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MPBRP- Mobility Prediction Based Routing Protocol in VANETs

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Abstract— Vehicular Ad-hoc Networks (VANETs) technology has been emerged as an important research topic in recent years. This is because the vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications are becoming more popular in the field of Intelligent Transportation System (ITS) so as to further enhance traffic efficiency, safety, emissions reduction and infotainment applications. Over the last few years, a number of routing protocols in VANETs have been developed. In particular, position-based routing protocols have attracted the most interest in VANETs as they are suitable for a frequently changeable network topology and highly dynamic nature of vehicular nodes. This paper develops a new Mobility Prediction Based Routing Protocol (MPBRP) for neighborhood detection, packet transmission and path recovery in VANETs by using driver's intention collected from the positioning systems. Several major contributions are made in the paper:

- (1) Combining both predictive forwarding strategy and recovery strategy to detect neighbors and transfer packets.
- (2) Utilizing the predicted position and angles in a pre-defined time with considering driver's intention to select the neighboring nodes and discover the transmission path.
- (3) Validating the effectiveness and feasibility of the proposed protocol by creating a unified simulation platform (Veins) and implementing it in real world scenarios.
- (4) Enhancing the overall performance as the proposed routing protocol achieved competitive improvement over existing protocols in terms of packet delivery ratio, end-to-end delay and average hops about 26.22%, 21.89% and 20.79% by average in grid-based scenario, and about 26.04%, 23.14% and 18.51% by average in urban scenario respectively.

Keywords— *geographic (position-based) routing protocols, mobility prediction, driver's intention, V2V communication, Vehicular Ad hoc Networks (VANETs)*

I. INTRODUCTION

The Mobile Ad-hoc Networks (MANETs) is one type of de-centralized networks which is composed of numerous wireless nodes without fixed infrastructure and pre-defined topology. Each node in MANETs can be considered as an end-system or router, and is free and independent to move. In addition, the network must be self-configured and message transmissions in MANETs are completely dynamic with multi-hop communications. The Vehicular Ad-hoc Networks (VANETs), one special subclass of MANETs, are the promising method for future ITS to ameliorate traffic efficiency and traffic safety. In VANETs, each vehicle in the real traffic environment can be seen as a node, its movement is relatively predictable because the vehicle are restricted to the existing roads. Moreover, each vehicle becomes one part of the network and it can manage and control the

communication on the network according to its own requirements [1].

The kinematic data from one vehicle can directly be transmitted to another if it is within its radio range, or indirectly to another through a multi-hop wireless communication using neighboring nodes as a relay [2]. Vehicular communication is the first step to detect nearby vehicles and establish the temporary vehicles' topology to collect kinematic information, such as velocity, position and traffic density. Currently, due to newly manufactured vehicles equipped with on-board units (OBUs), positioning systems (i.e., GPS devices and navigation systems) and wireless communication devices (i.e., IEEE 802.11p and IEEE 1069 standards), VANETs can guarantee low-cost communication services with the low-cost short-range communications and the minimum infrastructure requirement[3].

Routing protocols in VANETs has been extensively analyzed in the past few years, which is responsible for selecting and maintaining routes from source to destination, and forwarding packets along the selected routes. Moreover, routing and forwarding packets in VANETs are the challenging tasks due to VANETs' unique characteristics, such as the frequently changing topology and variable vehicle velocities. VANETs are totally different from MANETs, therefore, most of traditional routing protocols of MANETs cannot directly apply to VANETs' environments. According to the position accusation, transmission strategy and the route updating method, routing protocols can be classified into six types: (1) Topology Based Routing Protocol, (2) Position Based Routing Protocol, (3) Broadcast Based Routing Protocol, (4) Unicast Based Routing Protocol, (5) Geo-cast Based Routing Protocol, and (6) Cluster Based Routing Protocol [4-6]. The position based routing protocol (also known as the geographic routing protocol) has been identified to be the most suitable for VANETs because of their stability in handling the rapid topology changing and highly changeable vehicles' velocities [2,7,8].

Traditional routing protocols applying to MANETs are lack of their feasibility in handling the highly dynamic environment and changeable speed in VANETs. And most existing position based routing protocols utilize beacon message to detect neighbours periodically, but the velocity of vehicles is assumed to be static during the transmission of beacon message. The mobility of vehicles during this period can not be ignored regardless of the sparse traffic density in highway scenarios or dense traffic flow in urban scenarios. That is why the accurate prediction of mobility is indeed indispensable. Moreover, several early position routing protocols only apply to highway environment without

considering radio obstacles in urban environment. The proposed Mobility Prediction Based Routing Protocol (MPBRP) can predict neighbor mobility by analyzing the kinematic data collected from beacon messages and then creates a temporary topology to achieve real-time vehicular communications. Different from other position based routing protocols, the proposed MPBRP can obtain the drivers' intention and vehicle's acceleration involved in the mobility prediction. Equipped with advanced positioning system, for example, navigation systems, drivers used to check the traffic status to the destination before their journey. Destination inputted in the navigation system can be the driver's intention and a crucial factor to predict the vehicular mobilities. By incorporating the comprehensive information from the positioning system and beacon messages, such as velocities, accelerations, positions and drivers' intentions, the proposed MPBRP can predict the vehicles' position accurately and transfer messages with high performance and confidence.

The rest of the paper is organized as follows. Section 2 states some related work on position-based routing protocols and performance metrics in VANETs. In Section 3, the proposed Mobility Prediction Based Routing Protocol (MPBRP) is explained in details. Section 4 describes the simulation experiments. Section 5 shows the results and discussion. Section 6 concludes the paper and details the future work.

II. BACKGROUND AND RELATED WORK

Significant efforts have been devoted to analyzing routing protocols in VANETs in the past few years. Routing protocol is responsible for selecting and maintaining routes and forwarding packets along the selected routes. The position-based routing has more potential to be accurate than other routing protocols for VANETs because of the geographical constraints.

A. Position based routing protocols in VANETs

Position based routing protocols have been identified as one kind of more suitable protocol for VANETs to give better performance and exhibit scalability and robustness against frequent topological changes. This section critically reviews existing position based routing protocols.

Greedy Perimeter Stateless Routing (GPSR) is a routing protocol for wireless datagram networks which uses the positions of routers and a packet's destination to make the forwarding decisions, however, it suggests a position based on an algorithm without prediction, which is suitable for highly dynamic environment and highway [9]. NS2 simulator has been used to test GPSR. Packet delivery ratio, routing protocol overhead and path length have been chosen to evaluate the GPSR. But the local topology information is static and GPSR is lack of the prediction of the vehicular nodes. The GPSR is not suitable for urban scenario as the radio obstacles in urban area have a significant negative impact on the performance of position-based routing protocol, which should not be ignored [10].

Greedy Perimeter Coordinate Routing (GPCR) does not use all the must pass packet intersections and street map information until it reaches its destination without prediction [2]. NS2 simulator has been used to test GPCR. Packet delivery ratio, communication distance and hops communication distance have been chosen to evaluate the GPCR. The disadvantage of GPCR is that it use a natural

planar graph of streets and junctions without using any global or external information [7].

Predictive Directional Greedy Routing (PDGR) relies on the position, direction, and the speed of each neighbor to select the next node to forward the information [14]. NS2 simulator has been used to test PDGR. Packet delivery ratio, end-to-end delay, average hops, send rates and number of nodes have been selected to test the PDGR. However, PDGR is only simulated for open environment without considering urban.

Predictive Geographic Routing (PGRP) is the latest routing protocol with the digital map, which improve the performance of routing by considering the mobility constraints and predictive nature of vehicles [8]. The MOVE platform combining SUMO and NS-2 have been used to test the PGRP. PGRP can be used in both urban environment and highway environment. However, PGRP is lack of using acceleration of each vehicle and the driver's intention to make better decision.

B. Performance Metrics based on Quality of Services in VANETs

Several geographic routing protocols used in VANETs are compared with MPBRP, such as GPSR [9], GPCR [10], PDGR [11] and PGRP [8]. The performance of position based routing protocols can be analyzed by different parameters, such as Hop Count, End-to-end Delay, Delivery Rate, Overhead and Latency. There are three popular metrics which are mainly chosen to evaluate their performance.

End-to-End Delay (E2E Delay): The Veins simulator allows the dynamic mobility. By predicting the position of each vehicle in the short future, some problems can be overcome, for example, being out of bound.

Packet Delivery Ratio: The percentage of the packet which can be sent from the source node to destination node successfully.

Average Hops: The average number of hops from the source node to the destination node.

C. Discussion

Most position based routing protocols suppose that the velocity of vehicles is static during the transmission of beacon messages without taking into account highly variable speed and direction changing in VANETs [2,7,8,9]. For example, within the transmission range of the source vehicle, if the closest vehicle to the destination runs at a different direction, the vehicle would be chosen by source to transmit the packet. However, this case would cause the high end-to-end delay and decrease the packet delivery ratio seriously due to future position of the chose vehicle. PGRP involves the prediction of vehicles' position according to vehicle position information gathered from GPS and beacon message so as to solve real-time V2V communication both in highway and urban scenarios [10]. But with the development of GPS and navigation technology, the destination information of driver can be easily collected, which can be potentially applied in the selection of neighboring node. As well, the acceleration can not be ignored in the prediction of vehicles' mobility. This paper proposes a novel position based routing protocol with considering the obstacle ratios in urban scenario, acceleration and drivers' intention, which is tested on a novel unified simulation platform. The results shows great improvements compared with some existing routing protocols stated above.

III. MPBRP: MOBILITY PREDICTION BASED ROUTING PROTOCOL

This section introduces a new mobility prediction based routing protocol (MPBRP) for VANET simulation. MPBRP can be a solution to deal with the problem of dynamic changeable topology and variable velocities in vehicular communication. By the positioning systems and V2V communication, MPBRP can collect the other vehicles' kinematic information, such as position, velocity, acceleration and drivers' intention. By predicting neighbors' positions, MPBRP would select the best neighbor to forward the information to the destination.

As for the routing protocols, two main issues should be solved, forwarding strategy and recovery strategy. In order to overcome the local maximum problem, two forwarding strategies are used here: (1) the first is the predictive greedy forwarding algorithm and (2) the second is the predictive perimeter forwarding algorithm.

The MPBRP's greedy forwarding algorithm is different from the normal forwarding strategy in various ways. The basic greedy forwarding strategy would make the source to broadcast beacon messages to define the neighbors within the communication range. As shown in Fig.1, the source would choose the node which is closest to the destination and forward the package to it. Finally, the packet is sent to the destination by the route $A \rightarrow B \rightarrow D \rightarrow E \rightarrow Z$. This greedy forwarding strategy is effective to deal with the static nodes. But as for VANETs environments, we should consider its high-speed mobility.

Fig.1. The Greedy Forwarding Strategy

Also, the MPBRP's perimeter forwarding algorithm is enhanced to meet the VANET's requirement. Two recovery methods should be mentioned firstly, there are Relative Neighborhood Graph (RNG) and Right Hand Rule which can solve the problem of greedy forwarding [9]. In the greedy forwarding algorithm, if the sender detects the nodes within the transmission range, but none of them is closer to the destination, the packet cannot be transferred to the destination. Compared to the greedy forwarding strategy, the perimeter forwarding can effectively solve this special case. As shown in Fig.2, the source A needs to send a packet to the destination Z. The node B and C are both inside A's transmission range, but distances to the destination are different, $d_{AZ} < d_{BZ} < d_{CZ}$. As a result, the node B and C cannot be the candidate to forward the packet. In order to forward the packet to the destination, RNG and Right Hand Rule are used to check the connectivity to the destination. Finally, the packet can be sent to the destination by the route $A \rightarrow C \rightarrow D \rightarrow E \rightarrow G \rightarrow H \rightarrow Z$. Here, the high mobility of VANET is ignored.

Fig.2. The Perimeter Forwarding Strategy

If the characteristics of VANET are taken into consideration, we should consider the speed and acceleration of vehicle. Therefore, the speed and acceleration of vehicle can be used to predict the vehicle's position during one time slot. If we assume it would take 1s to send the beacon messages and get the response from the neighborhood, the vehicle will change its position in one second because of its high speed. Instead of the static condition, the dynamic model can be more suitable and more realistic. The transmission information between vehicles should conclude the velocity, acceleration and position. And then the predictive greedy forwarding strategy can predict the vehicle's position in the short future. The source would use new position topology to choose the best node to forward packets.

Also, the prediction of vehicles' position is also very important in the forwarding strategy. For example, assuming that the node C in Fig.2 moves at a high speed, shown in Fig.3, the chosen node C would change the position and be out of bounds if we follow the rule of perimeter forwarding strategy. The packet on node C will be dropped. It will result in high end-to-end delay, low packet delivery ratio and high counted hops. By the predictive perimeter forwarding strategy, the new topology will be used by source node A. And node A can deliver the packet by the route $A \rightarrow B \rightarrow D \rightarrow E \rightarrow F \rightarrow H \rightarrow Z$.

Fig.3. The Predictive Forwarding Strategy

The Mobility-Prediction Based Routing Protocol combines two predictive forwarding strategies above. Instead of the static model, MPBRP use vehicles' dynamic information and beacon time to predict their position in short future. The dynamic topology is more reasonable for transmitting the packet. Inside the MPBRP, two position information should be calculated for the source, such as, the distance from the neighbor node to the destination and the angle of the neighbor in relation to the destination. The angle here can be used to identify the moving direction of the vehicle. These two information would influence the node choosing by different weight. Finally, both the distance and the angle should be taken into consideration to make the decision. Seven stages to implement MPBRP are shown below.

Step1: Calculate the weight of source node.

Step2: Detect the neighbors.

Step3: Calculate the distances of neighbors to the destination node within transmission range in short future.

Step4: Calculate the angle of neighbors and the destination node within transmission range in short future.

Step5: Calculate the angle of neighbors' intention and the intention of the destination node within the transmission range.

Step6: Calculate the weight of each neighbor and check if the local maximum occurs.

Step7: Select the best neighbor to deliver the messages.

In order to calculate the weight of the source node and neighbor nodes, three factors should be assigned to the relative distance and angles, p , $q1$ and $q2$. p is the factor for the distance. And $q1$ and $q2$ are the factors for two angles. The sum of p , $q1$ and $q2$ is 1, which can be represented in (1):

$$p+q1+q2=1 \quad (1)$$

$L_s (X_s, Y_s)$ and $L_d (X_d, Y_d)$ denote the location of the source node and the location of the destination respectively. The distance between the source node and destination node is shown in (2).

$$distance_{(s,d)} = \sqrt{(X_s - X_d)^2 + (Y_s - Y_d)^2} \quad (2)$$

The angle θ between the source node and destination node is shown in (3).

$$\theta = \cos^{-1} \left(\frac{\vec{v} \times \overrightarrow{L_s L_d}}{\|\vec{v}\| \times \|\overrightarrow{L_s L_d}\|} \right) \quad (3)$$

where $\vec{v}$ denotes the vector of velocity for current vehicle.

By the beacon interval t , the predictive position of each node can be calculated below. (4) shows the predictive position of one node. Here, v is the velocity of the vehicle. And a is the acceleration of the vehicle.

$$\begin{cases} x' = x + (vt + \frac{a}{2} \times t^2) \times \cos \theta \\ y' = y + (vt + \frac{a}{2} \times t^2) \times \sin \theta \end{cases} \quad (4)$$

Then, (4) can be used to calculate the predictive $distance^*$ between two new nodes, which is shown in (5).

$$distance^* = \sqrt{\left(x_1 + \left(v_1 t + \frac{a_1}{2} t^2 \right) \cos \theta_1 - x_2 - \left(v_2 t + \frac{a_2}{2} t^2 \right) \cos \theta_2 \right)^2 + \left(y_1 + \left(v_1 t + \frac{a_1}{2} t^2 \right) \sin \theta_1 - y_2 - \left(v_2 t + \frac{a_2}{2} t^2 \right) \sin \theta_2 \right)^2} \quad (5)$$

Where in (5), a denotes the acceleration of the vehicle and θ denotes the direction of the vehicle. v_1 and v_2 are original speeds of two vehicles. (x_1, y_1) and (x_2, y_2) represent original positions of two vehicles respectively.

Next, $L_i (X_i, Y_i)$, $L_a (X_a, Y_a)$ and $L_b (X_b, Y_b)$ denote the locations of neighbor's destination, neighbor's intention and destination node's intention respectively. The angle of two intentions can be calculated in (6).

$$\theta_i = \cos^{-1} \left(\frac{\overrightarrow{L_i L_a} \cdot \overrightarrow{L_i L_b}}{\|\overrightarrow{L_i L_a}\| \times \|\overrightarrow{L_i L_b}\|} \right) \quad (6)$$

Finally, the weight of each neighbor i can be calculated by the (7). The neighbor with high weight can be next-hop's candidate.

$$weight_i = p \left(\frac{distance_{s,d}^* - distance_{i,d}^*}{distance_{s,d}^*} \right) + q1 \cos(\overrightarrow{v_i}, \overrightarrow{L_i L_d}) + q2 \cos \theta_i \quad (7)$$

Form (7), if the neighbor is closer to the destination with the similar direction as the destination and the intentions of them are similar, this neighbor can be weight higher to be selected for the relay.

IV. SIMULATION EXPERIMENTS

A comprehensive review and analysis indicate that the Veins is the best platform to test the developed MPBRP protocol. The map exported from OpenStreetMap is modified to meet the requirement of real environment by Java-OSM. SUMO can convert the map from the OpenStreetMap and generate the traffic flow [12]. We use Original/Destination metrics to generate the traffic flow in two scenarios. In the Scenario 1, the map is created manually by NetEdit, as shown in Fig.4. In the Scenario 2, the real map of the Loughborough town (UK) is used to validate the proposed method. In addition, the O/D metrics are used in the Scenario 2 to meet the real-world environment and represent the intention of each vehicle. In order to achieve precise O/D metrics, the data from the council government and the field statistics is collected. Tab.1 shows the parameters for vehicles which are used in SUMO to represent vehicles in the grid-based map. In the Scenario 2, one advanced map is modified to simulate the realistic traffic flow of Loughborough, as shown in Fig.5. The parameters in Scenario 2 are similar to the Scenario 1's, but the area size is expanded to 5km $\times$ 5km.

OMNET++ is connected with SUMO by the Veins. OMNET++ is an extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators, which can handle vehicular communication [13].

Fig.4. The map of Scenario 1

Sumo parameters for grid-based scenario

Maximum vehicle speed	13.3m/s-31.1m/s
Vehicle acceleration	(-5)- 5 m/ s ²
Vehicle length	5m
Simulation area	400m * 400m
Number of vehicle	100, 200, 300,400, 500, 600, 700

Tab.1.The parameters of Scenario 1

Fig.5.The map of Scenario 2

The implementation of traffic mobility has been done. Then we need to use Veins to enable the communication between the SUMO and OMNET++ to test the proposed protocol. Relative parameters should be set up for the proposed MPBR, as shown in Tab.2.

Veins parameters for proposed MPBR

Beacon interval	1.5s
Maximum transmission range	300m
Minimum signal reception threshold	minus 85 dBm
Propagation model	Shadowing and Obstacles
Packet size	1052 bytes
Simulation time	200s
Mac protocol	IEEE802.11p

Tab.2.Veins parameters for two scenarios

Fig.6.(a).The packet transmission of Scenario 1 (b) The packet transmission of Scenario 2

Finally, the MPBRP can be tested in the OMNET++ IDE with visual animation, which is shown in Fig.6.

V. RESULTS AND DISCUSSION

A. Scenario 1- Grid-based Simulation

(a)

(b)

(c)

Fig.7.(a) Packet delivery ratio in the Grid-based Simulation (b) End-To-End Delay in Grid-based Simulation (c) Average hop in the Grid-based Simulation

As shown in Fig.7, the proposed MPBRP achieved better results on PDR, E2E delay and Average hop, because it integrates the advantages of GPSR, GPCR, PDGR and PGRP. Fig.7.(a) indicates the MPBRP's packet delivery ratio which is compared with GPSR, GPCR, PDGR and PGRP. With the increase of the vehicle density, the PDRs of MPBRP, GPSR,

GPCR, PDGR and PGRP all grow. However, MPBRP outperforms GPSR, GPCR PDGR and PGRP. As shown in Fig. 7.(a), the PDR of MPBRP is 38.36%, 44.74%, 15.24% and 6.54% higher than GPSR, GPCR PDGR and PGRP's respectively. PGRP's result is close to MPBRP's, because both of these two routing protocols use the prediction method to choose the forwarding node. Fig. 7.(b) shows their end-to-end delays, their end-to-end delays all increase with the growth of the number of the vehicle. And the E2E of MPBRP is 26.88%, 24.80%, 29.39%, 6.47% lower than GPSR, GPCR PDGR and PGRP's respectively. Fig. 7.(c) shows their average hops, their average hops all increase with the growth of the number of the vehicle. And the average hop of MPBRP outperforms GPSR, GPCR PDGR and PGRP's by 22.50%, 26.24%, 28.82%, 5.60%.

B. Scenario 2- Urban Simulation

(a)

(b)

(c)

Fig.8.(a) Packet delivery ratio in the Urban Simulation (b) End-To-End Delay in Urban Simulation (c) Average hop in the Urban Simulation

As shown in Fig.8, the proposed MPBRP also performs better results on PDR, E2E delay and Average hop, because it modifies the disadvantages of GPSR, GPCR, PDGR and PGRP. Fig.8.(a) shows the MPBRP's packet delivery ratio which is compared with GPSR, GPCR, PDGR and PGRP. With the increase of the vehicle density, the PDRs of MPBRP, GPSR, GPCR, PDGR and PGRP all have a stable growth. However, MPBRP outperforms GPSR, GPCR PDGR and PGRP by a different degree. As shown in Fig.8.(a), the PDR of MPBRP is 35.80%, 34.65%, 26.52% and 7.17% higher than GPSR, GPCR PDGR and PGRP's respectively. PGRP performs the similar result as MPBRP, because both two routing protocols use the prediction method to choose next forwarding node. Fig.8.(b) shows their end-to-end delays, their end-to-end delays all increase with the growth of the number of the vehicle. And the E2E of MPBRP is 35.06%, 37.08%, 14.46%, 5.97% lower than GPSR, GPCR PDGR and PGRP's respectively. Fig.8.(c) shows their average hops, their average hops all increase with the growth of the number of the vehicle. And the average hop of MPBRP outperforms GPSR, GPCR PDGR and PGRP's by 26.20%, 27.30%, 16.24%, 4.30%.

VI. CONCLUSION AND FUTURE WORK

In this paper, a new position based routine protocol termed as the Mobility Prediction Based Routine Protocol (MPBRP) in VANETs was developed. Relative to existing similar routing protocols, the developed MPBRP achieved better performance by avoiding the local maximum, selecting the best next-hop node and checking the connectivity to the destination. Two enhanced forwarding strategies support the MPBRP and this improved the packet delivery ratio, overcame end-to-end delay and reduced the average hop. The simulation results showed that compared with GPSR, GPCR, PDGR and PGRP, the developed routing protocol achieved competitive improvement in terms of packet delivery ratio, end-to-end delay and average hops about, on average, 26.22%, 21.89% and 20.79% respectively in the grid-based scenario, and about 26.04%, 23.14% and 18.51% respectively in the urban scenario. By comparing these two scenarios, it was found that the result for the urban scenario performed better than the result for the grid-based scenario. The difference between these two simulations was the size of simulation area. The urban area is much bigger than the edited grid, which causes the low vehicle density and low vehicle connectivity. In addition, the reason why the urban scenario performs better should be investigated further. Furthermore, Software Defined Network (SDN) technology can be potentially combined with the proposed MPBRP to achieve better performance. Moreover, the Veins platform can be used to implement the SDN in VANETs environment.

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