

# Research on Region-Based Vehicular Ad Hoc Network Clustering Algorithm

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**Abstract.** Aiming at the complicated environment of Vehicular Ad Hoc Networks(VANET),in this paper,a region-based adaptive clustering algorithm (ZACA) is proposed.Through classifying the road environment into segment and intersection, respectively calculating the connectivity according to the different road environments, and combine it with the regional location and the traditional synthesis weights of the Weighted Clustering Algorithm,the election of the cluster head under different road models and the maintenance of cluster based on the network area are realized.Simulation result shows this method can adapt to vehicular network environment effectively, and also can improve the stability of the cluster and reduce the clustering overhead.

## 1. Introduction

Due to the challenges that caused by the dynamic change of network topology during data transmission,VANET gained great attention by industry and academia[1,2,3] and the clustering technique has become a research hotspot.

Peng F et al.[4] proposed a weighted clustering strategy suits to the VANET which based on Weighted Clustering Algorithm, it adds the traffic information and modifies the weight of average speed  $v$  to adapt to the vehicle's mobile environment.The HD clustering strategy[5] uses the combination of node connectivity and the minimum ID as the basis of clustering.By maintaining the information of neighbor table,it selects the node with optimal connectivity as the cluster head.This strategy is simple and effective, it ensures a smaller scale of cluster and reduces the packet delivery delay[4,5,6].

This paper considering connectivity and link up time of segment and intersection respectively, then combine the traditional Weighted Clustering Algorithm to achieve the election and maintenance of cluster head,thus improved the stability and suitability of the cluster effectively.

## 2. Dynamic clustering algorithm based on region adaptive

### 2.1 The calculation of connectivity

In order to describe the connectivity of vehicular ad hoc network, defined as follows:

i) The topology of vehicular ad hoc network can be seen as an undirected graph which constituted by nodes and links,denoted by  $G(V, E)$ ,  $V$  is the set of vehicle nodes,  $E$  is the set of links.

ii) Connectivity of node

The connectivity of node  $N_a(t)$  is the quantity of all the neighbor nodes that can be connected with vehicle node  $a$  at time  $t$ ,its formula is as shown in Formula(1),  $D_{ai}(t)$  is the distance between node  $a$  and node  $i$  at time  $t$ ,  $D_{th}$  is the threshold which satisfied  $D_{th} \leq r$ ,  $r$  is the communication radius of the vehicle.

$$N_a(t) = \sum_{i=0}^m i \{i | D_{ai}(t) \leq D_{th}\} \quad (1)$$

iii) Average strength of connectivity

$Q_a(t)$ , strength of connectivity, is the average duration that node  $a$  linking with its neighbor node  $i$  at time  $t$ . Calculation formula is as shown in Formula (2),  $T_{ai}(t)$  is the predicted duration that node  $a$  can connecting with node  $i$  at time  $t$ .  $m$  represents  $N_a(t)$ .

$$Q_a(t) = \left( \sum_{i=0}^m T_{ai}(t) \right) / m \quad (2)$$

iv) Connectivity of region

$C_z(t)$ , connectivity of region, is the average connectivity of the nodes that in the region  $Z$  at time  $t$ . It shows the situation of the region's connectivity. Calculation formula is as shown in Formula (3),  $i$  is a node in region  $Z$ .  $N_i(t)$  is the connectivity of node  $i$ .  $n$  is the quantity of the nodes in region  $Z$ .

$$C_z(t) = \left( \sum_{i=0}^n N_i(t) \right) / n \quad (3)$$

## 2.2 Connectivity time $T_{ab}(t)$

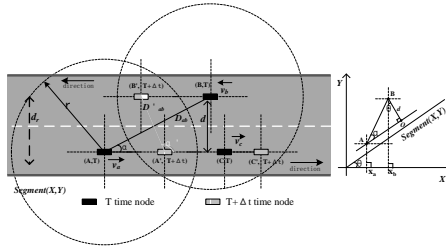


Fig.1 Segment prediction

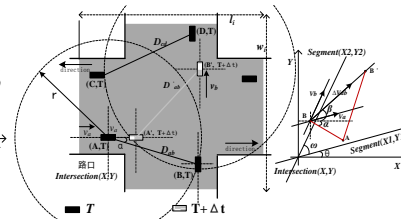


Fig.2 Intersection prediction

The road environment is divided into segment model and intersection model, then calculate the link connecting time of node separately.

i) Connectivity prediction of Segment

Under the segment model, the vehicles' positions are approximately in a straight line. Relative moving direction of the vehicles is divided into the same and opposite directions. When node A and B are in the connected state at time  $t$ , the connectivity time  $T_{ab}(t)$  satisfies Formula (4).  $x_a(t)$  and  $y_a(t)$  respectively represent the abscissa and ordinate of node A.  $v_a(t)$  is the velocity vector of node A at time  $t$ .  $r$  is the node's communication radius.  $D_{ab}(t + \Delta t)$  is the distance between node A and B at time  $t + \Delta t$ , it is calculated by the Formula (5).  $\alpha$  is the angle between the line which connected by node A and B and the road at time  $t$ , it satisfies  $0^\circ \leq \alpha \leq 180^\circ$ .  $\overline{\Delta v_{ab}}$  is the average relative speed of node A and B during the time  $\Delta t$  and satisfies  $\overline{\Delta v_{ab}} = \overline{v_a(\Delta t)} - \overline{v_b(\Delta t)}$ .  $D_{ab}$  is the distance between vehicles and satisfies Formula (6).  $d$  is the distance between node A and B that in the direction perpendicular to the road. Under the segment model, when A and B in the same lane,  $d$  is 0, when A and B in the adjacent lanes,  $d$  is similar to  $d_r$ ,  $d_r$  is the width of road.

$$D_{ab}(t + T_{ab}(t)) \leq D_{th} \quad (4)$$

$$D_{ab}(t + \Delta t) = \sqrt{(\sqrt{(x_a(t) - x_b(t))^2 + (y_a(t) - y_b(t))^2} \cdot \cos \alpha - \overline{\Delta v_{ab}} \cdot \Delta t)^2 + d^2} \quad (5)$$

$$\sqrt{(x_a(t) - x_b(t))^2 + (y_a(t) - y_b(t))^2} = d \cdot \csc \alpha \quad (6)$$

As shown in fig.1, the distance  $d$  and the coordinates of node A and B meet the Formula (7).  $\theta$  is the angle between the road and the horizontal direction, it satisfies  $0^\circ \leq \theta \leq 90^\circ$ .

$$d \cdot \cot \alpha = |x_a(t) - x_b(t)| \cdot \frac{1}{\cos \theta} + d \cdot \frac{\sin \theta}{\cos \theta} \quad (7)$$

Combine the Formula (7), (6), (5), (4), we get the simplified formula as Formula(8):

$$T_{ab}(t) = \frac{-\sqrt{D_{th}^2 - d^2} \cdot \cos \theta + |x_a(t) - x_b(t)| + d \cdot \sin \theta}{\Delta v_{ab} \cdot \cos \theta} \quad (8)$$

## ii) Connectivity prediction of Intersection

As shown in fig.2, the gray region is defined as the intersection region. Definitions as follows:

When the vehicle A and B are located in the *Intersection*( $x, y$ ) at the same time and the moving directions of the A and B point to different sections.

1) If the distance between A and B satisfies the Formula(9), then  $T_{ab}(t) = 0$ .  $l_i$  and  $w_i$  represent the length and width of the intersection.

$$D_{ab}(t) > \sqrt{l_i^2 + w_i^2} / 2 \quad (9)$$

2) If the distance between A and B doesn't satisfy the Formula(9), the calculation formula of distance at time  $t + \Delta t$  is as shown in Formula(10):

$$D_{ab}(t + \Delta t) = \sqrt{[x_a(t + \Delta t) - x_b(t + \Delta t)]^2 + [y_a(t + \Delta t) - y_b(t + \Delta t)]^2} \quad (10)$$

The calculation formula of node A's location coordinates at time  $t + \Delta t$  are as shown in Formula(11), Formula(12),  $\theta$  is the angle between the direction of the segment where node A in and horizontal direction, it satisfies  $0^\circ \leq \theta \leq 90^\circ$ .

$$x_a(t + \Delta t) = x_a(t) + \overline{v_a(\Delta t)} \cdot \cos \theta \cdot \Delta t \quad (11)$$

$$y_a(t + \Delta t) = y_a(t) + \overline{v_a(\Delta t)} \cdot \sin \theta \cdot \Delta t \quad (12)$$

As shown in fig.2, we also can get the calculation formulas of node B's location coordinates at time  $t + \Delta t$ , they are as shown in Formula(13), Formula(14).  $\omega$  is the angle between two segments where node A and B respectively in, it satisfies  $0^\circ \leq \omega \leq 180^\circ$ .

$$x_b(t + \Delta t) = x_b(t) + \overline{v_b(\Delta t)} \cdot \cos(\theta + \omega) \cdot \Delta t \quad (13)$$

$$y_b(t + \Delta t) = y_b(t) + \overline{v_b(\Delta t)} \cdot \sin(\theta + \omega) \cdot \Delta t \quad (14)$$

Combine all the above formulas and Formula(4), under the condition that the distance is less than or equal to the  $D_{th}$ , we can get the calculation formula as Formula(15):

$$T_{ab}(t) = \frac{-(\Delta v_x \cdot \Delta x + \Delta v_y \cdot \Delta y) + \sqrt{[(\Delta v_x)^2 + (\Delta v_y)^2] D_{th}^2 - (\Delta v_x \cdot \Delta v_y - \Delta x \cdot \Delta y)^2}}{(\Delta v_x)^2 + (\Delta v_y)^2} \quad (15)$$

$\Delta v_x$  and  $\Delta v_y$  respectively represent the difference between node A's and node B's horizontal and vertical velocity components of the coordinate system during  $\Delta t$ ,  $\Delta x$  and  $\Delta y$  respectively represent the difference between node A's and node B's horizontal and vertical components of the coordinate system at time  $t$ .

## 2.3 Priority selection

In this paper, we take the improved scheme that based on weighted clustering WCA as the cluster head election mechanism, weighted for different parameters, distinguish the current environment of the road that the node on. The node with the maximum overall weight value has the best performance and it will be elected as the cluster head node preferentially. The calculation formula of node comprehensive connectivity weight as Formula(16):

$$W_{con}(i) = \omega_1 \cdot \Delta q(i) + \omega_2 \cdot \frac{N_i}{N_{th}} + \omega_3 \cdot \Delta v(i) + \omega_4 \cdot \frac{N_c}{N} \quad (16)$$

$N_i$  is the connectivity of node,  $N_{th}$  is the connectivity threshold of system and its size depends on the network size and the quantity of vehicles,  $N$  represents the quantity of node i's neighbor

nodes.  $N_c$  is the quantity of the neighbor node that with the same direction of motion as node  $i$ .  $\omega_1, \omega_2, \omega_3, \omega_4$  are the weighting factors.  $\Delta q(i)$  is the normalized value of node  $i$ 's connectivity strength and it represents the relative size of the current node's connectivity strength and neighbor node's, it satisfies  $\Delta q(i) \leq 1$ .  $\Delta v(i)$  represents the motion state of the current node  $i$  and it satisfies  $\Delta v(i) \leq 1$ . The calculation formulas of  $\Delta q(i)$  and  $\Delta v(i)$  as Formula(17) (18) :

$$\Delta q(i) = \frac{Q_i}{\max \{Q_i, (Q_j | j = 1, 2 \dots N)\}} \quad (17)$$

$$\Delta v(i) = \frac{1}{(1 + \delta(i, t))} \cdot \frac{\ln(v_{\max}) - \ln(v_i)}{\ln(v_{\max})} \quad (18)$$

$Q_i$  and  $Q_j$  represent the connectivity strength of node  $i$  and node  $j$ ,  $v_{\max}$  represents the maximum speed,  $v_i$  represents the current speed of node  $i$ ,  $\delta(i, t)$  is the speed variance of node  $i$  during the period  $(t - \Delta t)$  and we define  $\Delta v(i) = 1$  when the vehicle's speed in the interval  $[0, 1]$ .

In the  $Intersection(x, y)$ , the connectivity strength of vehicle is higher and the speed is slower, the comprehensive connectivity weight  $W_{con}$  is bigger. After the node becomes a cluster head, the stability of clustering is better.

## 2.4 Formation of cluster

In the network initialization phase, the node acquires the location information  $p(x, y)$ , speed  $v$  and direction  $d$ , then populates the location information to the appropriate field of BM package and broadcasts it to the neighbor nodes. After the node receives the BM package that sent from its neighbor node, it updates the neighbor table. By traversing the neighbor table, calculate the current node's connectivity  $N_i$ , connectivity strength  $Q_i$ , region connectivity  $C_z$  and the comprehensive connectivity weight  $W_{con}(i)$ , then start to perform the network region clustering algorithm ZACA. The cluster formation flow chart is as shown in fig.3.

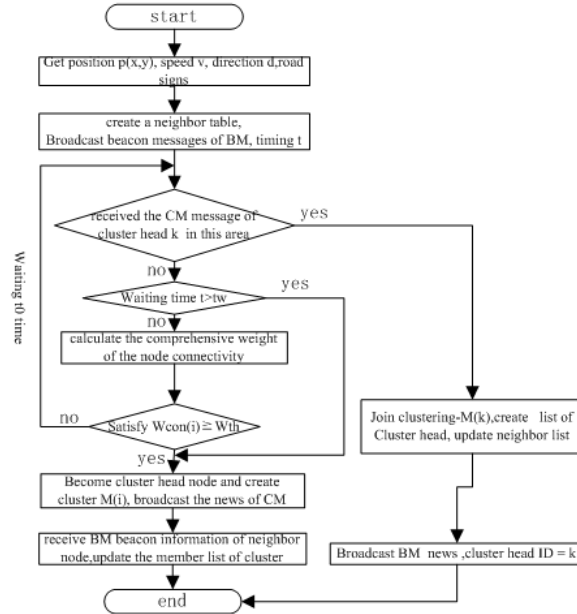


Fig.3 Cluster formation flow

## 2.5 Cluster maintenance process

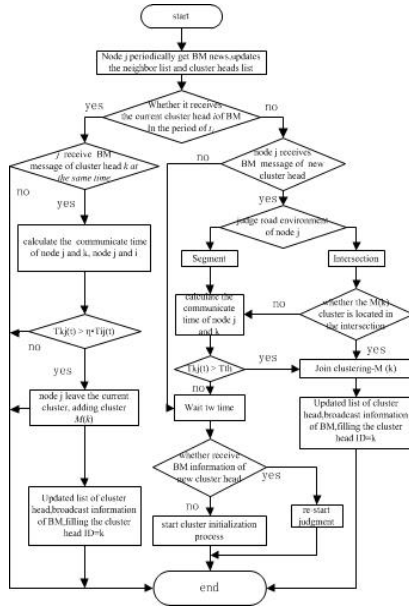


Fig.4 The maintenance flow

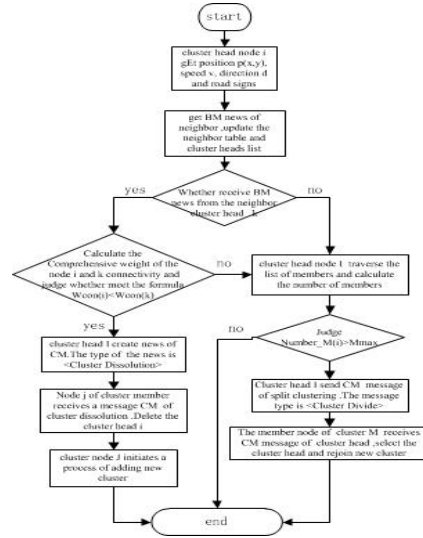


Fig.5 The adjustment flow

1 The maintenance flow chart of join and leave the cluster is as shown in fig.4.

2 In order to reduce the superposition degree and redundant of clusters, cluster's adjustment flow chart is as shown in fig.5.

### 3. Simulation Result

It can be seen from fig.6, with the movement of the vehicles, the quantity of cluster head is stable and the range is [22,31] when using the ZACA clustering algorithm, while the quantity of cluster heads is large fluctuating when using the HD clustering algorithm. HD's average quantity is higher than ZACA's.

It can be seen from fig.7, with the vehicle quantity increasing, compared with HD clustering algorithm, the

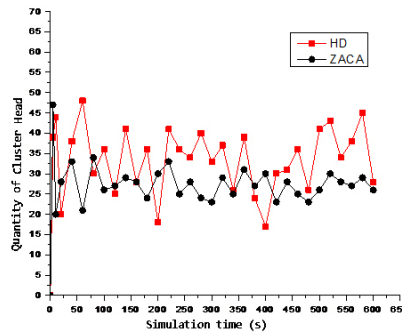


Fig.6 Quantity of cluster head

ZACA algorithm has a slower growth of node average transfer times.

It can be seen from fig.8, with the increasing of the node quantity, compared with HD clustering algorithm, the cluster update times of the ZACA algorithm is lower and the growth of update time is slower

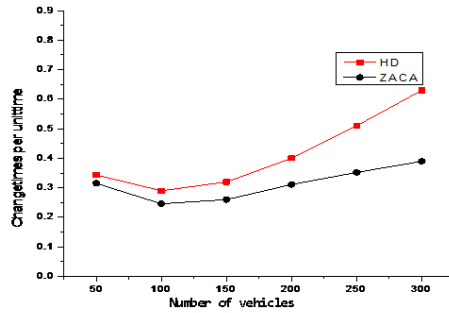


Fig.7 Change times per unit time

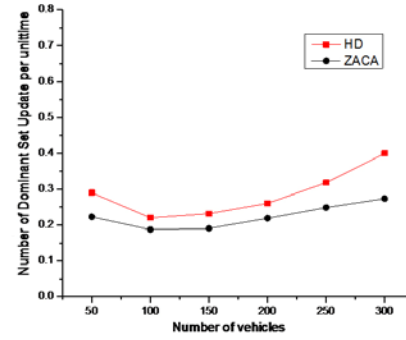


Fig.8 Cluster update times

#### 4. Conclusions

This paper proposed a new node clustering algorithm ZACA which based on the region. The simulation results show that the ZACA clustering algorithm has the ability to improve the stability of cluster , environmental adaptability, and reduce the costs effectively.

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