A scheme of D2D-based delay analysis and vehicle relay algorithm in VANET

Yinze Zhao* and Lingyun Jiang

College of Telecommunications & Information Engineering, Nanjing University of Posts and Telecommunications, Nanjing, China

*Email: zhaoyinzemvp@163.com

Abstract. The D2D-based VANET (Vehicular Ad-hoc Network) makes up for the defects of the traditional IEEE 802.11p network, and has the advantages of low latency and high throughput. In order to reduce the delay of message transmission between vehicles, a D2D-based hybrid V2I/V2V (Vehicle-to-Infrastructure/Vehicle-to-Vehicle) IoV (Internet of Vehicle) architecture was considered, which firstly clusters vehicles on the road according to motion consistency. The message is transmitted between the clusters, and in addition to being transmitted through the RSU (Road Side Unit), it can also be relayed by establishing a D2D link between the vehicles. Based on the SINR (Signal to Interference plus Noise Ratio) and the minimum capacity constraint, the optimal transmission path is selected by predicting the delay of each cellular link and D2D link to reduce the end-to-end delay. In addition, for accurate modeling and analysis, a three-step method is used to predict and compare end-to-end delays. The simulation proves that this relay algorithm significantly reduces the delay compared with other methods.

1. Introduction
Recently, the rapid increase in the number of vehicles has intensified the problems of traffic accidents and congestion., which led to the increasing attention of ITS (Intelligent Transportation Systems). Various ITS-based applications, including traffic monitoring, autopilot, etc., will lead to smarter, more convenient and more efficient modes of travel[1][2][3]. 3GPP (3rd Generation Partnership Project), METIS (Mobile and Wireless Communications Enablers for the Twenty-Twenty (2020) Information Society) and other alliances are working hard to coordinate efficient and reliable in-vehicle communication in next-generation networks[4][5]. During the driving process, some safety-related information such as CAM (Cooperative Awareness Messages) and DEMN (Decentralized Environmental Notification Messages) usually need to be transmitted in the surrounding vehicles in a cyclical or event-triggered manner. In this case, strict delay and reliability requirements are required. For example, in the METIS project, it is necessary to control the end-to-end delay to within 5 milliseconds and the reliability to 99.999% for 1600-byte packet transmission[6].

In VANET (Vehicular Ad-hoc Network), the RSU (Road Side Unit) can be used as a wireless access point to transmit vehicle information to the cloud or destination vehicle. The existing standardized protocol is the IEEE 802.11p protocol for the V2I (Vehicle-to-Infrastructure) and the V2V (Vehicle-to-Vehicle) communication links[7]. However, some recent studies[8][9][10] show that some problems exist in the IEEE 802.11p protocol due to the nature of its physical layer, such as...
unpredictable channel access delay, unguaranteed QoS (Quality of Service), and poor scalability. And the IEEE 802.11p networks can only provide intermittent and short-term V2I connections due to its limited transmission range and lack of roadside units. On the contrary, cellular networks cover a wide range and can flexibly control network resources flexibly. D2D communication, as one of the key technologies of 5G, allows users to directly communicate with cellular spectrum resources under the control of cellular systems[11]. Compared with IEEE 802.11p protocol transmission, D2D has wider communication range, higher transmission rate and better high-speed mobile performance[12]. Therefore, a cellular network supporting D2D will become a kind of Promising solutions in order to achieve efficient and reliable vehicle communication.

At present, there have been some studies on the introduction of D2D in VANET. In [13], Sergio and Tralli control the cellular receiver causing interference when the D2D transmitter re-uses cellular resources by limiting the transmit power of the D2D user. In [14], an interference-limited area control scheme is proposed to protect the D2D receiver from cellular interference, where D2D users are not allowed to share spectrum with cellular users located in interference-limited areas and the SINR (Signal to Interference plus Noise Ratio) is above a predetermined threshold at the D2D receiver. In addition, a three-step approach was proposed to design power control and spectrum allocation to maximize system throughput while minimizing the SINR of cellular and D2D links in [15]. Although these documents all consider interference and their optimization goals are mostly throughput, reliability, delay is a very important factor that has to be considered in many applications of IoV (Internet of Vehicle).

In [16][17], the delay performance of D2D communication is studied. And in [18], a new joint mode selection algorithm is proposed according to the vertex coloring method, aiming at achieving higher spectral efficiency and reducing communication delay. However, high mobility in the vehicle environment can cause wireless channels to change rapidly over time [19]. The traditional method for D2D communication under the assumption of full CSI (channel state information) is no longer applicable because it is difficult to track channel changes on such a short time scale.

Therefore, this paper considers a D2D-based IoV architecture, which first clusters vehicles according to motion consistency to increase the continuous connection time of the vehicle to reduce the probability of disconnection. And then, a D2D-based vehicle relay algorithm is proposed based on the SINR and the minimum capacity constraints to reduce the end-to-end delay. Finally, it is verified by simulation to compare the performance of the relay algorithm with the other.

The rest of the paper is arranged as follows. The second section introduces the system model and proposes a clustering algorithm based on motion consistency. The third section analyzes the delay and proposes a D2D-based vehicle relay algorithm. The simulation and analysis are carried out in four sections, and the fifth section is summarized in this paper.

2. System model

2.1. Problem description

![Figure 1. A D2D-based hybrid V2I/V2V VANET architecture.](image)
We consider a VANET that supports D2D, as shown in figure 1, where is a user that communicates with the roadside base station via the V2I link, called a cellular user, and a user that performs V2V communication through the D2D link, called D2D user. We first clusters vehicles on the road to maintain a stable and long-lasting connection. The cluster head vehicles can be connected via V2I and V2V links. Due to the low use of uplink resources, D2D users use orthogonally allocated cellular users. The uplink spectrum not only improves spectrum utilization, but also makes interference at the base station easier to manage.

The data transmission between vehicles can be divided into cellular links and D2D links. Our goal is to select the optimal transmission path of the message to minimize the delay. It is assumed that the entire data transmission delay is \( D \) for a period of time, that is, the objective function is:

\[
\min \sum_{i \in I} D = \min \sum_{i \in I} (D_{D2D} + D_{V2V})
\] (1)

Since the D2D link is based on the cellular spectrum, it is necessary to consider interference between the cellular V2I link and the D2D pair. Let \( h_{p,B} \) be the channel power gain between the \( p \)th cellular user and the base station, which can be expressed as:

\[
h_{p,B} = g_{p,B} \beta_{p,B} A L_{p,B}^{-\gamma} \approx g_{p,B} \alpha_{p,B}
\] (2)

where \( g_{p,B} \) represents the small-scale fast fading power component, and assumes that the exponential distribution is a unit mean, \( L_{p,B} \) represents the distance from the \( p \)th cellular user to the RSU, \( A \) is the path loss constant, and \( \gamma \) is the decay exponent. \( \beta_{p,B} \) is a log-normal shadow fading random variable with a standard deviation \( \xi \).

We assume that large-scale fading components for the channel, such as the path loss of the link, are known to the RSU because they usually depend on the location of the user and vary less [20]. We can measure the parameters \( \alpha_q \) and \( \alpha_{p,q} \) at the receiver of the D2D user and send it to the RSU periodically, so that the RSU can calculate the link parameter \( \alpha_{p,B} \) between the cellular user and the RSU and the link parameter \( \alpha_{q,B} \) between the D2D user and the RSU.

Thereby, the SINR value \( \gamma^c_p \) of the \( p \)th cellular user and the SINR value \( \gamma^d_q \) of the \( q \)th D2D user received at the RSU can be obtained:

\[
\gamma^c_p = \frac{P^c_p h_{p,B}}{\sigma^2 + \sum_{q \in Q} P^d_q h_{q,B}}
\] (3)

\[
\gamma^d_q = \frac{P^d_q h_k}{\sigma^2 + \sum_{p \in P} P^d_q \rho_{p,q} P^c_p h_{p,q}}
\] (4)

where \( P^c_p \) and \( P^d_q \) represent the transmit power of the \( p \)th cellular user and the \( q \)th D2D user respectively, \( \sigma^2 \) represents the noise power, and \( \rho_{p,q} \) represents the spectrum allocation indicator, that is, when the D2D user reuses the \( p \)th cellular user, \( \rho_{p,q} = 1 \), and other times \( \rho_{p,q} = 0 \).

The traversal capacity of the \( p \)th cellular user is:

\[
C_p = E[\log_2(1 + \gamma^c_p)]
\] (5)

In addition to considering delay optimization, we also consider the QoS difference between the V2I link and the D2D link. Because the V2I link can connect the vehicle to the Internet, there may be transmission of large-capacity data, so the minimum capacity threshold is set for each cellular user.

In summary, the constraint is:

\[
E[\log_2(1 + \gamma^c_p)] \geq \gamma^c_o, \forall p \in P
\] (6)

\[
Pr\{\gamma^d_q \leq \gamma^d_o\} \leq P_o, \forall q \in Q
\] (7)
\[ 0 \leq P_p^c \leq P_{\text{max}}^c, \forall p \in P \]  
\[ 0 \leq P_q^d \leq P_{\text{max}}^d, \forall q \in Q \]  
\[ \sum_{p \in P} \rho_{p,q} \leq 1, \rho_{p,q} \in \{0,1\}, \forall q \in Q \]  
\[ \sum_{q \in Q} \rho_{p,q} \leq 1, \rho_{p,q} \in \{0,1\}, \forall p \in P \]  

where \( y_0^c \) represents the minimum capacity threshold of the cellular user, and \( y_0^d \) represents the minimum SINR threshold required for the D2D user to establish a reliable D2D link. \( \Pr\{y_0^d \leq y_0^d\} \) gives the probability of interruption due to the inability to reach the SINR requirement, \( P_0 \) is the tolerable outage probability of the D2D link, and \( P_{\text{max}}^c \) and \( P_{\text{max}}^d \) are the maximum transmit power threshold of the cellular user and the D2D user respectively.

2.2. Vehicle clustering algorithm

In order to maintain the performance of long connections, we divide the vehicles in the RSU into multiple clusters. The clustering principle is as follows: 1) Ensure the distance between the member vehicles in a single cluster to be similar, that is, within a certain threshold range. 2) Guarantee the vehicles classified into the same cluster remain for a period of time. Firstly, in order to satisfy the first principle, the initial division can be initially based on the proximity range. Secondly, in order to satisfy the second principle, the vehicles that meet the requirements can be divided into new clusters according to the speed of the member vehicles, and the vehicles that do not meet the requirements are deleted from the cluster.

Suppose there are \( N \) cars on the road, we divide them into \( M \) clusters, and ensure that the driving directions of the vehicles in the same cluster are the same, assuming that the number of cars contained in the \( k \)th cluster is \( N_k \), where \( k = 1,2,...,M \), the speed of the \( i \)th car in the \( k \)th cluster is \( v_{k,i} \), where \( i = 1,2,...,N_k \). So the average speed of the \( k \)th cluster is:

\[ \bar{v}_k = \frac{1}{N_k} \sum_{i=1}^{N_k} v_{k,i}, i = 1,2,...,N_k \]  

**Algorithm 1: Vehicle clustering algorithm**

Input: Number of clusters \( M \), Vehicle distance \( d_{k,i} \)  
Output: Clusters \( \Omega_k \), Cluster head \( \Omega_{k,\text{head}} \)  
Initialize: Divide \( N \) vehicles into \( M \) clusters, each cluster is \( \Omega_k \), according to \( d_{k,i} \leq L_k, k = 1,2,...,M, i = 1,2,...,N_k \)  
Calculate the average speed of the vehicle in the \( k \)th cluster \( \bar{v}_k, k = 1,2,...,M \)  
1:  
2: for \( k = 1 \) to \( M \) do  
3: for \( i = 1 \) to \( N_k \) do  
4: if \( \bar{v}_k \geq v_{k,i} + L_k + d_{k,i} \) and \( \bar{v}_k \leq v_{k,i} + L_k - d_{k,i} \) then  
5: if \( d_{k,i} \leq d_{k,\text{max}} \) then \( \Omega_{k,\text{head}} \leftarrow \Omega_{k,i}, d_{k,\text{max}} \leftarrow d_{k,i} \)  
6: else if \( d_{k,i} \leq d_{k,\text{min}} \) then \( d_{k,\text{min}} \leftarrow d_{k,i} \)  
7: end if  
8: end if  
9: else \( \Omega_k \leftarrow \Omega_k - \Omega_{k,i} \)  
10: end if  
11: end for  
12: end for
As shown in algorithm 1, the vehicles with similar geographical locations are first classified into the same initial cluster, and then the average speed of the vehicles in each initial cluster is calculated. We set a certain time threshold to determine whether the vehicles in the initial cluster will run at a certain time. Outside the range of the cluster, the vehicles still in the cluster classify them into new clusters and judge whether they are cluster heads, thereby obtaining new clusters and cluster heads of each cluster.

3. Delay analysis and relay algorithm

3.1. End-to-end delay analysis

In this system, the source vehicle can use a D2D-based V2I/V2V link to transmit messages to the forward or backward target vehicle and we can select the best transmission mode by expecting the delay of each path. For accurate analysis, we consider the different data transfer phases and their associated delays. Since our clustering algorithm is based on motion consistency, we can assume that the data information in a single cluster is shared, and the data transmission delay in the cluster. The control is within a certain range, and the data is transmitted between the clusters through the cluster head.

If the source cluster and the target cluster are in the same RSU range, only the D2D connection needs to be made between the cluster and the cluster. Since the traveling directions of the vehicles in the same cluster are the same, we can obtain the probability density function of cluster size[21]:

\[
 f_c(x) = \frac{x^{\lambda-1}e^{-\frac{x}{\theta}}}{\theta^\lambda \Gamma(\lambda)}, \quad x > 0
\]

where \( \lambda = \frac{E(C_t)^2}{E(C_t)^2-E(C_k)^2}, \quad \theta = \frac{E(C_k^2)-E(C_k)^2}{E(C_k)}, \) and \( C_k \) indicates the range of the vehicle cluster.

For accurate modeling, the message transmission can be divided into three phases: the source vehicle to the nearest forward RSU phase, the intermediate vehicle or RSU relay phase, and the transmission phase within the RSU of the message to the destination vehicle. In the first phase, the data packet is from the source vehicle to the nearest forward RSU stage, as shown in figure 2. This phase can transmit messages in two ways, one is transmitted from the source vehicle to the RSU by way of forward vehicle relay. The vehicle in the range is relayed to the backward RSU through the backward vehicle and then transmitted through the RSU. Assuming that the source vehicle position is \( V_0 \), the vehicle cluster set to the nearest forward RSU is \( \{1,2,\ldots,S\} \), and the time from the \( s-1 \) cluster to the \( s \) cluster is \( t_s \). There is SAC delay and wireless communication delay and we can discuss it in two cases. When the distance between communication vehicles is less than D2D communication range, the D2D link can be directly established to communicate between vehicles. In this case, there is no SAC delay, so \( t_s = \frac{d_s}{v_d} \), where \( d_s \) represents the \( s \) cluster to the \( s+1 \) cluster and \( v_d \) represents the D2D communication rate. In addition, when there is no other vehicle in the communication range of the vehicle carrying the message, it needs to store and forward the message data, and the SAC delay generated at this time is \( (d_s - L) / v_{s,head} \), where \( L \) represents the communication distance of D2D and \( v_{s,head} \) represents the speed of the cluster head vehicle of the \( s \)th vehicle cluster. In summary, \( t_s \) can be expressed as:

![Figure 2. Source vehicle sending messages to the nearest forward RSU.](image-url)
Let \( V_0 \) be the location of the source vehicle, \( C_0 \) be the location of the cluster head of the source cluster, and thus the transmission delay in this cluster can be obtained as \( (V_0 - C_0)/v_d \). Similarly, Let \( V_S \) be the position of the vehicle connected to the forward RSU, \( C_S \) be the cluster head position of the cluster connected with the RSU, and the transmission delay in this cluster is \( (C_S - V_S)/v_d \), so the total delay in this mode can be expressed as:

\[
T_{d, beg} = \sum_{s \in S} t_s + \frac{V_0 - C_0}{v_d} + \sum_{s \in S \setminus \{0,S\}} \frac{C_S + C_S - V_S}{v_d} \tag{15}
\]

Next, we discuss the delay in the backward direction transmission, assuming that the vehicle cluster set of the source vehicle to its nearest backward RSU is \( \{1, 2, \cdots, K\} \), and \( V_K \) is the vehicle position connected to the backward RSU, \( C_S \) is the cluster head position of the cluster where the vehicle is located, \( d/v_c \) is the transmission delay between RSUs, where \( d \) represents the distance between RSUs, and \( v_c \) represents the speed of cellular transmission, so the transmission delay between the reverse vehicle and the RSU can be obtained for:

\[
T_{c, beg} = \sum_{k \in K} t_k + \sum_{k \in K} \frac{C_k}{v_d} + \frac{C_K - V_K}{v_d} + \frac{d}{v_c} \tag{16}
\]

In summary, the expected delay for this phase is

\[
\mathbb{E}\{D_{h, beg}\} = \int_0^a \left( T_s + \frac{V_0 - x}{v_d} \right) f_c(x)dx + \int_a^{+\infty} T_{c, beg} f_c(x)dx \tag{17}
\]

where \( T_s + \frac{V_0 - x}{v_d} \) represents the delay experienced by the vehicle at the initial position at \( x \) through the D2D vehicle relay, and \( a \) represents the distance threshold at which the relay transmission can be used, which is obtained by the above analysis: \( T_s = \sum_{s \in S} t_s + \sum_{s \in S \setminus \{0,S\}} \frac{C_S}{v_d} + \frac{C_S - V_S}{v_d} \), \( a = V_0 + \sum_{s \in S \setminus \{0\}} C_s - V_s + \sum_{s \in S} t_s v_d \).

The second stage is analyzed below. In the message transmission process, it is necessary to select a suitable relay vehicle or choose to transmit through the base station. We select the delay path with the smallest delay by predicting the delay of each path.

Assuming that the \( V_X \) position is a certain vehicle position before the first RSU and has not yet connected with the RSU, the \( V_S \) position is the position of the carrying message vehicle connected with the last RSU before reaching the destination vehicle. When the message is transmitted from the \( V_x \) position to the \( V_S \) position through the vehicle relay, the delay of the message transmitted in the carrying vehicle cluster is \( (V_x - C_x)/v_d \), and the delay of the last carried message in the cluster is \( (C_S - V_S)/v_d \). Whereby the total delay at this stage can be expressed as:

\[
T_{d, rel} = \sum_{s \in S} t_s + \frac{V_x - C_x}{v_d} + \sum_{s \in S \setminus \{0,S\}} \frac{C_s}{v_d} + \frac{C_s - V_S}{v_d} \tag{18}
\]

The delay of the message transmission between the RSU is:

\[
T_{c, rel} = d/v_c \tag{19}
\]

where \( d \) represents the distance between RSUs, and \( v_c \) represents the transmission speed of the cell. Similarly, the latency expectation experienced at this stage is:

\[
\mathbb{E}\{D_{h, rel}\} = \int_0^b \left( T_s + \frac{V_x - x}{v_d} \right) f_c(x)dx + \int_b^{+\infty} T_{c, rel} f_c(x)dx \tag{20}
\]
where $b = V_x + \sum_{s \in S \setminus \{0\}} C_s - V_S + \sum_{s \in S} t_s v_d$.

In the final stage, when the message is transmitted to the RSU where the target vehicle is located, the relay vehicle needs to choose whether to continue to select the vehicle relay forward, or to transmit to the RSU, and then transmit it to the destination vehicle by the RSU.

The transmission situation in the destination vehicle base station is exactly the opposite of the source vehicle transmission process, and it is easy to get:

$$E[D_{h, end}] = \int_0^c \left(T_s + \frac{V_y - x}{v_d}\right) f_c(x) dx + \int_c^{+\infty} T_{c, end} f_c(x) dx$$

where $c = V_y + \sum_{s \in S \setminus \{0\}} C_s - V_S + \sum_{s \in S} t_s v_d$, $T_{c, end} = \sum_{k} T_k + \sum_{k \in \mathcal{K}} C_{v_d} \frac{C_{v_d} - V_k}{v_d} + \frac{d}{v_c}$.

As summarized in the review, the total end-to-end delay can be obtained as follows:

$$E[D_h] = E[D_{h, beg}] + E[D_{h, rel}] + E[D_{h, end}]$$

### 3.2. D2D-based vehicle relay algorithm

Through the above delay analysis, we propose algorithm 2 to get the optimal transmission path of the message according to the source vehicle, the target vehicle and the information of the intermediate vehicle. According to the previous clustering algorithm, the vehicles on the road are divided into corresponding clusters, and then the message transmission direction and the vehicle traveling direction are considered to be consistent. If they are consistent, the D2D link and the cellular link are respectively calculated according to the formula (15) (16). Considering that the message transmission distance may be long, it is necessary to pass through a plurality of RSUs, and the above method is used to select the best relaying vehicles and RSUs.

---

**Algorithm 2: Vehicle relay algorithm**

Input: Source vehicle position $V_0$, target vehicle position $V_e$

Output: Message transmission path, including relay vehicle collection, RSU collection

1. Cluster vehicles
2. if $V_0 < V_e$ then
3. Calculate $T_{d, beg}$ and $T_{c, beg}$ according to (15)(16)
4. if $P_p \leq P_{max}$, $P_{d} \leq P_{max}$, $T_{d, beg} < T_{c, beg}$ then
5. Add relay vehicle collection, Calculate $T_{d, rel}$, $T_{c, rel}$
6. while $T_{d, rel} < T_{c, rel}$ do
7. Add relay vehicle collection, Calculate new $T_{d, rel}$, $T_{c, rel}$
8. end while
9. end if
10. while $V_e > V_y + d$ do
11. Add RSU collection
12. end while
13. Calculate $T_{d, end}$, $T_{c, end}$
14. if $T_{d, end} < T_{c, end}$ then
15. Add relay vehicle collection
16. end if
17. end if

### 4. Simulation results and analysis

This section simulates the performance of the clustering algorithm and the vehicle relay algorithm proposed in the previous two sections. Based on the Veins vehicle networking simulation platform, the simulation environment is set in the traffic simulator SUMO, and then we develop C++ program to...
simulate the clustering algorithm and the relay algorithm respectively in the network simulator OMNeT++. We assume that the simulation scene is a 20km highway. This section of the highway starts with a total of 200 vehicles. The initial position of each vehicle on this road is obtained by a random function. In order to match the actual situation, it is assumed that each vehicle is in the process of driving. The speed range is [10–35] m/s, and the initial velocity is randomly generated between [10–35]. During the running of the vehicle, the vehicle is changed every 10 seconds to shift at a certain acceleration within the above speed range, assuming an acceleration of 2m/s². Each time we randomly select 20% of the vehicles in these vehicles to generate data packets, and at the same time randomly select the destination vehicles that the data packets need to transmit, these data packets will be transmitted to the destination vehicle through RSU or vehicle relay. In order to compare performance fairly, keep the algorithm 100 times and take the average value each time keeping other scenes consistent. Table 1 is the specific simulation parameter settings[22].

| Parameter                              | Value    |
|----------------------------------------|----------|
| Minimum capacity of D2D users $y^c_0$  | 0.5bps/Hz|
| SINR threshold of D2D users $y^d_0$    | 5dB      |
| Maximum transmit power of Cellular users $P^c_{max}$ | 17dBm    |
| Maximum transmit power of D2D users $P^d_{max}$ | 23dBm    |
| Noise power $\sigma^2$                 | -114dBm  |
| RSU distance $L$                       | 5km      |
| Cellular range $d_c$                   | 500m     |
| RSU antenna height                     | 25m      |
| RSU antenna gain                       | 8dBi     |
| Vehicle receiver noise figure          | 9dB      |

Firstly, in order to analyze the performance of the dynamic clustering algorithm in this paper, we compare it with the location-based clustering algorithm from the average continuous communication time and delay of the vehicles in the cluster. As shown in figure 3, the abscissa is the vehicle maximum speed, the ordinate of figure 3 (a) is the average continuous communication time of the vehicles in the cluster, and the ordinate of figure 3 (b) is the average delay. It can be seen that there is no significant difference between the performance of the geolocation clustering algorithm and the dynamic clustering algorithm when the vehicle is slow. However, as the speed increases, the advantages of the dynamic clustering algorithm become more and more significant, mainly because the geolocation clustering algorithm does not consider the moving speed of the vehicle, and can only ensure that the vehicles in the cluster are in a relatively constant position in a short time. The dynamic clustering algorithm based on motion consistency considers the moving speed of the vehicle and predicts the trajectory of the vehicle during a period of time, thus ensuring the connection of the vehicles in the cluster for a long time. However, when the maximum speed of the vehicle is large, the speed of the vehicle changes significantly, which causes the performance of our algorithm to degrade. Finally, it is no different from the location-based clustering algorithm.
Next, we compare the D2D relay algorithm of this paper with the RSU transmission and random relay algorithm. As shown in figure 4, we use the delay as an indicator to compare the maximum speed of different vehicles and the number of different vehicles. As shown in Fig. 4(a), when the vehicle speed changes little, the SAC delay is large, so the delay of using the RSU transmission is lower than other algorithms. However, as the vehicle speed increases, the number of relay vehicles that can be selected for message transmission increases. The D2D relay algorithm in this paper will choose the optimal relay vehicle, so the performance will be better than the random relay selection and RSU transmission. As shown in figure 4(b), the performance of the RSU transmission is the worst, the random relay performance is slightly better than that of the base station transmission, and the D2D relay algorithm in this paper is optimal. And as the number of vehicles increases, the performance of the RSU transmission gradually deteriorates. The performance of several relay algorithms gradually becomes better, and then tends to be stable, mainly because of the increasing number of vehicles lead to resource shortage and performance degradation. In contrast, the relay strategy of this paper is better because of the SAC delay to be reduced or even disappeared due to the increase of vehicles. However, when the number of vehicle reaches a certain amount, due to the SINR interference constraint, it is necessary to select a relay vehicle with small interference, so the performance will not increase all the time, and will reach a relatively stable state in the later stage.

5. Conclusion
In this paper, a hybrid V2I/V2V vehicle networking system architecture based on D2D is considered. Firstly, the vehicles on the road are clustered according to the motion consistency and based on this, a D2D-based vehicle optimal relay algorithm is proposed. The simulation proves that the relay algorithm in this paper significantly reduces the end-to-end delay in the message transmission process, especially in a certain range, the more the number of vehicles, the better the performance of this relay algorithm, the lower the delay. And when the number of vehicle reaches a certain amount, the delay will tend to be stable.

References
[1] D. Jiang, L. Huo, Z. Lv, H. Song and W. Qin, "A Joint Multi-Criteria Utility-Based Network Selection Approach for Vehicle-to-Infrastructure Networking," in IEEE Transactions on Intelligent Transportation Systems, vol. 19, no. 10, pp. 3305-319 (2018).

[2] M. M. Rana, "Attack Resilient Wireless Sensor Networks for Smart Electric Vehicles," in IEEE Sensors Letters, vol. 1, no. 2, pp. 1-4 (2017).

[3] Y. Xia, X. Qin, B. Liu and P. Zhang, "A greedy traffic light and queue aware routing protocol for urban VANETs," in China Communications, vol. 15, no. 7, pp. 77-87 (2018).

[4] A. Soua and S. Tohme, "Multi-level SDN with vehicles as fog computing infrastructures: A new integrated architecture for 5G-VANETs," 2018 21st Conference on Innovation in Clouds, Internet and Networks and Workshops (ICIN), Paris, pp. 1-8 (2018).

[5] G. Luo et al., "Cooperative vehicular content distribution in edge computing assisted 5G-VANETs," in China Communications, vol. 15, no. 7, pp. 1-17 (2018).

[6] L. Liang, G. Y. Li and W. Xu, "Resource Allocation for D2D-Enabled Vehicular Communications," in IEEE Transactions on Communications, vol. 65, no. 7, pp. 3186-197 (2017).

[7] Y. Yang, D. Fei and S. Dang, "Inter-vehicle cooperation channel estimation for IEEE 802.11p V2I communications," in Journal of Communications and Networks, vol. 19, no. 3, pp. 227-38 (2017).

[8] A. A. Almohammedi, N. K. Noordin, A. Sali, F. Hashim and M. Ballaqäh, "An Adaptive Multi-Channel Assignment and Coordination Scheme for IEEE 802.11P/1609.4 in Vehicular Ad-Hoc Networks," in IEEE Access, vol. 6, pp. 2781-802 (2018).

[9] R. Tomar, M. Prateek and H. G. Sastry, "Analysis of beaconing performance in IEEE 802.11p on vehicular ad-hoc environment," 2017 4th IEEE Uttar Pradesh Section International Conference on Electrical, Computer and Electronics (UPCON), Mathura, pp. 692-96 (2017).

[10] B. Bloessl, M. Segata, C. Sommer and F. Dressler, "Performance Assessment of IEEE 802.11p with an Open Source SDR-Based Prototype," in IEEE Transactions on Mobile Computing, vol. 17, no. 5, pp. 1162-175 (2018).

[11] R. Wang, Jia Liu, G. Zhang, Shuanghong Huang and Ming Yuan, "Energy efficient power allocation for relay-aided D2D communications in 5G networks," in China Communications, vol. 14, no. 6, pp. 54-64 (2017).

[12] L. Shi, L. Zhao, K. Liang and H. Chen, "Wireless Energy Transfer Enabled D2D in Underlaying Cellular Networks," in IEEE Transactions on Vehicular Technology, vol. 67, no. 2, pp. 1845-849 (2018).

[13] S. Cicalò and V. Tralli, "QoS-Aware Admission Control and Resource Allocation for D2D Communications Underlaying Cellular Networks," in IEEE Transactions on Wireless Communications, vol. 17, no. 8, pp. 5256-269 (2018).

[14] X. Cao, L. Liu, Y. Cheng, L. X. Cai and C. Sun, "On Optimal Device-to-Device Resource Allocation for Minimizing End-to-End Delay in VANETs," in IEEE Transactions on Vehicular Technology, vol. 65, no. 10, pp. 7905-916 (2016).

[15] D. Feng, L. Lu, Y. Yuan-Wu, G. Y. Li, G. Feng and S. Li, "Device-to-Device Communications Underlaying Cellular Networks," in IEEE Transactions on Communications, vol. 61, no. 8, pp. 3541-551 (2013).

[16] M. Salehi, A. Mohammadi and M. Haenggi, "Analysis of D2D Underlaid Cellular Networks: SIR Meta Distribution and Mean Local Delay," in IEEE Transactions on Communications, vol. 65, no. 7, pp. 2904-916 (2017).

[17] W. Xu and Y. Wang, "Heterogeneous Statistical-Delay QoS and Security Provisioning for D2D Underlay Cellular Networks," 2018 IEEE 87th Vehicular Technology Conference (VTC Spring), Porto, pp. 1-5 (2018).

[18] Y. Li, M. C. Gursoy, S. Velipasalar and J. Tang, "Joint Mode Selection and Resource Allocation for D2D Communications via Vertex Coloring," GLOBECOM 2017 - 2017 IEEE Global Communications Conference, Singapore, pp. 1-6 (2017).
[19] H. Chour, Y. Nasser, H. Artail, A. Kachouh and A. Al-Dubai, "VANET Aided D2D Discovery: Delay Analysis and Performance," in IEEE Transactions on Vehicular Technology, vol. 66, no. 9, pp. 8059-071 (2017).

[20] W. Sun, E. G. Ström, F. Brännström, K. C. Sou and Y. Sui, "Radio Resource Management for D2D-Based V2V Communication," in IEEE Transactions on Vehicular Technology, vol. 65, no. 8, pp. 6636-650 (2016).

[21] Y. Zhuang, J. Pan, Y. Luo and L. Cai, "Time and Location-Critical Emergency Message Dissemination for Vehicular Ad-Hoc Networks," in IEEE Journal on Selected Areas in Communications, vol. 29, no. 1, pp. 187-96 (2011).

[22] L. Liang, G. Y. Li and W. Xu, "Resource Allocation for D2D-Enabled Vehicular Communications," IEEE Transactions on Communications, vol. 65, no. 7, pp. 3186-197 (2017).