A Novel Routing Protocol Based on Mobile Social Networks and Internet of Vehicles

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Abstract. IOV (Internet of Vehicles) has received extensive attention recently as a part of ITS (Intelligent Transportation System). Due to various factors, such as high speed, road condition and traffic flow, the routing protocol becomes one of the important challenging problems in IOV. In this paper, we first present a mobility model at intersection and analysis it by the use of Markov method. On the basis of the mobility model, we propose a novel routing protocol in which the mobile social temporary relationship between vehicles has been considered for the urban transportation environment. Finally, the simulation results show that the packet delivery ratio and the average end-to-end delay of the proposed protocol are better than the traditional protocols.

Keywords: Routing Protocol, Internet of Vehicles, Mobility Model.

1 Introduction

As a part of Intelligent Transportation System (ITS), Internet of Vehicles (IOV) has been recently attracting an increasing attention from both research and industry communities so as to provide an effective solution to exchange safety messages between vehicles and avoid traffic jams [1].

The network structure of IOV mainly includes four components: OBU(On-Broad Unit), RSU(Road-Side Unit), CC(Control Center) and Internet, as shown in Fig.1. The OBU has GPS positioning module, vehicle state parameter acquisition module, the V2V (Vehicle-to-Vehicle) communication module, the V2R (Vehicle-to-Road) communication module and input/output devices. RSUs deployed along with the roads are responsible for the communication between vehicles and infrastructure, therefore the OBUs could exchange the traffic information with CC within the coverage area. Through Internet or satellites, the messages could be broadcasted more widely and meanwhile more information could be acquired.

An increasing number of car manufacturers are equipping vehicles with onboard computing and wireless communication devices, in-car sensors, and the global positioning system (GPS) which may be used for the deployment of large-scale vehicular networks. Whereas, due to various kinds of factors, such as high speed, dynamic topology, road condition and traffic flow, the design of routing protocols becomes one

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of the important challenging problems in IOV [2]. On the other side, vehicles are not isolated, so temporary social relationship between vehicles has also brought advantage for routing selection.

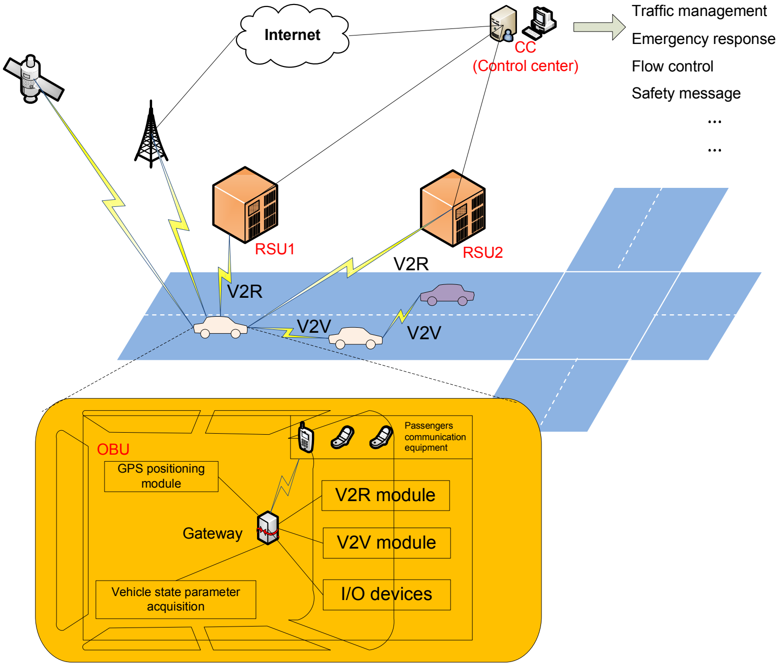

Fig. 1. Network structure of IOV

Mobile social networking is social networking where individuals with similar interests converse and connect with one another through their mobile devices [3], like Facebook or Wechat. Mobile social networking occurs in virtual communities, and it has a bright application prospect. The mobile social network based on vehicle communications may set up the inherent links between vehicles and drivers through coupling the license plate number with driver's phone number without having to build a new vehicle network. The network architecture is simple and easy to realize the communication between vehicles. According to the regularity of the movement of cars in urban cities, this paper presents a layered network structure and a group routing protocol based on mobile social relationship between vehicles, which is called MSGR (Mobile Social Group Routing) protocol. Different from the traditional group routing, our protocol depends on both the geographic information and the movement of vehicles behavior. Through the novel grouping method based on temporary social relationship between vehicle nodes, it can effectively reduce the routing delay, especially at the intersections in urban environment.

The rest of the paper is organized as follows: Section 2 describes the related works of mobility models and routing protocols in IOV. A mobility model at intersections is given and analysis in Section 3. And a novel routing strategy is proposed in Section 4, the simulation results and analysis are also discussed in this part, and Section 5 concludes the paper.

2 Related Works

2.1 Mobility Models of IOV

Since a strong interaction has been defined between the network protocol and vehicular mobility, the mobility model is a critical aspect in simulation studies of IOV.

Globally, vehicular mobility models may be classified into four different classes: *Synthetic Models* wrapping all models based on mathematical models, *Survey-based Models* extracting mobility patterns from surveys, *Trace-based Models* generating mobility patterns from real mobility traces, and finally *Traffic Simulators-based Models*, where the vehicular mobility traces are extracted from a detailed traffic simulator[4].

It is important to use a realistic mobility model so that results from the simulation can correctly reflect the real-world performance of IOV[5]. A realistic mobility model should consist of a realistic topological map which reflects different densities of roads and different categories of streets with various speed limits. Another important parameter should be modeled is the obstacles. Many previous studies [5], [6] have shown that a realistic mobility model with sufficient level of details is critical for accurate network simulation results. We found that realistic vehicular mobility model at intersections has rarely been studied.

2.2 Routing Protocols for IOV

Recently, researchers have proposed different routing algorithms[7-12] for IOV from the point of view of different characteristics, many routing protocols have been developed for Mobile Ad Hoc Networks (MANETs), and some of them can be applied directly to VANETs, such as GPSR (Greedy Perimeter Stateless Routing) and DSR (Dynamic Source Routing) [7],[8]. DSR is a classic on-demand routing protocol based on source routing, however, due to the delay is relatively increased, it is not suitable for real-time safety message transmission. GPSR forwards packets by greedy algorithm based on geographical position, whereas this algorithm is easy to lead to the routing void, i.e. the distance of all neighbors are farther than the node, but at this time the routing process is not over.

According to the characteristics of highly dynamic topology and frequently disconnected network, authors in literature [9],[10]and [11] proposed some novel protocols based on the connection, in view of communication between vehicles in city and highway environment. In literature [12] the author proposed a method called Long Lifetime Anypaths (LLA) providing stable communication paths. The mainly addressed the problem of stability of anypath communications in VANET networks in the presence of inter-vehicle link failures being result of vehicles mobility. However, those routing algorithms do not consider the temporary relationship between vehicles.

3 Vehicular Mobility Model at Intersection

3.1 Intersection Model

Usually, an intersection can be divided by two parts: horizontal-street and vertical-street. Considering a typical case in actual urban traffic, we establish a vehicular mobility model at intersection in urban road traffic as follows. In our mobility model, horizontal-street stands for the East-West direction and vertical-street stands for the South-North direction. Each direction has three lanes, a total of six lanes. In order to facilitate description, the streets are assumed as grids that have regular shape. Fig.2 shows the model.

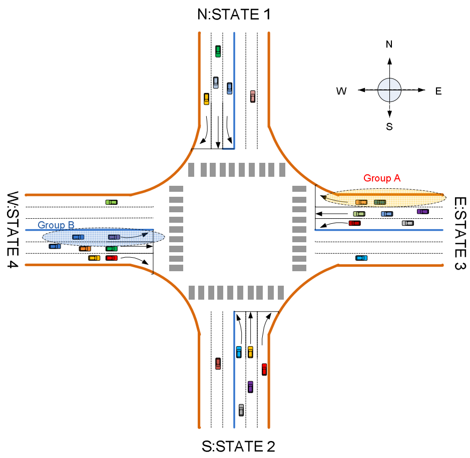

Fig. 2. Vehicular mobility model at intersection

Mobile nodes can move along the grid of the topology map, and at the intersections of the streets, the mobile nodes choose to turn right or left or go forward (remain unchanged) with a certain probability. The speed of mobile nodes in a certain moment is related with the previous moment. In addition, the speed of vehicles in the same lane also is related with each other.

As shown in Fig. 2, intersection is divided into four directions, east, west in horizontal direction and north, south in vertical direction. Vehicles in every direction are divided into three groups and they are set to D = {left, right, straight}, which means turning left, turning right and going straight respectively. So a intersection can be divided into twelve groups, which are set to M= {N→E, N→S, N→W, S→W, S→N, S→E， W→N, W→E, W→S, E→S, E→W, E→N}. The corresponding transition probability P_{ij} represents the radio of the vehicles in one group (i→j) to the total vehicles coming from direction i. For example, P_{NS} represents the radio of the vehicles from north to south to the total vehicles from north .Therefore, P_{NE}+ P_{NS} +P_{NW}=1. At the same time, the vehicles with the same destination are called groups with a high social relationship.

In order to simplify the modeling, assuming there are N mobile nodes in the model area, distributed randomly in the lanes within the model area, each node has the same signal transmission range and the same speed. The model complies with limited steps of execution in discrete time and the transition of limited state in the system according to the different probability, so it can be modeled as a Discrete Time Markov Chains (DTMCs). The streets are bidirectional and the intersections are regulated by means of traffic lights. At each intersection, the vehicles will choose its next direction following a Markov chain whose probabilities are calculated based on road segments attraction weights. The attraction weights usually are obtained by observed data.

3.2 Markov Process Analysis

Markov analysis method is widely applied to many fields, such as: market prediction and traffic transition prediction. In this paper, we use this method to predict traffic situation at signalized intersections.

Discrete Time Markov Chains Model can be defined as (S, P, $X(0)$). S corresponds to the state space, P is a matrix representing transition probabilities from one state to another, and $X(0)$ is the initial probability distribution of the states in S .

$$\begin{bmatrix} X_1^{(k+1)} \\ X_2^{(k+1)} \\ \vdots \\ X_n^{(k+1)} \end{bmatrix}^T = \begin{bmatrix} X_1^{(k)} \\ X_2^{(k)} \\ \vdots \\ X_n^{(k)} \end{bmatrix}^T \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix} \tag{1}$$

Where k=1, 2,…m, m is the total transition steps.

In our mobility model, there are four states which classified by directions, S_1 is the north state, S_2 is the south state, S_3 is the east state and S_4 is the west state. We collected the traffic observed data at an intersection of Sidaokou in Beijing during a particular period. According to the statistics data, we calculated the transfer probability of vehicles at the intersection. Suppose P_{ij} represents the transition probability from State i to State j (i,j=1,2,3,4), then the transition probability matrix P obtained as follows:

$$P = \begin{bmatrix} 0 & P_{NS} & P_{NE} & P_{NW} \\ P_{SN} & 0 & P_{SE} & P_{SW} \\ P_{EN} & P_{ES} & 0 & P_{EW} \\ P_{WN} & P_{WS} & P_{WE} & 0 \end{bmatrix} = \begin{bmatrix} 0 & P_{12} & P_{13} & P_{14} \\ P_{21} & 0 & P_{23} & P_{24} \\ P_{31} & P_{32} & 0 & P_{34} \\ P_{41} & P_{42} & P_{43} & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0.70 & 0.15 & 0.15 \\ 0.60 & 0 & 0.10 & 0.30 \\ 0.25 & 0.40 & 0 & 0.35 \\ 0.35 & 0.30 & 0.35 & 0 \end{bmatrix} \tag{2}$$

Fig. 3 is the Markov probability transition diagram at a certain intersection.
Furthermore, according to equation (1) and (2), it can be deduced as follows.

$$\begin{bmatrix} \delta_1^{(k)} \\ \delta_2^{(k)} \\ \delta_3^{(k)} \\ \delta_4^{(k)} \end{bmatrix}^T = \begin{bmatrix} \delta_1^{(k-1)} \\ \delta_2^{(k-1)} \\ \delta_3^{(k-1)} \\ \delta_4^{(k-1)} \end{bmatrix}^T P = \ldots = \begin{bmatrix} \delta_1^{(0)} \\ \delta_2^{(0)} \\ \delta_3^{(0)} \\ \delta_4^{(0)} \end{bmatrix}^T P^k = \begin{bmatrix} \delta_1^{(0)} \\ \delta_2^{(0)} \\ \delta_3^{(0)} \\ \delta_4^{(0)} \end{bmatrix}^T \begin{bmatrix} 0 & P_{12} & P_{13} & P_{14} \\ P_{21} & 0 & P_{23} & P_{24} \\ P_{31} & P_{32} & 0 & P_{34} \\ P_{41} & P_{42} & P_{43} & 0 \end{bmatrix}^k \tag{3}$$

where k=1,2,3,…m. $\delta_i^{(k)}$ represents the TFO (Traffic Flow Occupancy) of the vehicles driving to direction i of the next k cycles in the future, where i= 1, 2, 3, 4. And TFO means the probability density of traffic flow.

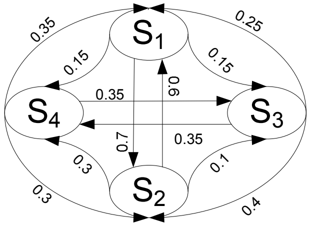

Fig. 3. Markov State Transition Diagram

3.3 Model Validation

Based on the analysis in 3.2, the predicted values of TFO within several cycles can be calculated. On the other hand, we have statistics the observed data in the same cycles, and compared the observed values to the predicted values for four states. The results are shown as Fig. 4. During the validation, it has been chosen 10 cycles to illustrate the values, and one cycle is 5 minutes.

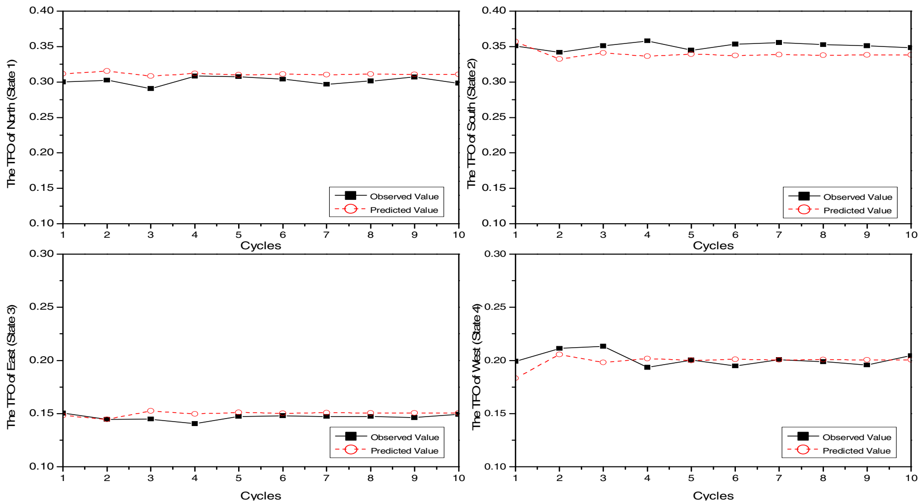

Fig. 4. Observed Values and Predicted Values of TFO for Different Directions

From the comparison it is obvious that the maximum error is not greater than 10%, therefore the Markov analysis method is feasible for the traffic situation at intersections in urban environment.

4 Routing Protocol

4.1 Description of MSGR Protocol

According to the regularity of the movement of vehicles in urban environment, this paper proposes a layered network structure and a group routing protocol based on mobile social temporary relationship between vehicles, which is called MSGR (Mobile Social Group Routing) protocol. Since the grouping method can be applied to routing strategies based on the location in urban environment, the basic idea of traditional method is to classify the nodes of network within the range of certain geographical location as a group. However, in this paper, we present a different and novel grouping method based on the temporary social relationship between vehicle nodes. The method depends on both the geographic information and the movement of vehicles behavior. For example, the nodes with a similar movement behavior in a certain range or the nodes with the same direction at a intersection have a higher probability to be considered as a group, as shown in Fig. 2, the vehicles in Group A and Group B have the same moving direction after crossing the intersection, so the priority of routing between these two groups is higher than other groups. In fact, these two groups will combine a new group after their turning. This grouping is dynamic by their temporary social relationships, so the routing should consider the special relationship between the vehicles. These close relations could communicate with each other with a higher priority. The grouping routing algorithm can reduce hops between the nodes of IOV and overhead of data transmission, meanwhile it can make the function of nodes more explicit and the management of network more convenient.

MSGR can find a route to the destination node with a high density of vehicles. It mainly contains three modules.

(I) *Grouping*, the vehicle nodes are grouped according to both the geographical location information and the temporary mobile social relationship, based on the mobility model in section 3, we assume that the vehicle can be divided into 12 groups, vehicle nodes within a group may communicate with a higher priority.

(II) *Next intersection choice*, when selecting the next intersection, as in equation (4), a transmitting node or intermediate node calculates a weight of each candidate intersection based on the number of vehicles and the distance to the destination node;

$$\text{Weight}（N_i）=a\times（1\text{-}D_\text{p}）+b\times T_\text{n}/\,T_\text{c} \quad (4)$$

Where, N_i means the next candidate intersection; a and b represent the weight factor of the distance and vehicle traffic, a+b=1; D_p determines the relative distance between the candidate intersection to the destination node; T_n represents the total vehicles between the candidate intersection to the destination node; T_c represents the total vehicles between the current intersection to the destination node.

(III) *Multiple attributes decision*, in order to transmit data between two intersections, the next forwarding node, which has the maximum value of UC_i, is chosen by the multiple attributes decision mechanism. UC_i represents a comprehensive utility value of distance, direction, speed, velocity and density.

The data transmission procedure according to the proposed routing scheme includes five steps. Firstly, a source node *S* prepares to send a message; secondly, node *S* determines which groups to receive the message within the range of communication; thirdly, the nodes which belong to the receiving groups are activated; fourthly, the message of source node *S* is sent to the nodes are activated successfully; fifthly, the nodes that having received the message may send the message to the following-up nodes which belong to the same group but beyond the range of communication of *S*.

The proposed MSGR strategy has better purposiveness and adaptability for actual traffic environment at intersections in urban cities, we will prove the effectiveness of this strategy through the network simulation results.

4.2 Simulation

The simulation is performed by MATLAB and NS-2 based on the Manhattan style grids, the source and the destination nodes are selected randomly between 2000m and 2000m. The performance of the proposed routing strategy is evaluated, compared to DSR and GPSR routing protocols. The simulation parameters are shown in Table 1.

Table 1. Simulation Parameters

Parameter	Value
Simulation area	2000m×2000m
Simulation time	1000s
Number of Intersections	9
Number of Vehicles	40~160
Vehicle Speed	5~20m/s
Maximum Transmission Range	250m
Data Packet Size	512bytes
Data Rate	11Mbps
MAC Protocol	802.11DCF
Wireless Propagation Model	Two Ray Ground Reflection

Our performance evaluations include the following metrics:

1) *The data packet delivery ratio* is the ratio of the number of data packets received by the destination to the number of data packets sent by the source;

2) *The average end-to-end delay* characterizes the average time that a packet experiences in the network from the source to the destination;

3) *The routing overhead* represents the ratio of the size of controlling packets to the size of total packets, including controlling packets and data packets.

Fig.5 and Fig.6 shows that the normalized packet delivery rate and the average end-to-end delay versus the number of vehicles, as the vehicles increases, the packet delivery rate increases and the average end-to-end delay decreases monotonically. Obviously, our MSGR protocol is better than other two protocols. The improvement is attributed to the consideration of the vehicle grouping strategy and multiple attribute routing forward mechanism. Consequently, it increases the success delivery ratio and avoids the routing void.

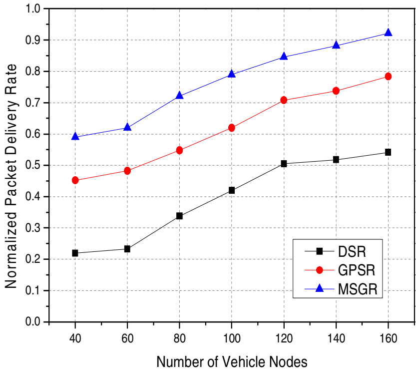

Fig. 5. Data Packet Delivery Ratio vs. Number of Vehicles

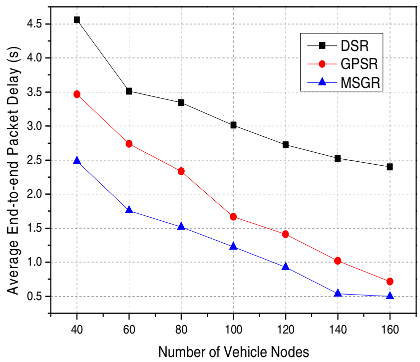

Fig. 6. Average end-to-end Delay vs. Number of Vehicles

The routing protocol overheads is also related to the density of vechiles, as shown in Fig.7. Among three protocols, since DSR does not need to periodically send Hello packets, its overhead is least. Compared to the GPSR, our MSGR reduces unnecessary information transmission by vehicles grouping, therefore the routing overhead is significantly reduced relatively. Although Hello packet increases some overhead in MSGR, considering the network performances of delivery ratio and end-to-end delay are significantly improved, it can be acceptable.

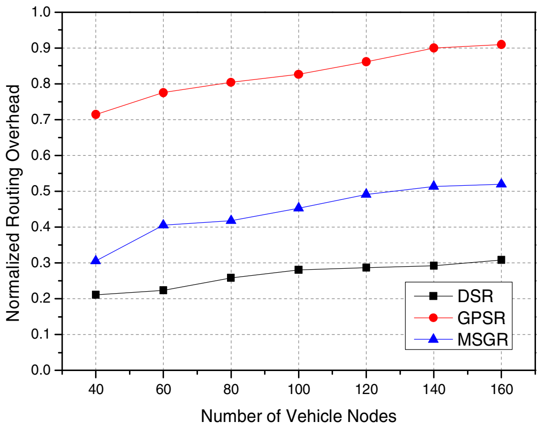

Fig. 7. Routing Overhead vs. Number of Vehicles

5 Conclusion

In this paper, we present a specific scenario model at intersection in urban environment for IOV, and then analysis the mobility model and validate the rationality. According to the realistic issues of traffic flow at intersections, we proposed a novel group routing protocol based on mobile temporary social relationship between vehicles, the simulation results show that our MSGR outperformed the DSR and GPSR. In the future, we would explore a more realistic joint system to improve the multiple attributes routing forward mechanism.

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