A Routing Protocol Based on CP Neural Network for Vehicular Ad Hoc Networks

Wei Wen*
Faculty of Information Engineering, Jiangxi University of Science and Technology, Ganzhou, 341000, China
*Corresponding author email: wenwei_jxust@126.com

Abstract. It is important to design efficient routing protocols based on link connectivity and the selection of optimal link forwarding data in vehicular ad hoc networks (VANET). We propose A routing protocol based on counter propagation (CP) neural network for Vehicular Ad Hoc Networks (CP-GPSR), which is to take into account the connectivity probability of the link, adopts a routing method based on data packets forwarded at intersections. The priority of the next segment is classified by the CP neural network, vehicle select the next segment of highest priority for data forwarding at the intersection. The simulation results show that CP-GPSR has a high packet delivery rate, the control overhead is lower.

Keywords: Greedy geographic routing protocol; Connectivity probability; CP neural network.

1. Introduction
With the wide application of GPS in vehicles, the greedy geographic routing protocol based on geo-location information has become one of the research hotspots in the vehicle ad hoc networks. In the traffic environment, the non-uniform density distribution of the vehicle and the high-speed motion of the vehicle, the link is easily disconnected due to the movement of the node, these problems have become a challenge for routing protocols in the vehicle ad hoc networks[1-2].

In recent years, the research and application of routing protocols have attracted more and more attention in the vehicle ad hoc networks. In the [3] proposed VADD (vehicle-assisted data delivery) protocol, the vehicle movement could be predicted by the vehicle traffic of the historical road segment, the node finds the next road segment of packet forwarding, which reduces the delay. The optimal path based on historical statistics is not real-time. CMGR protocol[4] considered that the connectivity of the link depends on the vehicle density and the expected value of the vehicle density change rate during the node sends a request packet until the node receives a response packet. When the link is stable, the minimum delays as the main parameter.

The existing predictive routing algorithms for intersections have the following problems: (i) The road segment of average vehicle density is obtained as the best route through statistical measurement or historical statistics, but the vehicle density will change dynamically with the high speed movement of the vehicle, the selected path is sometimes very poor[5]. (ii) The non-uniform distribution of vehicle density can’t guarantee the connectivity between nodes.

2. Hello Packet Exchange Algorithm
We think that the width of the road is much smaller than the communication radius of the vehicle, so the vehicle on the road may be approximately considered to be in an one-dimensional space. We use Markov process to model the link state, describe it as a Markov chain with absorption boundary. The
link connection probability is calculated based on the first arrival probability and one step transition probability matrix.

2.1. Link Connectivity Probability
The vehicle is mapped to an one-dimensional space in the lane, as shown in fig.1, the ellipse is the communication range of the vehicle A, the state 0 indicates that the nodes A and B overlap, and R is the communication radius of the nodes, that is, the state where the nodes A and B are separated from each other. State space \( Y = \{0, 1, 2, \ldots, R\} \), let \( u_a \) be the probability that A node first reaches state R from state \( a \), the first probability of A node is \( u_a \), and state 0 and state R are taken as the absorption states. A, B nodes overlap in states 0, A and B must be connected, \( u_a = 1 \), the link is disconnected between A, B nodes in states R, \( u_R = 0 \). If node A moves from state \( i \) to \( i+1 \) with probability \( p \) relative to B, \( u_i \rightarrow u_{i+1} \), similarly, node A moves from state \( i \) to \( i-1 \) with probability \( q \) relative to B, \( u_i \rightarrow u_{i-1} \), using the full probability formula:

\[
\begin{align*}
\sum_{k=0}^{R} (u_i - 1) \sum_{j=0}^{k-1} \left( \frac{q}{p} \right)^j
\end{align*}
\]

So that is

\[
\begin{align*}
u_R - u_i &= (u_i - 1) \sum_{i=k}^{R-1} \left( \frac{q}{p} \right)^i \\
k &= 0, 1, 2, \ldots, R
\end{align*}
\]

If \( k=0 \), according to \( u_0 = 1, u_R = 0 \), calculated

\[
\begin{align*}
-1 &= \left( u_i - 1 \right) \sum_{i=0}^{R-1} \left( \frac{q}{p} \right)^i \\
&= \frac{1}{\sum_{i=0}^{R-1} \left( \frac{q}{p} \right)^i}
\end{align*}
\]

Substitute equation(3)into equation(2)

\[
\begin{align*}
u_R - u_k &= \frac{-1}{\sum_{i=0}^{R-1} \left( \frac{q}{p} \right)^i} \\
k &= 0, 1, 2, \ldots, R
\end{align*}
\]

If \( k = a, u_R = 0 \) then Connectivity probability

\[
\begin{align*}
P_c &= 1 - u_a = \frac{1 - \left( \frac{1-p}{p} \right)^a}{1 - \left( \frac{1-p}{p} \right)^R}
\end{align*}
\]

2.2. One-step Transition Probability Matrix
The communication radius $R$ is divided into $n$ and the like $s = \frac{R}{n}$, the probability of $s_{k-1}$ arrival $s_k$ after one step (i.e., one time slot), it is a one-step transition probability, so that the one-step transition probability $p = P_{ij}$, the one step distance are within the $(0,ns)$ interval, $s \in [(i-1)n,in]$, $i \in [1,s]$.

$$P_{ij} = \frac{\int_{(i-1)n}^{in} \int_{(i-1)n}^{in} f(s_k|s_{k-1})f(s_{k-1}) ds_{k-1} ds_k}{\int_{(i-1)n}^{in} f(s_{k-1}) ds_{k-1}}$$  \hspace{1cm} (6)$$

Set $v$ as the current speed and $a$ as the maximum acceleration of the vehicle, then one-step distance $s = v + \frac{1}{2}a$, according to the vehicle ad hoc network intelligent driving mobile model IDM, there is

$$s = v + \frac{1}{2}a[1-(\frac{v}{v^*})^\delta - (s_0 + v/v^* \frac{v^*}{2\sqrt{ab}})]$$  \hspace{1cm} (7)$$

$v^*$ is the target speed, $\delta$ is acceleration correlation coefficient, usually $\delta \in [1,5]$, $s_0$ is the blocking distance of the vehicle, $T$ is the safe interval time, $\Delta v$ is the difference between the speed of the vehicle ahead and $b$ is the maximum deceleration.

The derivative of the one step distance is obtained:

$$s'(v) = 1 - \frac{a(v/v^*)^{\delta-1}}{2} - 2(T + \frac{1}{2\sqrt{ab}})(T + \frac{\Delta v}{2\sqrt{ab}})$$  \hspace{1cm} (8)$$

$$f(s) = \frac{f(v)}{|s'(v)|}$$  \hspace{1cm} (9)$$

Transfer probability density function

$$f(s_k|s_{k-1}) = \int_0^{2\pi} f_{s_k|s_{k-1}}(s_k|s_{k-1}, v_k)f(v_k) dv_k$$  \hspace{1cm} (10)$$

According to the literature [5], $v_k$ the probability density is basically in line with the Gaussian distribution, $s_k = s_{k-1} + v_k$ and therefore $f_{s_k|s_{k-1}}(s_k|s_{k-1}, v_k)$ is also a Gaussian distribution, probability density function of the relative rate $v_k$ between two nodes:

$$f(v_k) = \frac{1}{\sigma \sqrt{2\pi}} \exp\left(-\frac{(v_k-u)^2}{2\sigma^2}\right)$$  \hspace{1cm} (11)$$

Substituting formulas (9), (10) and (11) into formula (6) can solve the one-step transition probability $p = P_{ij}$, and then substituting formula (5) to obtain the connectivity probability $P_c$. The connectivity probability has a one-to-one relationship with the hello packet exchange period. The maximum Hello packet exchange period $T = \frac{R-\alpha S}{2v^*}$, set Hello packet exchange period to $t$, with $t = \lambda t_c = \frac{R-\alpha S}{2v^*}$, $\lambda$ is the Hello packet exchange period correlation coefficient. Set a connectivity probability threshold $P_{th}$, when $P_{th}$ approaches zero, the link can be considered disconnected.

3. Predictive Routing Method Based on CP Neural Networks

CP networks refer to counter propagation neural networks. The CP neural network classifies the priority of the next road segment where the packet is forwarded at the intersection.

3.1. Parameter Setting of CP Neural Network

CP neural network is used to classify the priority of the next segment of packet forwarding. As shown in figure 2, input the average link connection probability, the average node density, the ratio of the distance from the next intersection to the destination and the distance from the current intersection to the destination is taken as input. As shown in Table 1, the probability of connection is divided into three levels: good, medium and poor. The corresponding quantization values are 0.9, 0.7, and 0.5. The density is divided into three levels: high, medium, and low. The normalized quantization values are 0.8, 0.5, and 0.3. Ratio of the distance is also divided into three grades: near, medium, and far. The normalized quantization values are 0.2, 0.4, and 0.6. Four expected outputs are represented by binary
codes. As shown in table 1, output values: 0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110. They represent the next road segment priority of packet forwarding. They are divided into 15 levels in total. The higher the connectivity probability, the lower the density, and the lower the distance ratio, then, the higher the next road segment priority of packet forwarding is set, the first priority level is highest, and so on.

Table 1. List of priority levels of the next road segment for packet forwarding

| Connected probability | Density | Distance ratio | Output number | Road segment priority |
|------------------------|---------|----------------|---------------|----------------------|
| 0.9                    | 0.5     | 0.2            | 0000          | 1                    |
| 0.9                    | 0.5     | 0.4            | 0001          | 2                    |
| 0.9                    | 0.5     | 0.6            | 0010          | 3                    |
| 0.9                    | 0.8     | 0.2            | 0011          | 4                    |
| 0.9                    | 0.8     | 0.4            | 0100          | 5                    |
| 0.9                    | 0.8     | 0.6            | 0101          | 6                    |
| 0.7                    | 0.5     | 0.2            | 0110          | 7                    |
| 0.7                    | 0.5     | 0.4            | 0111          | 8                    |
| 0.7                    | 0.5     | 0.6            | 1000          | 9                    |
| 0.7                    | 0.3     | 0.2            | 1001          | 10                   |
| 0.7                    | 0.3     | 0.4            | 1010          | 11                   |
| 0.7                    | 0.3     | 0.6            | 1011          | 12                   |
| 0.5                    | 0.3     | 0.2            | 1100          | 13                   |
| 0.5                    | 0.3     | 0.4            | 1101          | 14                   |
| 0.5                    | 0.3     | 0.6            | 1110          | 15                   |

3.2. Optimal Road Segment Selection for Packet Forwarding

Node check whether they are located at an intersection based on the GPS location information in the vehicle ad hoc network, and if so, it uses its own node identification number. All inputs are normalized and input into the trained CP network to obtain the priority of each adjacent road segment, the highest priority road segment is selected as the data packet forwarding road segment. Obtain the density information: we divide the road into fixed small area units. The vehicles of each unit form a cluster, with the vehicle closest to the center of the unit as the cluster head. The cluster head node calculates the node density in the cluster, then the node density in the cluster construct the...
unit density packet, the node density of the whole segment is obtained by transferring and updating the density value in the unit density packet between the clusters.

4. Simulation Results

The traffic map is customized in the vehicle movement activity generating tool VanetMobisim, greedy geographic routing protocol is transplanted into the Network Simulator-V2 network simulation platform. The simulation scenario is set as shown in table 2. In the same traffic scenario and the same data flow environment, greedy geographic routing protocol (GPSR) is compared with greedy geographic routing protocol based on connectivity probability Hello packet exchange period (called CP-GPSR). When node build neighbor node table, GPSR uses periodic Hello packet exchange period algorithm, while CP-GPSR uses Hello packet exchange period algorithm based on connectivity probability.

| Table 2. Setting of Simulation Scenarios |
|-----------------------------------------------|
| GPSR, VADD, CMGR | CP-GPSR |
| scene size | 1000m×1000m |
| number of nodes | 50,60,70,80,90,100 |
| rate of motion | [30,40],[40,50],[50,60],[60,70],[70,80],[80,90] (km/h) |
| communication radius | 250 m |
| mac protocol | 802.11P |
| data type | CBR 512 bit |
| data rate | 10/s |
| Hello packet exchange period | 5s | The dynamic calculation of connected probability |
| simulation time | 300S |

As shown in fig. 3, GPSR, VADD, CMGR use periodic Hello packet exchange and CP-GPSR uses Hello packet exchange based on connectivity probability, they are at the same node movement rate ([30,40]km/h), the same node communication radius R = 250. With the increase of the number of nodes in the network, the density of nodes increases, which greatly improve the success rate of data packet transmission from the source node to the destination node. CMGR sends a Hello packet with a fixed period, the average expected error of the estimated density change rate is very large, so that its data packet transmission success rate is not as good as CP-GPSR. As shown in figure 4, as the number of nodes increases, the control overhead of each protocol increases accordingly. CP-GPSR uses a trained CP neural network model. When the packet selects the forwarding road segment at the intersection, the protocol overhead is lower and the control cost is better than the CMGR protocol.

![Figure 3. Packet transmission success rate when the number of nodes increase](image)
5. Conclusion

In this paper, we propose a routing protocol based on CP neural network for vehicular ad hoc networks. The connection probability of the current link is calculated based on the first arrival probability and one-step transmission matrix. The link connection probability corresponds to the running time of a link, triggers the next Hello packet exchange to use the running time. The CP neural network classifies the priority of the next road segment in which the packet is forwarded at the intersection, selects the highest priority road segment as the packet forwarding road segment. Simulation results show that the proposed routing protocol is superior to GPSR, VADD and CMGR in performance.

Acknowledgements

This research is supported in part by foundation research project of the Natural Science Foundation of JiangXi Province under Grant No. 20181BBE58018 and the Science and Technology Project of Jiangxi Education Department under Grant No. GJJ190460.

References

[1] Darwish, T., Abu Bakar, K., Lightweight intersection-based traffic aware routing in Urban vehicular networks. Computer Communications 2016(87): 60–75.
[2] García-Costa, C., Egea-López, E., García-Haro, J., Evaluation of MAC contention techniques for efficient geo-routing in vehicular networks. Ad Hoc Networks 2016(37): 44–62.
[3] Zhao J. Cao G. VADD: Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks, INFOCOM 2006. 25th IEEE International Conference on Computer Communications, 2006.
[4] K. Shafiee, V.C.M. Leung. Connectivity-aware minimum-delay geographic routing with vehicle tracking in VANETs, Ad Hoc Network. 2017 (2):131–141.
[5] Rivoirard, L., Wahl, M., Sondi, P., Berbineau, M., Gruyer, D., Chain-Branch-Leaf: A clustering scheme for vehicular networks using only V2V communications. Ad Hoc Networks 2018(68): 70–84.