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Vehicle networking data-upload strategy based on mobile cloud services

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Abstract

While traditional vehicle network communication architecture is based on special short-range communication, it is difficult to meet the demand for quality of service of vehicle networking data transmission. The relevant data can be uploaded to the server through the mobile gateway, which can be transmitted to the target vehicle by the decision of the server, which can then extend the data broadcast domain and greatly reduce the time delay of data transmission. Combined with the idea of mobile cloud services, a new network architecture and data transmission method is proposed in this paper. We first describe the specific process of the gateway service to the registration of cloud service information. Secondly, we propose a method to select the cloud service gateway. The method combines historical cloud data and real-time data, and dynamically determines the gateway service provider and the service scope of the service. Gateway access to services consumers in broadcast news, they considered the communication load, stability link channel quality and other performance parameters to select the best gateway service provider, and then transmitted the data to the gateway service provider and uploaded it to their cloud. Finally, the transmission performance of the proposed method is evaluated for different traffic scenarios. The results show that the proposed method can obtain a shorter transmission delay and ensure a higher transmission success rate and the theoretical analysis herein proves the validity of the method.

Keywords: Vehicle networks, Cloud computing, Gateway server, Gateway consumer

1 Introduction

With the rapid development of vehicular networks, mobile cellular networks and cloud computing, cloud-based vehicle networking architecture, also known as the cloud network, has been widely discussed in both academic and industrial circles [1]. Cooperative control technology, real-time traffic information and services through intervehicular analysis, combined with mobile cloud computing vehicle networking applications, can effectively reduce traffic accidents and energy consumption and improve traffic safety and vehicle efficiency. The car networking forum of the International Federation of Electric Power Organizations has pointed out that the deployment of future vehicle networking applications can reduce the loss of life and property caused by traffic accidents. The US Department of Transportation estimates that between-vehicle dedicated short-range communication, based on communication between vehicles and infrastructure, can effectively prevent 82% of accidents, save thousands of lives and reduce economic losses of billions of dollars [2].

Vehicle networking applications are highly dependent on intervehicular data transmission and interaction. However, data transmission in the vehicle network must contend with various complex traffic environments. Due to the high mobility and fast topological changes in such environments, the link between the nodes is short and the connectivity of the vehicle network is reduced. V2V or V2I communication, based on the opportunity network, can only occur when nodes enter their respective transmission range. Thus, the demand for quality of service for data transmission is difficult to guarantee. The realization of fast and efficient data transmission is the most challenging application in vehicle networking.

The converged mobile cellular network-car network can not only provide short-range communication by Dedicated Short Range Communications (DSRC), but both cellular networks can rapidly transfer data to the

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remote vehicle. Such a data transmission mode is not overly dependent on traffic density and it can effectively avoid carrying forward the message transmission delay, high and low transmission rate. The current global 3G network development is relatively mature; many countries are now actively promoting the development and deployment of the 4G and 5G networks and related equipment manufacturers and operators intend to speed up the industrial layout of these networks. This provides a good environment for the integration of vehicle networking and mobile cellular networks. However, in the current traffic environment having each vehicle equipped with a cellular network interface is not feasible. Firstly, when road vehicle density is high, vehicles attempting to communicating with the base station will greatly increase the load and transmission delay of the base station. Secondly, if, while maintaining communication with the Internet the vehicle produces a considerable amount of redundant data, this will generate significant network traffic costs which will reduce its commercial attraction. Therefore, it is more feasible to select a suitable gateway to access the Internet from the peripheral equipment of the vehicle using a cellular network interface. This process is mainly based on DSRC, and the cellular mobile network communication as the auxiliary communication architecture is the future developmental direction of car networking [3].

Our paper puts forward a form of vehicle networking architecture based on mobile cloud services and studies how to upload the data to the cloud data-upload strategy within the architecture. Compared to the existing methods, the cloud can use both historical data and real-time data to determine the scope of gateway system (GWS) services and services that participate in the service, thereby enhancing the service coverage of the gateway service provider, thus saving channel resources. After receiving the service information, the gateway controller (GWC) comprehensively considers the data transmission requirements and GWS-related performance to select the best GWS for data-upload. This combines global information and GWS local information to select the optimal transmission path, reduces data transmission delay and improves transmission success rate.

2 Review

The development of cloud computing provides a new way to solve the problem of gateway selection and data transmission in vehicle networking architecture [4, 5]. The main idea behind cloud computing is that some of the complex and difficult-to-manage local work entrusted to the cloud will be returned to local cloud processing. On the basis of traditional cloud computing, mobile cloud computing is a new research area. It focuses mainly on research into how mobile agents interact with the current environment. By combining the local data and global data acquired by the cloud, the data are processed to obtain an optimal solution. This action effectively shares the scheme with the neighboring network nodes and does not have to give all the tasks to the cloud. Compared with traditional cloud computing, mobile cloud computing can considerably reduce communication and channel resources which enables more reasonable use of computing and storage resources, thus improving work efficiency.

Taking the optimal path of the vehicle as an example, in the traditional sense this generally refers to the shortest path taken by the vehicle to reach its destination. However, this means that all vehicles can in theory navigate a similar local optimal path, which leads to traffic congestion with other road vehicles. However, in the mobile cloud computing environment, mobile cloud agents can combine the global information of the cloud with their own through a sensor or through local information interaction with surrounding vehicles. This provides different paths for vehicle reference, so as to balance the various road traffic loads and achieve an overall optimal situation. However, the application of mobile cloud computing depends to a large extent on network node data transmission and information interaction; the best way to quickly and efficiently transfer data to the mobile cloud agent in each network node is the key point of this paper.

In the current traffic environment, there are a large number of network nodes that can connect to the Internet and provide an Internet access service. These network nodes may also have some computing and storage capacity. The mobile cloud agent, which is composed of these network nodes, is called the gateway service. The cloud needs to manage the service time and scope of these gateway services. In a traffic situation, the gateway server periodically broadcasts service information to the surrounding vehicles. Vehicles that require gateway services are called gateway consumers. The gateway server selects the best gateway server to access the Internet according to the received service information and, through that gateway server, to upload the data to the cloud. After receiving the data from the cloud, the data are processed and analyzed to distribute them to the target area. This method is adapted from Wu et al. [6]. Combining the data-upload method and distribution method in this way can greatly reduce the data transmission delay, while expanding the broadcast domain. Due to the presence of a large number of potential gateway services (GSW) in the current traffic environment, we used the notion of mobile cloud computing to propose a new mobile cloud-based networking architecture and data-upload strategy.

At present, the data transmission method is mainly based on two kinds of communication architecture [7]: (1) V2V or V2I communication architecture based on DSRC and (2) vehicle networking communication architecture based on the mobile gateway.

Now, car networking data transmission research is mostly based on DSRC car networking architecture: Byehkovsky et al. [8] proposed a multihop broadcast protocol based on geographic location information. A cross-layer broadcast protocol is proposed in PMBP by Bi et al. [9] and A multihop broadcast communication protocol based on intersection traffic phase information is proposed by Zhang et al. [10]. However, although the data transmission method based on Dedicated Short Range Communication (DSRC) can transmit the data to the node of the vehicle, the data transmission quality of service (QoS) is hard to guarantee.

For example, based on DSRC vehicle networking communication scenarios, the road section 2 on the vehicle A traffic accident, the need to pass the safety message to the road section 1 and 3 on the road section of the vehicle. Due to the presence of the traffic lights, the maximum communication distance between the two waves of the shortest distance of more than DSRC, cannot be carried forward to the way the security message in a timely manner to the road section 1 of the vehicle. In addition, due to the interference of the signal at the intersection of the building, the security information cannot be transmitted to the vehicle in a timely manner to 3 of the road. Section 1 and section 3 of the vehicle due to inability to receive timely message security to a large influx of sections 2, may cause serious traffic congestion. Then, the distal end of the vehicle cannot get the timely security message, leading to inability to advance the optimal path planning, and cannot conducive to police cars and ambulances and other special vehicles quickly arrived at the scene to deal with traffic accidents.

Through the mobile gateway, data can be sent to the area that cannot connect to the DSRC. Then it can solve the DSRC based on the communication mode of time delay problem. Vehicle B and vehicle C can connect to the Internet through the cellular mobile network, and in the event of a safety accident, vehicle A send the safety message in the V2V mode to the vehicle C.

The vehicle C uploads data to the server, and the server transmits the data to vehicle B. Then the data is transmitted to the road section 1 by vehicle B and vehicle C as security message relay. Compared with the traditional V2V transmission mode, the transmission mode of the combined V2V and V2I will undoubtedly improve the connectivity of the whole road vehicles, and the transmission delay is not easy to be affected by the location of the vehicle.

Cellular mobile networks are ubiquitous in the traffic environment, especially in the urban traffic environment; the cellular mobile network can significantly improve the rate of data transmission and increase broadcast coverage. However, current research focuses mainly on network convergence architecture and there is little research on the network broadcast of the cellular network.

Based on the VANETLTE hybrid architecture network, Zhioua et al. [11] propose a QoS-balanced gateway selection method and Jia et al. [12] present a form of queuing-vehicle cooperative data-upload method.

3 Data-uploading method based on the mobile cloud service

3.1 Problem discussed

Based on mobile cloud services in the car networking architecture, vehicles request to upload data to the server before the gateway service has been acquired by the surrounding GSW of the relevant information and they are stored in the GSW list. How to select a suitable gateway service provider from the list according to the data type and gateway server's relevant parameters, and how to quickly upload the data to the cloud are the focuses of this section.

Using communication resources as an example, in the current urban environment there may be massive distribution to service gateway nodes, such as those equipped with the 4G network interface for buses or taxis, or through a fiber-optic cable connected to the Internet in the Roadside Unit (RSU) etc. Through these nodes, the vehicle can pass data to the cloud and can also receive data from the cloud. Some nodes, in addition to providing gateway services, also have the ability to process and analysis the received data.

The following section presents a composite gateway selection vector, which comprehensively considers link stability (*LET*), network signal strength (*RSS*), transmission bandwidth (*BW*), service cost (*CC*), packet error rate (e_p) and transmission load (*CL*) to calculate the vector value. A small vector value is selected as the service GSW. The gateway selection vector calculation method is as follows:

$$\begin{aligned} F = a_1 \times \left(1-\frac{LET}{LET_{\max}}\right) + a_2 \times \left(1-\frac{RSS}{RSS_{\max}}\right) \\ + a_3 \times \left(1-\frac{BW}{BW_{\max}}\right) + a_4, \times \frac{CC}{CC_{\max}} \\ + a_5 \times \frac{e_p}{E_{\max}} + a_6 \times \frac{CL}{CL_{\max}} \end{aligned} \tag{1}$$

(1) Link stability (*LET*) *LET* is a measure of the link stability between the current vehicle and the GWS.

Based on vehicle location and travel direction, the speed of the vehicle can be calculated, and it can be used to explain if two vehicles are in the mutual communication range in the next period of time. Suppose the coordinates of i and j of the two vehicles are, respectively, (x_i, y_i) and (x_j, y_j) and v_i and v_j show the speed of the vehicle, θ_i and θ_j, respectively, are the slope of the road with respect to the X-axis of the vehicle node, and R is the transmission radius. The formula for calculating LET is then as follows:

$$LET_{ij} = \frac{-(ab+cd)+\sqrt{(a^2+c^2)R-(ad-bc)^2}}{a^2+b^2}, \quad (2)$$

here,

$$\begin{aligned} a &= v_i \cos\theta_i - v_j \cos\theta_j, \\ b &= x_i - x_j, \\ c &= v_i \sin\theta_i - v \sin\theta_j, \\ d &= y_i - y_{j.} \end{aligned} .$$

(2) Packet error rate e_p

e_p reflects the quality of V2V communication based on DSRC and can be obtained from the measured signal to noise ratio of the physical layer. By means of Binary Phase-shift Keying (BPSK) modulation, the packet error rate, e_p, of data transmission by white Gaussian noise channel is as follows:

$$e_p = 1-\left[1-Q\left(\sqrt{\frac{2P_r}{R_b \times N_0}}\right)\right]^L, \quad (3)$$

here, $Q(x) = \left(1/\sqrt{2\pi}\right)\int_x^{\infty} e^{-t^2/2}dt,$

in the above, N_0 is the noise energy spectral density, P_r is the received signal power and R_b is the base rate of data transmission.

This section mainly relates to the theoretical analysis of GWS access delay and GWC data transmission delay. In order to analyze the performance of this method, the mathematical model of this section is based on the following three points:

(1) The vehicle from the end of the road comes into the road at a speed of v. The number of vehicles entering the road is subject to a Poisson distribution of λ
(2) The vehicles are equipped with a global positioning system and data transceiver equipment
(3) The physical channel is reliable and does not generate errors

$TC(G_i, G_{i+1})(i = 0, 1, \cdots, n)$ represents the transmission delays of the cloud sending messages to the GWS. $TD(G_i, G_{i+1})(i = 0, 1, \cdots, n)$ represents the broadcast delay from the GWS sending-beacon to all target area vehicles. $T(G_i, G_{i+1})(i = 0, 1, \cdots, n)$ indicates that the time delay of the service information is received by all the target vehicles in the subsection. Then:

$$T(G_i, G_{i+1}) = TC(G_i, G_{i+1}) + TD(G_i, G_{i+1}), \quad (4)$$

and

$$\begin{aligned} T_{ac} = \max\{&T(G_0, G_1), T(G_1, G_2), \\ &\cdots, T(G_n, G_{n+1})\}. \end{aligned} \quad (5)$$

Suppose the random variable x represents the number of vehicles entering the road within the time interval (0, t]. The density function and mathematical expectation of x can then be expressed as follows:

$$P(x = n) = \frac{(\lambda l)^n \times e^{-\lambda l}}{n!} \quad (6)$$

$$E(x) = \lambda l. \quad (7)$$

If d represents the distance between two adjacent vehicles, then $d = vt$. If two cars can communicate with each other, then $d \le R$. The conditional probability density function and mathematical expectation of d is then as follows:

$$P(d = k | d \le R) = \frac{1-e^{-(\lambda k/v)}}{1-e^{-(\lambda R/v)}} \quad (8)$$

$$E(d) = \frac{v}{\lambda} - \frac{R}{e^{\lambda R/v}-1}. \quad (9)$$

The number s of vehicles in the vehicle transmission distance can be expressed as follows:

$$E(s) = |R/E(d)| = \left|\frac{R\lambda\left(e^{\lambda R/v}-1\right)}{v\left(e^{\lambda R/v}-1\right)-R\lambda}\right|. \quad (10)$$

The average number of hops for data transmission in a section of l length is as follows:

$$h(l) = \left|\frac{E(x)-1}{E(s)}\right| = \left|\frac{\lambda l-1}{E(s)}\right|. \quad (11)$$

Beacon single-hop delay T_b is defined as the time interval from which the beacon is successfully received and forwarded from the beacon to the receiving node. Because the beacon sends no back-off process and message confirmation, T_b can be expressed as follows:

$$T_b = T_{aifs} + \delta + L_b/r_b, \quad (12)$$

where T_{aifs} is the arbitrary frame interval. δ is the average time when the timer changed to 0, L_b is the size of beacon and r_b is the speed of transmission.

$$TD(G_i, G_{i+1}) = T_{aifs} + \delta + T_b \times \left|\frac{h(l_{rs})}{2} - 1\right|, \tag{13}$$

where, l_{rs} is the length of road section. With GWC as the selected service gateway, the data transmission of a single hop transmission time T_d can be expressed as follows:

$$T_d = \sum_{m=0}^{\infty} e^m (1-e) \left[T_{sifs} + \omega + \delta + L_d/r_b + m \times \left(T_{sifs} + \omega + \delta + L_d/r_b\right)\right], \tag{14}$$

where, T_{sifs} stands for the short frame interval, L_d is the transmission data size and ω is the time of the back-off process.

$$\omega = \sum_{j=0}^{CW[3]} (\omega|j) \frac{1}{CW[3]+1} \tag{15}$$

$$\omega|j = \begin{cases} \sum_{k=1}^{j} \overline{Y}_k, j \in [1, CW[3]] \\ 0, \quad j = 0 \end{cases}, \tag{16}$$

where, $CW[3]$ represents the contention window size of the third types of channel access type messages, Y_k represents the time length of the first time slices in $CW[AC]$, AC is the channel access type and $\overline{Y}_k$ is the average of Y_k.

Suppose the distance from the vehicle to the service gateway is l_c, then:

$$T_{tr} = \sum_{m=0}^{\infty} e^m (1-e) \left[T_{sifs} + \omega + L_d/r_b + m \times \left(T_{sifs} + \omega + L_d/r_b\right)\right] + T_d \times \left[\frac{h(l_c)}{2} - 1\right]. \tag{17}$$

3.2 Experiments

We wrote the simulation program on the OMNeT++ and SUMO platforms. OMNeT++ is mainly a simulated vehicle node communication protocol. SUMO is used to simulate traffic scenarios.

In this paper, through simulation experiments based on data-upload strategy-related properties of mobile cloud services, including GWS information service coverage, channel occupancy rate, access delay, data transmission delay and transmission rate, we propose to verify our theoretical analysis and other related agreements presented herein.

3.3 Service information coverage and channel occupancy

Figure 1 shows the relationship between the coverage rate of GWS service information and traffic density. P is the proportion of GWS accounting for the total number of vehicles.

Because of the delay in receiving service information, this time-lag will cause the service information to be out of date. In the experiment, if the vehicle only receives the service information for which the transmission time delay is more than 5 s, the vehicle is not counted as being in the service range of the vehicle.

As can be seen from Fig. 1, CDUL can guarantee a high coverage rate of service information in the case of different GWS ratios and traffic densities. When the vehicle density is too low, the connectivity of the vehicle is relatively low, and service information delay is too high. At this time the service message coverage is relatively low. However, the cloud can dynamically adjust the number of service information broadcast hops so that even if the GWS ratio is low, it can actually guarantee the service information coverage rate to be greater than 95%.

Figure 1 also shows the use of the traditional beacon broadcasting method of service information coverage. At this point, because all GWS only broadcasts one hop for service information, when the GWS number is too small it is difficult to ensure service coverage.

Figure 2 shows the relationship between channel occupancy rate and vehicle density. It shows that GWS service information does not take up too much of the channel resources under different GWS ratios. This is because the cloud in the choice of service gateway can effectively avoid GWS. This is compared with the channel occupancy rate without the use of CDUL and it is clear that when all the GWS are involved in the service, a large amount of service information broadcasting leads to excessive channel resource occupancy and, especially when the request for gateway service is less, channel

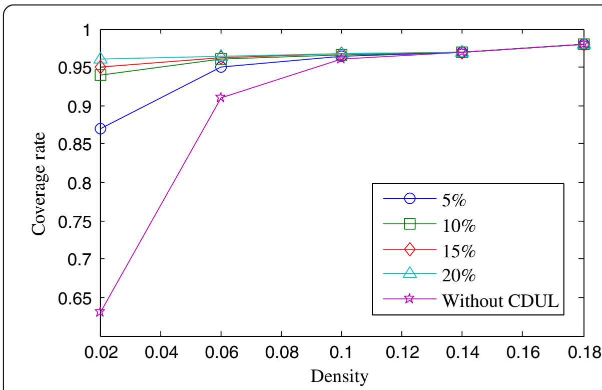

Fig. 1 Coverage ratio

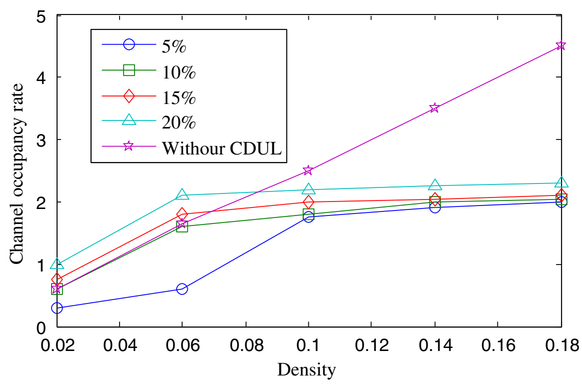

Fig. 2 Channel occupancy rate

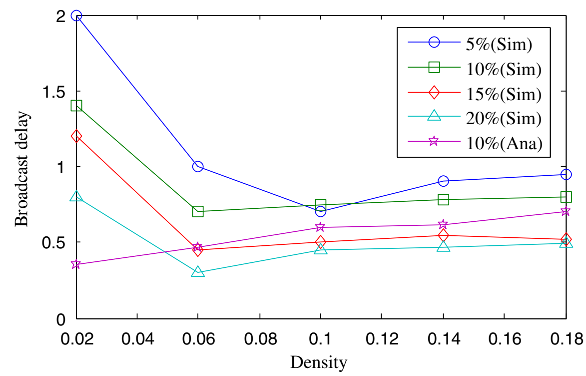

Fig. 4 Broadcast delays

resource waste is serious and not conducive to the rapid broadcast of other urgent messages.

3.4 Access delay

GWS access delay is composed of two parts: cloud transmission delay (TC); and service information broadcast delay (TG). TC is related to network type and transmission bandwidth factors. In the experiment, the 4G network environment, which covers a wide range of urban traffic environments, is selected to test the transmission delay of the TC network. One hundred sets of tests were performed at different locations during the test. The measured results are shown in Fig. 3. From Fig. 3 we can see that time delay (TC) is concentrated over 7–15 ms.

Figure 4 shows the relationship between GWS service information broadcast delay (TG) and traffic density.

When the traffic density is low at sections, the gateway number is too small. Information service is needed through multi hop manner to pass to the road of the vehicle. Due to the inter vehicle lower connectivity, the vehicle cannot directly send service information to the surrounding vehicles and work on the carrying forwarding mode, which leads to the traffic density is 0.02 and the access delay is relatively high. If the GWS ratio is 5% at this time, the entire section is only 2 GWS. Access delay is greater than 1s, and it is difficult to ensure that the vehicle quickly receive service information. In addition, from the experimental results, it is shown that the delay of transmitting information from the cloud to the GWS is much longer than that of the GWS to broadcast the service information to the surrounding vehicles. So as far as possible, the choice of some static service gateway can effectively reduce the access delay. From Fig. 4 it can be seen that the traffic density is 0.02 units/meters, and the vehicle can provide information broadcast service through carrying forward. On the whole, the experimental results have a high consistency with the theoretical curve.

3.5 Data transmission delay

Figure 5 shows the GWC data transmission delay under different traffic densities. It can be seen that when the GWC node reaches a certain number, data transmission delay is very low, and in different traffic densities when the transmission delay environment is very stable, the experimental curve and the theoretical curve have a high degree of consistency.

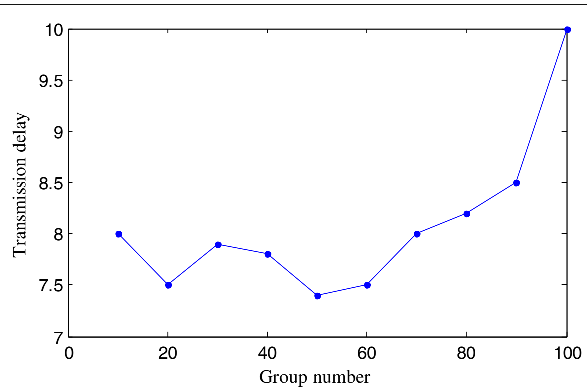

Fig. 3 Transmission delay

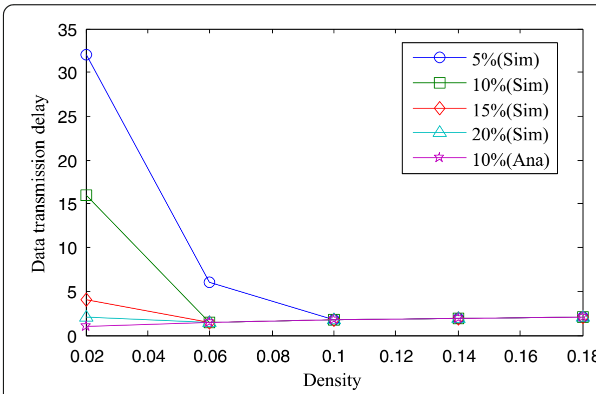

Fig. 5 Data for transmission delays

Figure 6 compares the cloud data upload largely (CDUL) with the gateway selection method clustering multi-gateway management (CMGM): (1) in view of the sparse data, we can see that the emergency message transmission delay, which is higher than that of the proposed method in this paper, can be seen from the experiment and that comparisons with CMGM delay time can be made. This is because in the CMGM protocol, a certain range of vehicles passes through a gateway to upload data, resulting in the gateway communication load being too high, whereas the choice of service gateway in CDUL is more dispersed and the communication load of each GWS is balanced. At the same time, the communication quality of the GWS is fully considered and the delay of data transmission is reduced when an emergency message is delivered; (2) in view of the relatively large data, the traffic information transmission delay with higher link stability is compared. It can be seen that when the traffic density is high, the CMGM will lead to high data transmission delay. In the choice of GWS, CDUL is considered for the link stability, communication load and other factors. Such a large data in the transmission of traffic information can ensure the lower transmission delay.

3.6 Data transmission rate

Figure 7 compares the transmission loss rate of CDUL and CMGM under different densities. CMGM will lead to a large number of vehicles in the same range selecting the same gateway, so that the gateway to send buffer queue packets overflows. In addition, if the mobile gateway is too concentrated this will lead to a large number of data transmission collisions. And CDUL in the gateway selection to avoid the GWS too concentrated, while considering the various GWS communication loads in order to avoid a large number of vehicles choosing the same gateway. As can be seen from Fig. 7, CDUL data transmission in the low packet has a loss rate, and with the increase in traffic density, packet loss rate increases slowly.

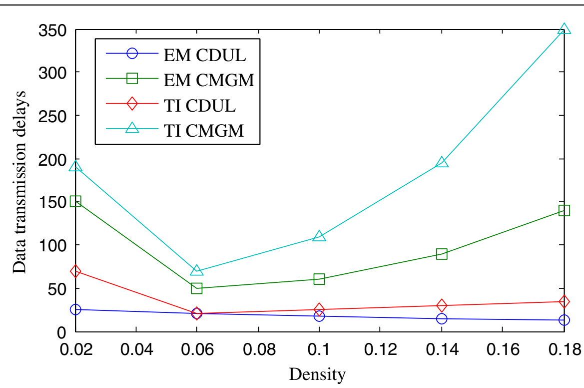

Fig. 6 Comparison diagram of gateway controller (GWC) data transmission delay

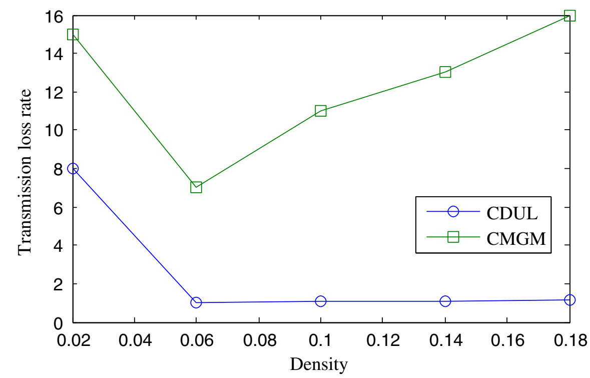

Fig. 7 Gateway server (GWS) packet loss rate

As can be seen from the experiment, when the GWS density reaches a certain level, the service information broadcast method proposed in this paper has higher coverage rate and lower channel occupancy rate. Compared with the existing methods, the transmission delay and packet loss rate of data upload is lower which is reflected in the very stable performance curve. If GWS density is too low, the performance parameters of the five have a certain effect, but in the current traffic environment it is very easy to meet the demand of GWS density, especially in many city buses and taxis with the deployment of such a large number of 4G network interfaces. A number of private cars have also begun to use such a network interface. It can be predicted that with the development of the car networking and mobile cloud services, some of the static GWS will also begin to be significantly deployed. Additionally, according to the mobile cloud services based on mobile network architecture and using a data-upload method to ensure that reliable data are rapidly uploaded to the cloud, this will not make too high a demand on the channel and communication resources.

4 Conclusion

All kinds of security, transportation, entertainment applications rely heavily on intervehicle and vehicle and the cloud of data transfer and interaction. In order to quickly and reliably upload data to the cloud, this paper first proposes a new, mobile, cloud-based networking architecture. The architecture divides the network nodes into three layers, namely the cloud, the gateway service provider layer and the gateway layer. Gateway services to the cloud register service information and status information by choosing which of the cloud services participate in the choice of cloud services. After gaining access to service information, gateway consumers, according to their own data transmission needs, select the best gateway from which to access the Internet and transmit data to the cloud.

In summary, this paper firstly solves the cloud service gateway decision problem in that the gateway service as far as possible, through a hop radio service, broadcasts information to all vehicles in the surroundings while avoiding the gateway service too closely and preventing an excess of signal collisions and channel resource waste. Hence, this solves the problem of service information broadcast coverage of the gateway service provider. When the service gateway density is low, the number of hops is increased, so that more customers can receive the service information. In this paper, we assist the gateway consumers in choosing the best gateway service according to the type of data transmission and related performance parameters. Experiments and theoretical analysis show that the method can be effective in managing various gateway services. To ensure the service coverage, while reducing channel and communication resource consumption, different types of data transmission can guarantee lower transmission delay and packet loss rate.

In this paper, the main problem we address is how to solve the uplink issue, that is how to transfer data from the cloud distribution to the target area and the target vehicle in a timely and reliable manner. In the future, however, we will base this on real traffic scenarios, combined with uplink and downlink data transmission methods, and use the transmission and distribution of data to expand further research and verification.

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Competing interests
The authors declare that they have no competing interests.

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