The Position Relationship for RSU Assisted Vehicular Opportunistic Networks

Yixin He(✉), Yi Jiang, and Song Pan

School of Electronics and Information, Northwestern Polytechnical University, Xi'an, China
914416406@qq.com, jiangyiv88@nwpu.edu.cn

Abstract. Vehicular Ad-hoc networks (VANETs) are promising information-sharing technologies for modern intelligent transportation systems (ITS), in which information can be disseminated and shared among a group of moving vehicles through wireless communication devices. Previous data dissemination schemes for VANETs are unable to meet the requirements of effective and efficient data dissemination in VANETs due to the dynamic nature of the framework such as the intermittent connection between vehicles. A position relationship and RSU assistance (PR) data dissemination algorithm was proposed for opportunistic VANETs. Through making use of road side unit (RSU), position information and transfer probability to improve the performance of PR algorithm. Simulation results show that the data delivery ratio of PR protocol is improved, the number of network copy is controlled, and network overhead is reduced.

Keywords: Vehicular Opportunistic Networks · Position relationship · RSU

1 Introduction

Vehicular Opportunistic Networks (VON) are wireless vehicle communication network, in which information can be disseminated and shared among a group of moving vehicles through wireless communication devices. Vehicular Opportunistic Networks is regarded as one of the most promising ad hoc networks in recent years. But some drawbacks like non-homogeneous distribution of nodes, frequent change of topology and unstable communication links, caused by high speed vehicles in the network, have brought challenges to the routing protocol design.

At present, the research on vehicle opportunistic network is at an initial stage. An opportunistic routing protocol based on expected delay was proposed, which optimizes the data transmission delay (EDOR) between source nodes and target nodes when they are both moving vehicles, but this routing protocol is very complex [1]. A traffic distribution based opportunistic routing (TDOR) in urban VANETs was proposed. TDOR protocol was designed as a two-phase algorithm, namely intersection selection phase and next hop selection phase, which improved the path, but this routing protocol was bad in energy consumption [2]. A data dissemination mechanism based on density-sensing (DDMD) for Vehicular Opportunistic Networks was proposed, this protocol

B. Li et al. (Eds.): IoTaaS 2018, LNICST 271, pp. 376–383, 2019.
https://doi.org/10.1007/978-3-030-14657-3_38

was aware of the network environment of node density [3]. But these three agreements focused on strengthening one aspect and ignored the other aspects.

Vehicular Opportunistic Networks is an important component of future wireless networks, therefore, it is an important method building road side unit (RSU) to assist communication for improving the performance of VON. This paper presents a position relationship and RSU assistance (PR) data dissemination algorithm was proposed for opportunistic VANETs. According to the design of the scheme design of RSU can connect directly to the backbone network and communicate with the vehicle for wireless communication. PR algorithm outperforms EDOR algorithm, TDOR algorithm and DDMD algorithm with less network resource consumption in broad scenarios.

2 The Position Relationship for RSU Assisted Vehicular Opportunistic Networks

2.1 System Overview and Network Modeling

It is assumed that the time for some vehicles to establish communication can be ignored, moreover, the vehicle can get the position information through the GPS.

Definition: Published information (PI) and Feedback information (FI)

1. PI means the message to be transmitted, it contains five parts, namely vector, position, source, TTL and message.
2. FI means the message to be returned, it contains three parts, namely vector, position and number.

2.2 Position Information

In PR algorithm, if vehicles have the network copy, they will send published information at set intervals. The feedback information will determine whether they continue to retain the network copy. The user can set the maximum network copies according to the requirement.

PR algorithm makes the above decision by calculating position information.

(1) The position relationship of send PI vehicle and send FI vehicle

When the send PI vehicle received the FI, it can calculate the angle of two vehicles, according to the vector information. The computation can be written as:

$$\zeta = cos^{-1}\frac{\overrightarrow{A_V} * \overrightarrow{B_V}}{\left|\overrightarrow{A_V}\right|\left|\overrightarrow{B_V}\right|} = cos^{-1}\frac{A_{VX} * B_{VX} + A_{VY} * B_{VY}}{\sqrt{(A_{VX}^2 + A_{VY}^2) + (B_{VX}^2 + B_{VY}^2)}} \quad (1)$$

Where $\overrightarrow{A_V}$ is A vehicle's velocity vector, $\overrightarrow{B_V}$ is B vehicle's velocity vector.

If $|\zeta| < 90$, it is thought that the direction of the two vehicles are same.

If $|\zeta| > 90$, it is thought that the direction of the two vehicles are not same.

(2) The position relationship of the vehicle and RSU

PR algorithm defines two relative states of vehicles and RSU: Driving toward RSU and Driving to the back to RSU. PR algorithm can get the two relationships by calculating the vehicles' velocity vector, angle relation and transfer probability.

As shown in Fig. 1, vehicle A travels at a speed of V_A, and the vehicle B travels at a speed of V_B. Both V_A and V_B are velocity vectors, which represent the traveling speed and direction of vehicle A and B. S represents RSU, AS is the distance vector of vehicle A to RSU, and BS is the distance vector of vehicle B to RSU. α is the angle between AS and V_A, and β is the angle between BS and V_B.

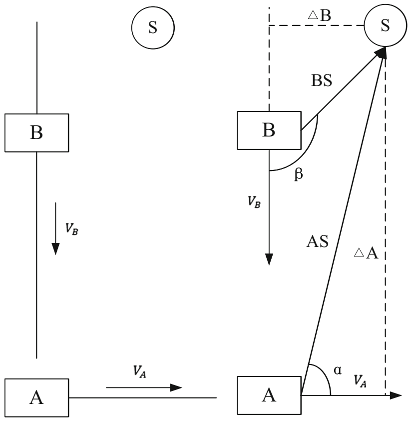

Fig. 1. Diagram of the vehicle and RSU

Obviously, to calculate α and β, we must get information about AS and BS. According to the foregoing assumptions, the AS and BS can be obtained by GPS. The calculation can be written as:

$$\alpha = tan^{-1}(AS_Y/AS_X) - tan^{-1}(A_{VY}/A_{VX}) \tag{2}$$

$$\beta = tan^{-1}(BS_Y/BS_X) - tan^{-1}(B_{VY}/B_{VX}) \tag{3}$$

Where, $\alpha, \beta \in (0, \pi)$.

By calculating α and β, we can get the following four results:

1. If $\alpha < \frac{\pi}{2}$, the vehicle A is considered to be traveling toward the RSU.
2. If $\alpha > \frac{\pi}{2}$, the vehicle A is considered to be far from the RSU.
3. If $\beta < \frac{\pi}{2}$, the vehicle B is considered to be traveling toward the RSU.
4. If $\beta > \frac{\pi}{2}$, then consider vehicle B away from RSU.

2.3 Transfer Probability

An Encounter-based Routing Algorithm for Social Opportunistic Networks proposed that it computes forwarding efficiency of each node based on past encounter information. Meanwhile, it computes the average contact duration based on the past information, considering transmitting messages of varied size differs in time. Thus, a message may directly forwarded to the destination node, or it is forwarded to other nodes if and only if the candidate node may encounter the destination node with a high probability and the average contact duration between them is longer than that of current node [4].

When any node A and B meet in the network, the computation of transfer probability can be written as:

$$P_{A,B} = P_{A,B_{old}} + (1 - P_{A,B_{old}}) * Q_{A,B} \tag{4}$$

$$Q_{A,B} = F_{A,B} * D(A) \tag{5}$$

Where $Q_{A,B} \in [0, 1]$

$Q_{A,B}$ represents the effective forwarding capability of nodes A and B. The effective forwarding capability is proportional to the transmission probability.

D(A) represents the number of nodes that A meets different new nodes at a given time interval accounts for the total number of nodes.

$F_{A,B}$ represents the social attribute of the node, the number of nodes A meeting with a specific node at a certain time interval accounts for the total number of nodes that the current node meets with other nodes.

If the nodes A and B do not meet in a time unit, the transmission probability will be reduced gradually. The computation can be written as:

$$P_{A,B} = P_{A,B_{old}} * \zeta^k \tag{6}$$

Where $\zeta \in [0, 1]$, k means time unit.

Through the analyses above, we can get the following four results.

1. If $\alpha < \frac{\pi}{2}$ and $\beta < \frac{\pi}{2}$, the vehicle A and B are considered to be traveling toward the RSU.
2. If $P_{RSU,B} \geq P_{A,B}$, the vehicle A and B are considered to be traveling toward the RSU.
3. If $\alpha > \frac{\pi}{2}$ and $\beta > \frac{\pi}{2}$, the vehicle A and B are considered to be far from the RSU.
4. If $P_{RSU,B} < P_{A,B}$, the vehicle A and B are considered to be far from the RSU.

2.4 Routing Algorithm

PR algorithm can be explained as follows:

1. Vehicle A carrying the message (PI) periodically broadcasts the trajectory of the target vehicle.
2. One-hop neighboring vehicles and RSU calculate the position relationship and transfer probability.

3. The vehicle calculating the value of α, β and ζ, we can get the following four results.
   - If $|\zeta| < 90$ and vehicle A, B runs away from RSU, pass information to the vehicle B.
   - If $|\zeta| > 90$ and vehicle A, B runs toward RSU, pass information to the RSU.
   - If $|\zeta| < 90$ and vehicle A, B runs toward RSU, it need to calculation transfer probability. If $P_{RSU,B} \geq P_{A,B}$, pass information to the RSU, or pass information to the vehicle B.
   - If $|\zeta| > 90$ and vehicle A, B runs away from RSU, the vehicle A continues to drive.
4. If the message had received, the vehicle B will discard the message.
5. This process is repeated until the target vehicle receives the message or until the message is invalid (Fig. 2).

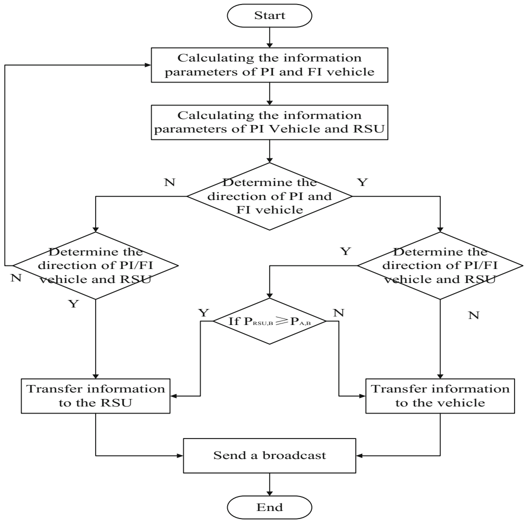

Fig. 2. PR algorithm flowchart

3 Performance Evaluation

In this section, we evaluate the performance of PR algorithm through extensive simulations using the ONE simulator. Since DTN routing is one of the possible solutions for message delivery to moving target without the help of stationary nodes, we have compared the performance of PR algorithm with two alternate DTN routing mechanisms—Epidemic Dissemination (ED) algorithm and Random Choice (RC) algorithm.

3.1 Simulation Parameters

We conducted 101 rounds of simulations with different random seeds for each vehicle number N. The scenario chosen for simulation was the road map of Helsinki, Finland. Each vehicle's movement pattern is determined by Shortest Path Map Based Movement model. In this model, vehicles take the shortest path on the road of the map exactly. For each simulation, a vehicle node was selected randomly as the target vehicle, and the simulation was repeated 10 times with different target vehicles for each random seed. Only a transmission message was considered in the simulation, and the loss of transmission during the communication procedure was not taken into consideration.

The simulations parameters are listed in Table 1.

Table 1. Simulation parameters

Parameter	Value
Size of network area	4500 * 3400 m^2
Simulation time	4500 s
Vehicle/RSU Transmit range	30/100 m
Vehicle/RSU Transmit speed	1/10 Mbps
Vehicle number N	[500:200:1900]
Average node speed	15–80 MPH
Message size	7 kB

3.2 Simulation Results and Analysis

(1) Network Copy

When the size of the simulation region is constant, the number of vehicles determines the average space density of the network.

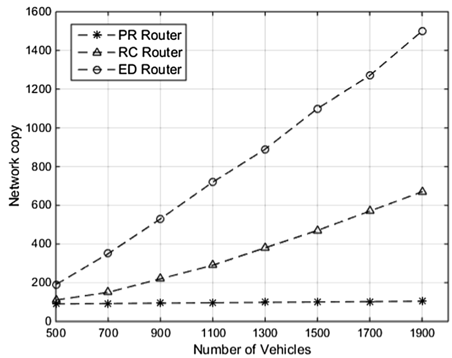

Fig. 3. The network copies comparison for different densities

In Fig. 3, we have plotted the network copies of algorithms with the vehicles number N increases. While the ED algorithm and RC algorithm employs multicast strategy, the overhead of ED algorithm and RC algorithm are obviously higher than the PR algorithm. But the PR algorithm adaptively removes outdated message copies and controls the number of replicas via RSU. From Fig. 3, it is obvious that PR algorithm has the lowest network copy of the three, and the gap between PR algorithm and the others increases as the density increases.

(2) Data Packet Successful Delivery Rate

Data packet successful delivery rate indicates the proportion of the successful transmit of the information to the destination vehicle. Data packet successful delivery rate represent the proportion of the successful transmit of the information to the destination vehicle.

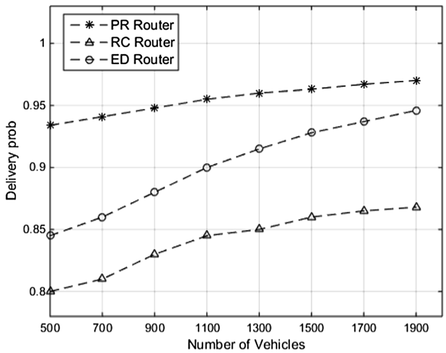

Fig. 4. The rate comparison for different densities

In Fig. 4, because the PR algorithm can choose RSU or vehicles to relay, it has the highest rate of the three. Due to its flooding characteristics, the ED algorithm increases its delivery rate as the number of vehicles increases, but it has been slightly lower than the PR algorithm. The success delivery rate of the RC algorithm has always been in a relatively low state, which is due to the random selection of the RC algorithm when selecting the relay node, so there may be a portion of the forwarding object that may have been forwarded or the useless vehicle nodes are passed on the information.

(3) Network Overhead

Although the PR algorithm can control the number of the network copy, with the increase of simulation time, if the speed of deleting the network copy less quickly than the speed of creating the network copy, network overhead can be well controlled.

Figure 5 demonstrates the transmission overhead (number of message replicas) for different densities. Since both the PR algorithm employ unicast strategy, the overhead of PR algorithm has the same characteristic with the network copy. From Fig. 4, it is obvious that PR algorithm has the lowest overhead of the three, and the gap between PR algorithm and the others increases as the density increases.

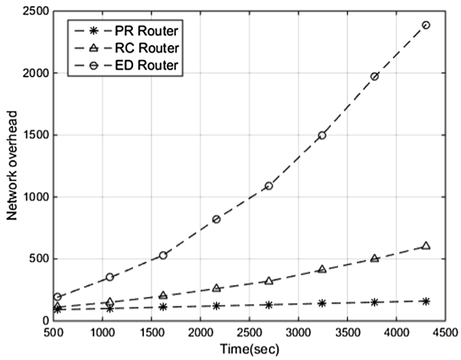

Fig. 5. The network overhead comparison for different densities

4 Conclusion

In this paper, we present and discuss PR algorithm, an opportunistic routing algorithm in vehicular networks. The main idea of PR algorithm is to calculate position relationship and transfer probability to identify a "better" message carrier (Vehicle or RSU). And the transmission procedure of PR algorithm is implemented completely through the message carrying and forwarding across vehicles, with the help of RSU. The evaluation results show that, when compared to the existing algorithms, PR algorithm has a good performance in various vehicle densities in terms of controlling the network copy, increasing the data packet successful delivery rate, and reducing the network overhead. Most notably when the vehicle density is high, PR algorithm had an impressive performance.

Acknowledgments. This work was supported in part by the National Natural Science Foundation of China (61571370, 61601365, and 61801388), in part by the Fundamental Research Funds for the Central Universities (3102017OQD091 and 3102017GX08003), in part by the China Postdoctoral Science Foundation (BX20180262), and in part by the Seed Foundation of Innovation and Creation for Graduate Students in Northwestern Polytechnical University (Grant no. ZZ2018129).

References

1. Liu, L., Pei, J.: Opportunistic routing algorithm for vehicular ad hoc networks based on delay expection. Transduc. Microsyst. Technol. **36**(10), 150–153 (2017)
2. Cai, Q., Niu, J., Liu, C.: Adaptive data dissemination algorithm for vehicular opportunistic networks. Comput. Sci. **38**(16), 58–63 (2016)
3. Zhang, L., Miao, J., Xu, X.: A data dissemination mechanism based on density-sensing for vehicular opportunistic networks. Comput. Eng. Design **38**(12), 36–40 (2017)
4. Yang, Y., Wang, X., Zhang, L., Liu, S., Lin, Y.: An encounter-based routing algorithm for social opportunistic networks. Comput. Technol. Dev. **28**(2), 64–73 (2018)
5. Khabazian, M., Aissa, S., Mehmet-Ali, M.: Performance modeling ofmessage dissemination in vehicular ad hoc networks with priority. IEEEJ. Sel. Areas Commun. **29**(1), 61–71 (2017)