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Study on V2V Clustering Algorithm in Heterogeneous Network Based on VANET and LTE-V2X

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Abstract. For the high reliability requirements of vehicle network message propagation, in order to solve the problems of network segmentation and broadcast storm of message propagation mechanism in current VANET, and to meet the performance of communication networks under different environments and high vehicle density. A heterogeneous network based on IEEE 802.11p-based VANET and LTE-V2X is constructed, to combine high-rate and high-reliability communication. The communication network is layered by an effective clustering algorithm, and the LTE-V2V is used for communication between the cluster heads, and the cluster members and the cluster heads adopt VANET communication. A new clustering algorithm is proposed to introduce the LTE base station received signal strength RSSI as a clustering factor into the weighted clustering algorithm, which ensures a good communication link between the cluster head and the base station. By improving the formula of the distance sum with the neighbor nodes, The distance between the node and each neighbor node is better described. At the same time, the algorithm also uses direction, mobility and node degree as weighting factors to form a more efficient cluster. The simulation results show that the architecture has better network performance, and is superior to the classical traditional algorithms in cluster stability, number of isolated nodes, and has practical application value.

Keywords: clustering, heterogeneous network, LTE-V2V, L-WCA, VANET

1 Introduction

Due to the complexity of the Internet of Vehicles system, the communication technologies applied to the Internet of Vehicles have their limitations. It is difficult to meet the requirements of high reliability and low latency of vehicle communication through a single network; And with the explosive growth of vehicle users, resulting in the lack of communication resources and increasing network congestion, reasonable resource management will become very important. In order to better meet the performance of communication networks under different environments and high vehicle densities, network heterogeneity has become a necessary trend for network development. In [1], the author studied the coexisting environment of Dedicated Short Range Communications (DSRC) network and LTE-Vehicle to Everything (LTE-V2X) network, and proposed that a small number of vehicles with two communication interfaces should relay packets under different networks to achieve network intercommunication. However, when there are data packets to be relayed, it is necessary to prioritize the available relaying vehicles within the communication range to select the optimal relaying vehicles, resulting in the increase of communication delay. and each time a message needs to be relayed, The choice of relays adds complexity to the system. In [2], the author introduced a multi-hop clustering method under the heterogeneous network of VANET and LTE. The cluster head (CH) sends the message to the base station, and the base station forwards it to the adjacent base station. The adjacent base station broadcasts the

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information to reach farther. However, the network topology of the Internet of vehicles changes rapidly, and the stability of multi-hop cluster is difficult to maintain, which seriously affects the communication performance of the system. Moreover, when the message is broadcast through the adjacent base station, it will interfere with the traditional cellular communication and affect the reliability of information transmission. Literature [3] integrates the heterogeneous network of VANET and 3G, and adopts mobile gateway to relay information of VANET to 3G network. However, due to the high mobility of vehicles, the effective time of selected gateways is very short, so frequent gateway selection is needed to increase the network overhead.

In order to solve the above problems, a heterogeneous network based on VANET and LTE-V2X is constructed. By integrating VANET and LTE-V2V into a heterogeneous network, the high rete and high reliability of communication are combined. In order to further optimize the performance of the network, reduce the death nodes in the network, reduce the total frequency of the base station scheduling resources to reduce the network overhead, and ensure the effectiveness of the cluster and the stability of the communication link between vehicles in the same cluster, a clustering algorithm considering both the measurement criteria of the cluster and frequent topology changes is proposed. Through the analysis of simulation, the network architecture and clustering algorithm proposed in this paper are improved in terms of network performance and cluster stability.

2 System Architecture

Nowadays, the mainstream technologies that are more commonly used are VANET based on 802.11p, centralized control structure based on LTE architecture, and LTE-V2X. VANET is a typical application of mobile ad hoc networks in intelligent transportation. No infrastructure is required in the communication process. Vehicles, as nodes, form intelligent transportation networks with other vehicles and roadside facilities, which can provide high-speed data transmission of 6Mbps to 27Mbps [4]. However, due to the high mobility of the vehicle, VANET has the characteristics of rapid network topology changes and difficulty in maintaining communication links; and when there are fewer or more vehicles, network interruptions and broadcast storms are prone to problems that seriously affect communication performance. As the LTE network has been widely deployed around the world, its network architecture has the characteristics of flexible bandwidth configuration and support for high-speed mobility, the LTE architecture is also used for vehicle networking. However, the LTE network protocol does not support direct communication between vehicles. All data packets need to be forwarded through the base station, which will cause serious interference to other cellular users. At present, 3GPP is making related standards for LTE-V2V. LTE-V2V technology will be realized through the enhancement of Device to Device Communication technology (D2D) [5]. In order to meet the characteristics of the Internet of Vehicles communication, the LTE-V2V scheduling method and resource allocation were redesigned based on D2D communication [6], and the resource allocation methods of mode 3 (base station scheduling resources) and mode 4 (autonomous vehicle resource selection) were proposed. Compared with the problem of resource selection conflict caused by Mode 4, Mode 3 can better ensure the reliability of communication, but there are a series of problems such as increased signaling overhead. And in urban scenes or high-density environments, due to insufficient resources, high delays and high packet loss rates are easily caused, and periodic messages are sent every 100ms, which is easy to overload.

Due to the complexity of the Internet of vehicles system, it is difficult to provide satisfactory inter-vehicle communication services only through a single wireless network. Therefore, by constructing a heterogeneous network based on VANET and LTE-V2X, and integrating the advantages of the two networks, it is expected to become a good platform to meet various stringent requirements of vehicle communication services [7]. The architecture adopts LTE-V2V combined with the vehicle self-organizing network, which can avoid interference with cellular communication when using LTE for message forwarding in traditional heterogeneous networks; and vehicle-to-vehicle communication of LTE-V2X belongs to end-to-end communication with delay performance better than forwarding over a cellular network.

Fig. 1 shows the constructed heterogeneous network architecture. First, make unified assumptions about the model of the system: (1) All vehicle nodes are equipped with communication on board units (OBUs) and global positioning systems (GPS) for V2V communication and to obtain information such as the position and speed direction of the vehicle nodes; (2) All vehicle nodes have an LTE base station interface for communication with the base station, LTE-V2V interface and 802.11p interface for communication between vehicle nodes [8]. Second, as shown in Fig. 1, this scenario considers two tracks in different directions on a specific road (highway). There are three types of vehicles on the road, cluster head vehicles, cluster member (CM) vehicles, and isolated nodes. In addition, There are two communication links. Within a cluster, CM send data packets to the CH through VANET; the data at the CH is aggregated, and the CH forwards it to other CH by the LTE-V2V mode 3. Compared with all vehicles that use mode 3 to directly request resources from the base station for communication, it is easy to cause a communication bottleneck. The hierarchical structure is adopted, and only the CH applies for resources to the base station, which can greatly reduce the number of vehicle nodes that request resources from the base station at the same time To avoid network congestion; And because vehicles moving along the same road, the base station switching mechanism is performed at almost the same time. Compared to each vehicle performing network switching, only the CH performs network switching at the cell edge, which can significantly reduce signaling overhead.

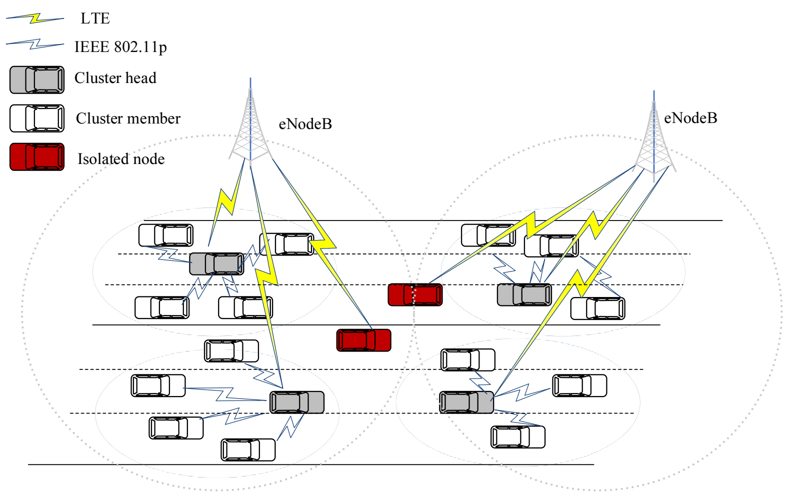

Fig. 1. Heterogeneous network architecture based on VANET—LTE-V2X

The use of a cluster structure in a heterogeneous network can effectively improve the problems of communication links are easily interrupted, network congestion, and increased signaling overhead caused by rapid and frequent network topology changes and excessive vehicle nodes. Therefore, it is very important that how to form an effective and stable cluster. Traditional clustering algorithms are mostly based on WSN networks with stationary or low-speed nodes, and Ad hoc networks with small node density [9]. For example, the traditional weighted clustering algorithm, the clustering factor considers the energy of the nodes, the sum of the distances between the nodes, the average moving speed, and other factors, which cannot meet the characteristics of high mobility and high density of the Internet of Vehicles. Under this background, this paper will propose a new weight clustering algorithm based on the constructed heterogeneous network environment. Compared with the traditional weighted clustering algorithm, the following three aspects will be improved. That is: (1) the introduction of Received Signal Strength Indication (RSSI) of LTE base station is one of the influencing factors of clustering. Since the communication between CH and CH needs to apply for resources from base station, the introduction of RSSI factor can better guarantee the communication link quality of CH and base station, CH and CH. (2) the distance variance formula between the node and the neighbor node is proposed to replace the distance sum formula between the node and the neighbor node in the traditional algorithm. Compared with the traditional formula, the distance between the node and each neighbor node can be better described to ensure that the vehicles in the neighborhood have a good communication distance. (3) In order to better adapt to the rapid mobility of the vehicle and the increase in the number of nodes, to ensure the effectiveness of the cluster and the stability of the link, in addition to the above two factors, factors such as vehicle movement direction, relative mobility and optimal size of clusters will also be considered.

3 Description of the L-WCA algorithm

3.1 Specific Representation of Clustering Parameters

Clustering and the election of cluster heads involve many factors. The parameters used are specifically defined and expressed below.

Direction. Since vehicles are high-speed moving objects, if the driving direction of the vehicle is not taken into account when clustering, the vehicles in different driving directions will quickly drive out of the communication range, resulting in the reorganization of the cluster. Therefore, it is necessary to judge the vehicles in the same direction before they can be separated into a cluster, that is, the driving direction of the vehicles in the cluster is consistent with that of the neighboring nodes.

The vehicle node can obtain its position, speed and other information through GPS of the vehicle equipment. The position information of point a and any node b is expressed as (x_a, y_a) and (x_b, y_b) in cartesian coordinate system. Then the angle θ between the moving directions of the two vehicle nodes is:

$$\theta = \cos^{-1}\left(\frac{x_a x_b + y_a y_b}{\sqrt{x_a^2 + y_a^2}\sqrt{x_b^2 + y_b^2}}\right) \tag{1}$$

When $\theta \le \pi/4$, the moving direction is regarded as the same; otherwise, the direction is considered opposite.

Relative distance. Limited by the communication distance, vehicle nodes must be within a certain distance to ensure communication quality, so the relative distance between nodes is an indispensable consideration for clustering. The relative distance between node a and any node b is expressed by Euclidean formula as:

$$d(a,b) = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2} \tag{2}$$

When node a has n neighbor nodes, the relative distance in the traditional clustering algorithm is expressed by the sum of the distances between the vehicle node and the neighbor nodes, but this expression only describes the overall distance between node a and the neighbor nodes, and It cannot be said that node a is in a better communication range with each neighbor node. In order to increase the number of nodes with the optimal communication distance among neighbor nodes and improve the quality of communication, the algorithm uses the variance of node a and n neighbor nodes to replace the sum of distances in the traditional algorithm, which is expressed as follows:

$$\overline{d(a)} = \frac{1}{n}\sum_{b=1}^{n} d(a,b) \tag{3}$$

$$d(a) = \frac{1}{n}\left[\left(d(a,1) - \overline{d(a)}\right)^2 + \ldots + \left(d(a,n) - \overline{d(a)}\right)^2\right] \tag{4}$$

Among them, the smaller $d(a)$ is, the smaller the distance between the node a and other vehicles is, and the more suitable it is to be a CH.

Relative mobility. Due to the high mobility of vehicle nodes, it will lead to the instability of the cluster or the frequent implementation of the re-clustering algorithm, which will increase the network overhead. Therefore, it is very important to choose the node with the least mobility relative to the neighbor node as the cluster head. Since the velocity and acceleration of the vehicle are always changing dynamically, the relative mobility of the two vehicles cannot be accurately expressed by considering only the current velocity and acceleration. Here, the signal power detected at the receiving node indicates the distance between the sending and receiving node pairs, that is, the relative mobility between nodes is represented by comparing the receiving power of the node that has successfully received the transmission message of a node for two consecutive times [10]:

$$M(a,b) = 10\lg\left(\Pr_{b\to a}^{new} / \Pr_{b\to a}^{old}\right) \tag{5}$$

Where $\Pr_{b\to a}^{new}$ represents the receiving power of node a when node b sends the packet to node a for the first time, and $\Pr_{b\to a}^{old}$ represents the receiving power when node b sends the packet to a for the second time. If $M(a,b) < 0$, it means that the two nodes are moving away from each other. If $M(a,b) > 0$, it means that the two nodes are moving closer to each other. When node a has n neighbor nodes, then:

$$\overline{M(a)} = \frac{1}{n}\sum_{b=1}^{n} M(a,b) \tag{6}$$

$$M(a) = \frac{1}{n}\left[\left(\overline{M(a)} - M(a,1)\right)^2 + \ldots + \left(\overline{M(a)} - M(a,n)\right)^2\right] \tag{7}$$

The smaller $M(a)$ is, the smaller the relative mobility of node a relative to other nodes is, and the more suitable it is to become a cluster head.

RSSI. In order to ensure good communication quality between the CH and the base station, RSSI is used as one of the reference factors for selecting the CH. First compare the received RSSI values, delete the nodes with poor signals, Secondly, according to the changes of $RSSI_{t-1}$ and $RSSI_t$ measured twice in succession, the nodes with increasingly strong or relatively good signal quality were selected as follows:

$$\Delta = \lg\frac{RSSI_t}{RSSI_{t-1}} \tag{8}$$

$\Delta < 0$ indicates that the signal quality is getting better and better, $\Delta > 0$ indicates that the signal quality is deteriorating.

Optimal node degree. A cluster that is too large or too small can seriously affect communication performance. If the size of the cluster is too large, the load on the cluster head will be too large, causing network congestion, and the quality of the network communication will deteriorate; if the size of the cluster is too small, network resources will be wasted. Therefore, the concept of node degree is introduced to control the size of the cluster size [11].

$$D_a = |d_a - \delta| \quad \textbf{(9)}$$

Among them, represents the number of one-hop neighbors of node a, and δ represents the number of best CM. When the number of nodes is N, the bandwidth within the cluster is W_1 and the bandwidth of the backbone network composed of CHs is W_2, the optimal number of CMs is $\delta = \frac{W_1}{W_2}\sqrt{N}$. The smaller D_a is, the more suitable it is to be a cluster head.

3.2 The Analysis Model of the System

In order to assign more reasonable weighting factors to different factors, this paper uses the analytic hierarchy process [12] to calculate the weighting factors. First, a multi-level analysis model is established to level the system problem, determine the target layer and the underlying factors of the system. The target layer to select the appropriate cluster heads, the underlying factors of relative mobility, relative distance, respectively RSSI values, node degrees. Then rank the underlying factors according to their importance. The judgment basis of the importance of the factors considered is shown in Table 1.

Table 1. Judgment basis for considering the importance of factors

scale	Important degree
1	Consider factor i as important as factor j
3	Considering factor i and j, the former is Slightly important
5	Considering factor i and j, the former is obviously important
7	Considering the factors i and j, the former is very important
9	Considering factors i and j, the former is extremely important
2, 4, 6, 8	According to the judgement compromise

Construction of the decision matrix. Suppose there are m factors $a_1, a_2, \cdots a_m$. According to Table 1, judge the mutual importance of the factors to be considered. According to the following parameter properties, the decision result is represented by a matrix.

(a) If a_{ij} represents the ratio of the importance of factors i and j, then $1/a_{ij}$ represents the importance of elements j and i.

(b) $a_{ij} > 0$

(c) $a_{ii} = 1$

According to the above rules, the distance, relative mobility, node degree, and RSSI values are $a_1, \cdots, a_4$, respectively. The decision matrix constructed is as follows:

$$W = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \quad \textbf{(10)}$$

Inspection of consistency. Because of the complexity of the system and high subjectivity, it is necessary to test the consistency of the decision matrix. The ratio formula of consistency is as follows:

$$CR = \frac{CI}{RI} \quad \textbf{(11)}$$

RI is a random consistency index, whose values are shown in Table 2. CI is the consistency index to be calculated. The calculation formula is:

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{12}$$

When $CR < 0.1$, it indicates that the decision matrix meets the requirement of consistency; otherwise, it is necessary to readjust the decision matrix until it meets the requirement of consistency.

Table 2. RI random consistency indicator

Order of the matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Calculate the weighting factor. Multiply each row in the matrix by W_i, and calculate its m square root, that is:

$$\overline{W_i} = \sqrt[m]{\prod\nolimits_{j=1}^{m} a_{ij}} \quad (i = 1, 2, \cdots m) \tag{13}$$

For $\overline{W_i}$ do normalized processing, get the weight of each factor corresponding: u_i

$$u_i = \overline{W_i} \Big/ \sum_{i=1}^{m} \overline{W_i} \tag{14}$$

According to the above formula, considering the scene of the highway, the weight factors of distance, relative mobility, node degree, and RSSI value are $\{0.25, 0.55, 0.1, 0.1\}$. Bringing each weight factor into the weighted combination expression, we can obtain:

$$W(i) = \begin{cases} 0, \theta \geq \pi/4 \\ \alpha_1 d(i) + \alpha_2 M(i) + \alpha_3 \Delta + \alpha_4 D(i), others \end{cases} \tag{15}$$

The one with the lowest weight is the most suitable to be the CH.

3.3 The Flow of L-WCA Algorithm

The algorithm flow of L-WCA clustering is shown in Fig. 2, and the steps are as follows:

(1) In the initial stage of the network, all network nodes are isolated nodes, and the nodes broadcast Hello packets containing their ID, direction, speed, and location within a hop range.

(2) Calculate the moving angle θ of the vehicle, and then determine whether it is in the same direction: if $\theta \geq \pi/4$, it is considered that the two nodes move in different directions, and the corresponding node will be immediately deleted from the neighbor node.

(3) Calculate its own W value and send the W value to other members in the neighbor list.

(4) The node compares its own weight W value with other W values in the received neighbor nodes, if the value W of this node is the smallest, it becomes the CH; otherwise, it is the CM. The CH node broadcasts an Invite package containing its own ID and W value to its one-hop neighbor. When other nodes in the network receive only one Invite, it immediately replies to the CH with a Join package to Join the cluster. If two or more Invite packages are received, it selects the one with the minimum W value to send the Join package.

(5) After the formation of the cluster, the CH node and the CM node will still periodically broadcast packets containing their own ID, speed, location and other information to facilitate the maintenance and update of the cluster.

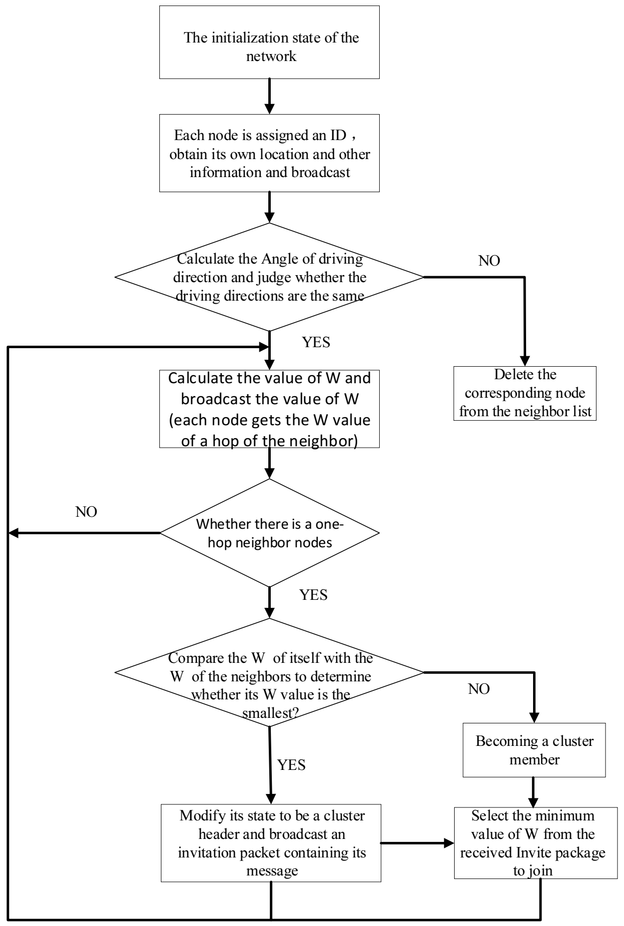

Fig. 2. Flow chart of cluster generation algorithm

4 Simulation Results and Analysis

The simulation of the L-WCA algorithm is implemented on the Matlab platform. The simulation environment considers a single cell network, including an eNB and several vehicle nodes, and the eNB is located in the center of the cell. Some parameters are shown in Table 3.

Table 3. Simulation parameter setting

parameter	Value
Vehicle density	20~60/km/direction
Maximum speed	33m/s
Channel bandwidth	20M
Highway length	2Km
Packet update frequency	10Hz
VANET technology	IEEE 802.11p
Vehicle transmission power	23dbm
Simulation duration	100s
VANET MAC Layer	DCF,CSMA/CA
Channel model	YANS

4.1 Performance Analysis of L-WCA Algorithm

The simulation compares the performance differences of L-WCA algorithm, traditional Mobic algorithm and classic WCA algorithm on the size of average cluster and the number of isolated nodes under different vehicle nodes.

Fig. 3 compares the relationship between the number of nodes and the average number of cluster members under L-WCA, MOBIC, and traditional WCA algorithms. It can be seen that because L-WCA and classical WCA algorithms take into account the factor of node degree, compared with MOBIC algorithm, when the number of vehicles increases, the performance of cluster size is still good, which can reduce the problem of excessive load caused by the large cluster size. But the classic WCA algorithm is not suitable for high-speed moving nodes, which will lead to poor performance in other areas. Due to the single factor considered by MOBIC algorithm, when the number of vehicle nodes increases, the average cluster size increases very rapidly, which is not conducive to the maintenance and management of the cluster.

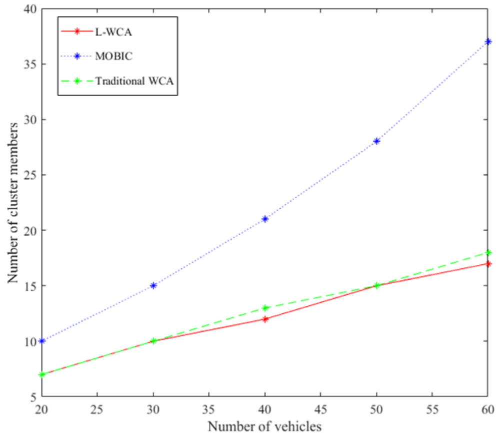

Fig. 3. Comparison of the average number of cluster members

In Fig. 4, the relationship between the number of different nodes and the number of isolated nodes under the L-WCA, MOBIC, and classic WCA algorithms are compared. Because L-WCA takes comprehensive factors into consideration and is more suitable for high-speed moving vehicle nodes, there are fewer isolated nodes in the clustering process, which can reduce the communication overhead and network congestion caused by isolated nodes.

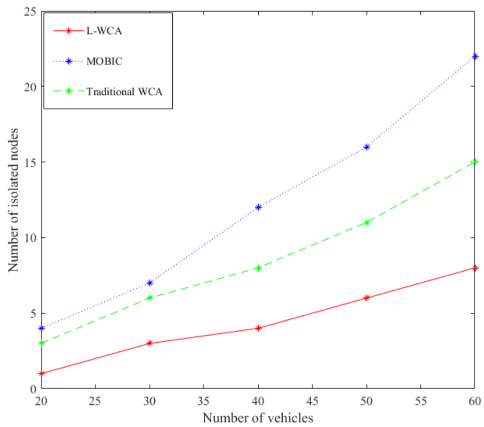

Fig. 4. Analysis of isolated nodes

Fig. 5 compares the relationship between the survival time of cluster head and one-hop communication distance under L-WCA, MOBIC, and classic WCA algorithms. The classic WCA algorithm does not consider the impact of different driving directions. Although the nodes are relatively close in geographic location and speed, it may also quickly drive out of the communication range due to different directions to cause cluster reorganization. MOBIC algorithm frequently reassembles clusters when the vehicle speed is fast and dynamic. When the mobility change is not obvious, the MOBIC algorithm will periodically update the cluster head in any scenario, so that the survival time of each selected cluster head node gradually decreases as the communication range increases, that is, the larger the communication range, The more easily the head is replaced by other nodes. However, the cluster head node selected by the L-WCA algorithm proposed in this paper can well maintain the characteristics of the cluster head on the straight road, so the survival time of the cluster head is basically not affected by the communication distance, which reduces the execution frequency of the cluster-generated algorithm and reduces the network overhead.

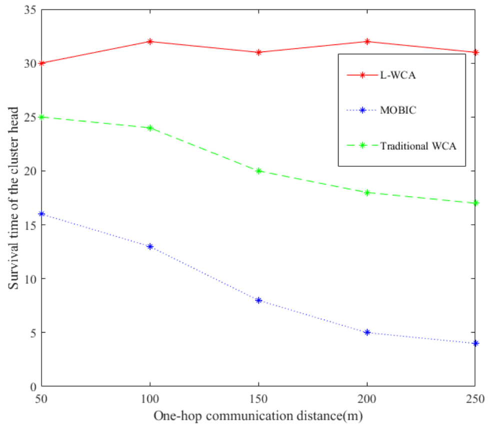

Fig. 5. The survival time of cluster head and communication distance

4.2 Analysis of the Performance of Heterogeneous Networks

The delay and DPDR performance of the heterogeneous network based on VANET and LTE-V2X proposed in this paper are compared with a single LTE-V2V and VANET.

As shown in Fig. 6, the architecture and algorithm proposed in this paper have higher DPDR under different vehicle densities, which effectively improves the problem of data transmission failure caused by network segmentation and broadcast storms. On the one hand, because when the number of vehicles is scarce, the heterogeneous network will compensate for the network interruption through LTE-V2V communication between CHs. On the other hand, when there are too many vehicles, the hybrid architecture reduces the number of transmissions in the VANET network by providing LTE-V2V communication, which in turn reduces media access contention and increases the probability of successful data packet transmission. Although LTE-V2V has a higher DPDR when the vehicle density is small, as the number of vehicles increases, a large number of vehicles request resources from the base station to transmit messages at the same time, which will cause network congestion and reduce the probability of successful data packet transmission. When the number of vehicles is small, VANET will cause network fragmentation due to sparse vehicles and affect the DPDR of the system. When the number of vehicles is too large, dense vehicles will lead to serious media access contention, leading to the decline of network performance and the decrease of DPDR.

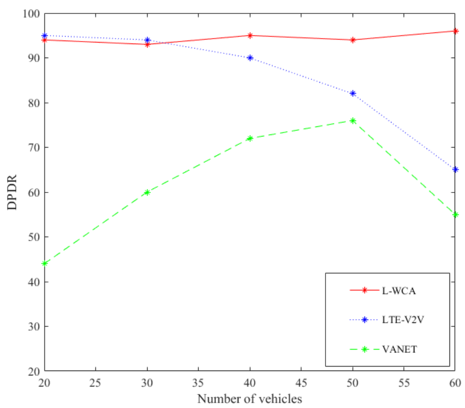

Fig. 6. DPDR performance analysis under different vehicle numbers

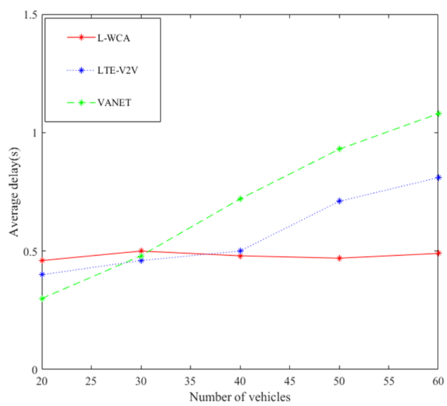

Fig. 7. Analysis of delay performance under different vehicle numbers

As shown in Fig. 7, when the number of vehicles is small, VANET, LTE-V2X, and the network architecture proposed in this article have small delays. With the increase of vehicle node density, the network architecture proposed in this paper still has good latency performance, but the latency of VANET and LTE-V2X networks increases significantly. This is because in LTE-V2X, with the increase of the number of vehicles, there are too many vehicles applying for resources from the base station, and the base station cannot timely allocate resources to vehicles, resulting in the increase of the delay. However, when there are a large number of vehicles in VANET, the distance of data transmission is far away and more forwarding nodes need to be passed, leading to the aggravation of the delay. It can be seen that the network architecture proposed in this paper can not only meet the high mobility of vehicles in the highway scenario, but also be suitable for urban scenarios with high node density.

5 Conclusion

This article builds a heterogeneous network based on a hybrid of VANET and LTE-V2X, which can not only meet the real-time requirement of information transmission, but also combine high-speed and high-reliability communication. The hierarchical structure is formed by effective clustering algorithm. The simulation results show that compared with the traditional VANET and LTE-V2V networks, the proposed heterogeneous network architecture has better DPDR and delay in the case of sparse and dense vehicles. And the greater the density of vehicles, the more obvious the superiority of the proposed heterogeneous network architecture. At the same time, compared with the classical WCA algorithm and MOBIC algorithm, the proposed clustering algorithm improves the stability of clusters and improves the number of isolated nodes. And with the increase of communication distance, the cluster head still has good stability. From the analysis of the results, we can see that the architecture of this network and clustering algorithm are not only suitable for highway scenes with high mobility, but also for urban scenes with high node density.

Reference

[1] B. Kim, S. Kim, H. Yoon, S. Hwang, M.X. Punithan, B.R. Jo, S. Choi, Nearest-First: Efficient Relaying Scheme in Heterogeneous V2V Communication Environments, IEEE Access 7(2019) 23615-23627.

[2] X. Ucar, S.C. Ergen, O. Ozkasap, Multi-hop Cluster based IEEE 802.11p and LTE Hybrid Architecture for VANET Safety Message Dissemination, IEEE Transactions on Vehicular Technology 65(4)(2016) 1-1.

[3] A. Benslimane, T. Taleb, R. Sivaraj, Dynamic clustering-based adaptive mobile gateway management in integrated VANET: 3G Heterogeneous Wireless Networks, IEEE Journal on Selected Areas in Communications 29(3)(2011) 559-570.

[4] H. Menouar, F. Filali, M. Lenardi, A survey and qualitative analysis of mac protocols for vehicular ad hoc networks, IEEE Wireless Communications 13(5)(2006) 30-35.

[5] R. Molina-Masegosa, J. Gozalvez, LTE-V for sidelink 5G V2X vehicular communications: a new 5G technology for short-range vehicle-to-everything communications, IEEE Vehicular Technology Magazine 12(4)(2017) 30-39.

[6] W. Sun, E.G. Ström, F. Brännström, Y. Sui, K.C. Sou, D2D-based V2V communications with latency and reliability constraints. <https://arxiv.org/abs/1501.02973>, 2015.

[7] K. Zheng, Q. Zheng, P. Chatzimisios, W. Xiang, Y. Zhou, Heterogeneous vehicular networking: a survey on architecture, challenges and solutions, IEEE Communications Surveys & Tutorials 17(4)(2015) 1-1.

[8] G.E.M. Zhioua, H. Labiod, N. Tabbane, S. Tabbane, A multi-metric QoS-balancing scheme for gateway selection in a clustered hybrid VANET network, in: Proc. IEEE 8th International Conference on Wireless and Mobile Computing, Networking and Communications, 2012.

[9] L. Abdullah, I. Almomani, A. Aburumman, Secure cluster-based SIP service over Ad hoc networks, in: Proc. IEEE Jordan Conference on Applied Electrical Engineering and Computing Technologies (AEECT), 2013.

[10] P. Basu, N. Khan, T.D.C. Little, A mobility based metric for clustering in mobile ad hoc networks, in: Proc. 2001 International Conference on Distributed Computing Systems Workshop, 2001.

[11] K. Xu, X. Hong, M. Gerla, An ad hoc network with mobile backbones, Proc ICC 2002 5(2002) 3138-3143.

[12] T.L. Saaty, Analytic hierarchy process, in: S.I. Gass, C.M. Harris (Eds.), Encyclopedia of Operations Research and Management Science, Springer, New York, 2001, pp.19-28.