state changes through cycles until the node reach the second intersection. Specifically, it is 2000 meters on the y-axis.

4 Simulation Analysis

The simulation is carried out on the OPNET simulation platform. All nodes use the vehicular mobility model. Five pairs are communication nodes. The sources start to generate data packets 30 seconds after the start of the simulation, considering all the nodes at that time have left the first intersection and scattered on the road. As soon as the couple communication nodes reach the second intersection, communication between them stops. When all the 5 pairs arrive at the second intersection, the whole simulation ends. Simulation parameters are given in Table 1. T_{max} is set as 80. Because according to the simulation in [9], the probability of the link that lives up to 80s is close to 0. So the remaining lifetime is meaningless if its value is larger than 80s.

Table 1. Simulation Parameters

Parameter	Value
Simulation area	37.5m×2000m
Number of lanes	10
Number of nodes	40,60,80,100,150,200
Traffic type	CBR(Constant Bit Rate)
Packet rate	5 packets/sec
Data Packet Size	512 bytes
Node speed	10km/h~80 km/h
Communication range(R)	250m
T_{max}	80sec
Max_delay	0.04sec
MAC	802.11b

4.1 Comparisons

Three performance indexes, packet delivery rate, the average end-to-end delay, normalized routing overhead, are collected to compare the function of receiver-based AODV with that of double-forwarding AODV and AODV. Here the parameter α is set to be 0.5 to obtain better performance. To improve the simulation accuracy, the results are obtained by averaging all the values simulated with 50 different seeds.

Packet Delivery Ratio. This is obtained by dividing the total number of data packets received to that sent by the source. It reflects the transmission quality of the network. Figure 4 illustrates that the packet delivery ratio of AODV,double-forwarding AODV and receiver-based AODV protocols are gradually increasing as the node group expands. This is because network connectivity is strengthen due to the growth in number of nodes, reducing the possibility of packet loss caused by inexistence of any route from source node to destination. The packet delivery ratio of receiver-based AODV is larger than that of double-forwarding AODV in the case of different number of nodes and furthermore the superiority is more evident when the number of nodes is larger. This can be explained by the added prediction of route lifetime in receiver-based AODV that help avoid frequent link breaks and improve packet delivery ratio.

Average End-to-End Delay. It means the average time that one data packet takes to reach the application layer of destination node, characterizing smoothness level of the network. It includes all possible delays as route discovery latency, queuing time and propagation delay. Figure 5 shows the relationship between the average end-to-end delay and the number of nodes. It is clearly that they are gradually decreasing with the rise in node density. Because each node can have more neighbors and has more choice to find an appropriate route if total number is large. Hence both route establishment time and route rediscovery frequency declines, resulting in lower average end-to-end delay. Double-forwarding AODV protocol simply use route remaining time in the route maintaining process instead of choosing a more stable link in the route discovery process. While receiver-based AODV considers not only the hops of route but also the stability, selecting the node located relatively farther but longer link lifetime. Thus its delay is shorter as compared to that of AODV, which is really helpful in VANET environment where topology change and packet retransmission occur frequently.

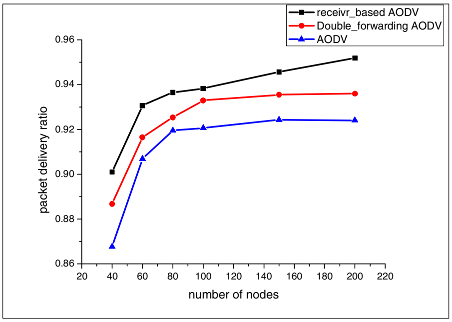


Fig. 4. Packet Delivery Ratio (α=0.5)

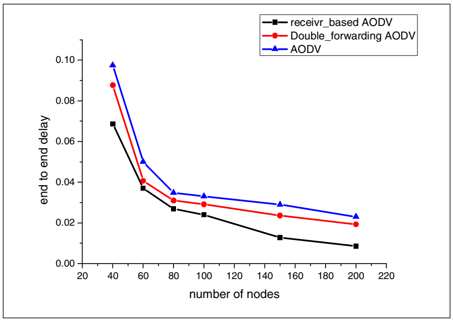


Fig. 5. Average End-to-End Delay (α=0.5)

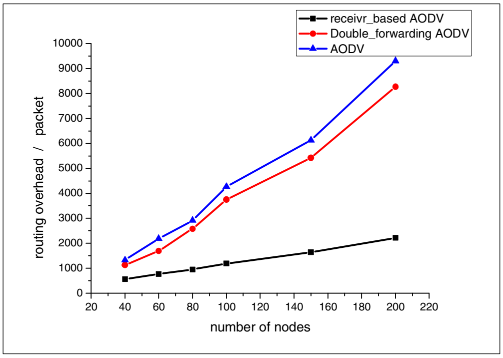


Fig. 6. Normalized Routing Overhead (α=0.5)

Normalized Routing Overhead. It denotes the ratio of the number of routing packets propagated by all nodes and the number of data packets received by the application layer of destination, indicating the congestion degree of the network. A Routing packet forwarded between intermediate nodes once is considered as a new one. It is clearly concluded in Figure 6 that as the number of nodes increases, RREQs can be received by more neighboring nodes and hence be further disseminated, leading to the constant rise in routing overhead. However, the growth of receiver-based AODV protocols routing overhead is significantly slower than the double-forwarding AODV and AODV protocol. This can be attributed to two reasons: on the one hand, the forwarding method based on receivers is able to effectively control the widespread of RREQs during route discovery process. On the other hand, the receiver-based AODV protocol builds a more stable route than double-forwarding AODV, thus needing less routing packets in the route maintenance process. As a whole, receiver-based AODV has greater efficiency as it cost less when transmitting equal number of data packets.

4.2 Effect of Weight α

This optimized routing metric includes two parts, the projection distance of the link between a node and its previous node to the P-D line, as well as the link remaining lifetime. Add these two parameters together in different proportion and then get the competing parameters ω and corresponding forwarding delay d_p. Similarly, every other node within the forwarding area calculates its own competing parameter and forwarding delay. Of all these nodes, the one with the maximum competing parameter enjoys higher priority to forward. The different proportion here is denoted by the weight α. Different α means the different proportion occupied by two factors in the competing parameter. Figure 7 and Figure 8 respectively depict the effect of weight α from 0 to 1 to the network with different number of nodes by two different performance indexes, route discovery times and routing overhead. As the curves show, both of them decrease first then increase with the minimum value existing at around $\alpha=0.5$.This is due to the consideration of both the link remaining lifetime and the projection distance that help find a relatively stable route hence ,leading to less route discoveries and further lower routing overhead.

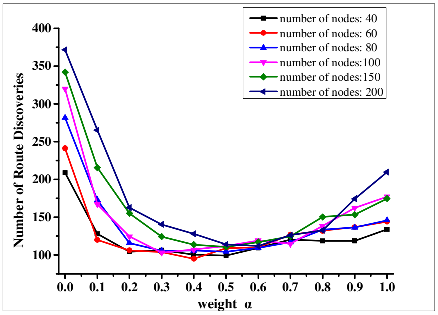


Fig. 7. Number of Route Discoveries

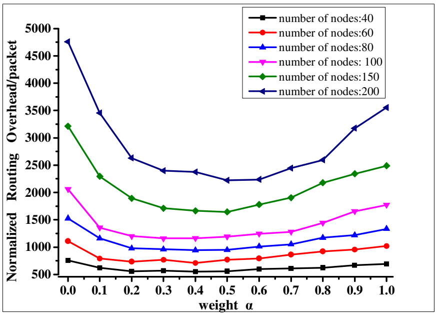


Fig. 8. Normalized Routing Overhead

If two nodes in the forwarding area move with the same speed and direction, then the one located close to the previous node can retain longer connection time with previous one. When α is 0, which means the competing parameter ω depends entirely on the link remaining lifetime, the node with maximum link remaining lifetime forward RREQ first in every hop, finally constituting the route from source to destination with numerous nodes. In that case, any one of them that changes its speed or direction can break the link. So the route established here is more fragile. When $\alpha = 1$, that is to say, only the projection distance to P-D line is considered. The node located in the farther site from the previous one has a greater competing parameter ω and takes precedence to forward packets. Consequently, the route is linked by small number of nodes, with long distance between each two, even close to the bonder of communication area. So the tiny movement of any nodes can lead to link break, increasing the route discovery times and hence routing overhead.

5 Conclusion

This paper can be summarized into two parts: one is the proposal of a receiver-based routing algorithm in which the routing metric considers the link stability as well as the number of hops. The decision-maker changes from sender to receiver when establishing a new route. All these can effectively reduce the generation and dissemination of broadcasting packets and also improve the stability of the route. The other one is the design of a new mobility model and a road simulation scenario on OPNET simulation platform in terms of urban traffic characteristics. The simulation results confirm that receiver-based AODV is more suitable for VANET in urban traffic environment. When the ratio of link remaining lifetime and projection distance in the routing metric is around half to half, receiver-based AODV can achieve best performance.

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References

1. Li, F., Wang, Y.: Routing in Vehicular Ad Hoc Networks: A Survey. IEEE Vehicular Technology Magazine 2(2), 12–22 (2007)
2. Yang, Q., Shen, L.: System Architecture and Communication Protocols in Vehicular Ad Hoc Networks. ZTE Technology Journal (2011)
3. Haerri, J., Filali, F., Bonnet, C.: Performance Comparison of AODV and OLSR in VANETs Urban Environments under Realistic Mobility Patterns. Department of Mobile Communication BP 193, 06904 (2006)
4. Xia, R., Liu, C., Zhao, Z., Shu, Y.: Routing Algorithm for Vehicular Ad Hoc Network Based on Double Forwarding Mechanism. Computer Engineering 39(06), 124–128 (2013)
5. Sun, Y., Chen, Y., Xu, Y.: A GPS Enhanced Routing Protocol for Vehicular Ad-hoc Network. In: 2011 IEEE International Conference on Robotics and Biomimetics (ROBIO), pp. 2096–2101 (2011)
6. Wang, W., Xie, F., Chatterjee, M.: Small-Scale and Large-Scale Routing in Vehicular Ad Hoc Networks. IEEE Transactions on Vehicular Technology 58(9), 5200–5213 (2009)
7. Taysi, Z., Yavuz, A.: Routing Protocols for GeoNet: A Survey. IEEE Transactions on Intelligent Transportation Systems 13(2), 939–954 (2012)
8. Heissenbüttel, M., Braun, T., Bernoulli, T., Wälchli, M.: BLR: Beacon-Less Routing Algorithm for Mobile Ad Hoc Networks. Computer Communications 27(11), 1076–1086 (2004)
9. Wu, Y., Liao, W., Tsao, C., Lin, T.: Impact of Node Mobility on Link Duration in Multihop Mobile Networks. IEEE Transactions on Vehicular Technology 58(5), 2435–2442 (2009)