Selection method of wireless communication modes in internet of vehicles

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Abstract

Internet of Vehicles has great effect on improving the efficiency of the transportation system and driving safety. Communication process of Internet of Vehicles can be done adopting various wireless communication modes which include 3G, WLAN and WAVE. As each wireless communication mode has different traffic scene applicability and different communication effects, this paper proposed a selection method for wireless communication mode based on support vector machine. This method obtained learning samples which indicate the communication mode with best communication performance through simulation of various traffic scenes in OPENT Modeler. Through the study of support vector machine algorithm, this designed method can output the predicted result mode of wireless communication adaptively under unknown traffic scenes. The outstanding results show that the selection method based on support vector machine can accurately choose the optimal communication mode in Internet of vehicles.

Keywords: internet of vehicles, wireless communication mode, support vector machine, communication performance, OPENT modeller

1 Introduction

Internet of Vehicles is important means of green travel for a modern city to reduce traffic congestion. Internet of Vehicles is the typical application of Internet of things in the transportation industry. With the vigorous development of the Internet of things technology in China, as an application of the Internet, Internet of Vehicles gets vehicles running parameters and road transport infrastructure such as usage, perception of real-time road traffic conditions and provides abundant comprehensive intelligent transportation services. Internet of Vehicles has a very broad application prospects in the aspect of improving efficiency of traffic and transportation system safety driving. According to the network architecture of Internet of things and the content of the web services it should provide and the networking architecture of Internet of Vehicles is shown in Figure 1. It can be divided into perception layer, network layer and application layer.

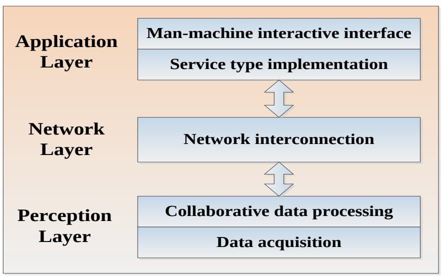

FIGURE 1 The networking architecture of Internet of Vehicles

Internet of Vehicles has similar characters with Vehicle Ad hoc Network (VANET) liking universality, movability and Intelligence. As its own constraints architecture of vehicle ad-hoc network, vehicle safety problems like lacking of entire network data acquisition, insufficient information sharing and non-real time data interaction exist [1]. As topology structure of vehicles in Internet of Vehicles changes rapidly, the efficiency and security of wireless communication are confronted with great challenges and it may need a variety of communication modes to complete wireless communication tasks, such as 3G, Wireless Local Area Networks (WLAN) and Wireless Access in the Vehicular Environment (WAVE) which are described in Figure 2. In order to get better network performance, more appropriate should be adopted in specific traffic scene.

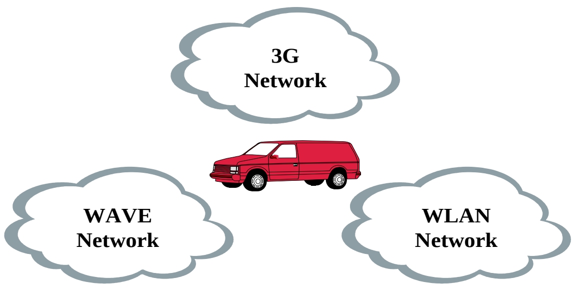

FIGURE 2 The structure of UMTS

Now many experts and scholars have constructed various communication modes and networking communication architecture in Internet of Vehicles. In [2], authors developed a simulation framework for holistic analysis of complex UMTS-based ITS. This framework couples simulation models with corresponding protocols of the UMTS link level, of higher network layers, and of road traffic. Based on our simulation framework and real-world 3G network coverage data, they evaluated a UMTS-based Traffic Information System (TIS) in a typical highway scenario, in which information about traffic jams needed to be communicated to other cars for optimized route planning. The evaluation clearly outlines the capabilities of the simulation framework and evaluation results are consistent with all expectations. In [3], this paper designs and implements a multimode wireless gateway based on embedded system. The hardware uses ARM11 microprocessor, S3C6410, as controller and integrates 3G module, IEEE802.11g module and Bluetooth module. The software is based on Embedded Linux, develops drivers of integrated modules and user applications, and realizes the function of protocol conversion and routing. In [4], authors use GPS information to calculate the expected capacity using location, direction, velocity and RSSI information, in advance. Therefore, we suggest a handoff algorithm that uses the expected capacity to guarantee bandwidth. We implemented the suggested algorithm and experimentally verified the performance of the algorithm.

In [5], authors envision design VANET-UMTS integrated network architecture. In this architecture, vehicles are dynamically clustered according to different related metrics. From these clusters, a minimum number of vehicles, equipped with IEEE 802.11p and UTRAN interfaces, are selected as vehicular gateways to link VANET to UMTS and encouraging results are obtained in terms of high data packet delivery ratios and throughput, reduced control packet overhead, and minimized delay and packet drop rates. In [6], Seamless Internet 3G and Opportunistic WLAN Vehicular Internet Connectivity (SILVIO) is proposed, a solution for providing Internet connectivity in multi-hop vehicular ad hoc networks. Real traffic traces from the city of Madrid were used to feed the simulator which considers large vehicles as obstacles, as well. The obtained simulation results show that using SILVIO the cellular network can be offloaded by a factor up to 80%.

Neural network is also applied in the transportation system widely, but it has not been used for communication mode selection. Lee and Wai designed adaptive fuzzy neural network control model that applied magnetic levitation transportation system, and its online learning algorithm has solved the problem of the chattering phenomenon and stability of the system [7]. In this paper, the neural network is used for integrate wireless communication mode. In [8], various methodologies for traffic information prediction are investigated. Authors present a speed prediction algorithm.

NNTM-SP (Neural Network Traffic Modeling-Speed Prediction) that trained with the historical traffic data and is capable of predicting the vehicle speed profile with the current traffic information. Experimental results show that the proposed algorithm gave good prediction results on real traffic data and the predicted speed profile shows that NNTM-SP correctly predicts the dynamic traffic changes. In [9], aiming at limitation of the conventional network traffic time series prediction model and the problem that BP algorithms easily plunge into local solution, an optimization algorithm - PSO-QI which combine particle swarm optimization (PSO) and the quantum principle is proposed, and can alleviate the premature convergence validly. Then, the parameters of BP neural network were optimized and the time series of network traffic data was modeled and forecasted based on BP neural network and PSO-QI.

The remainder of this paper is structured as follows. Section II gives a scope of wireless communication modes in Internet of Vehicles. Section III describes the proposed selection method for wireless communication mode based on support vector machine and verification for it is presented in Section IV. Section V finally concludes this paper.

2 Scope of wireless communication modes

2.1 3G COMMUNICATION MODE

UMTS (Universal Mobile Telecommunication Systems), as a 3G &beyond cellular network technology, operates with a frequency range of around 2 GHz [10]. UMTS make the WCDMA as the preferred air interface technology and achieve continuous improvement [11], but it also has introduced the TD-SCDMA and HSDPA technology. The structure of UMTS system mainly includes the wireless access network, CN (Core Network, the core network), UE (User Equipment) and UTRAN (UMTS Terrestrial Radio Access Network). UMTS support transmission rate with 1920 kbps and a peak downlink data rate of 2 Mbps. The structure of UMTS is described in Figure 3.

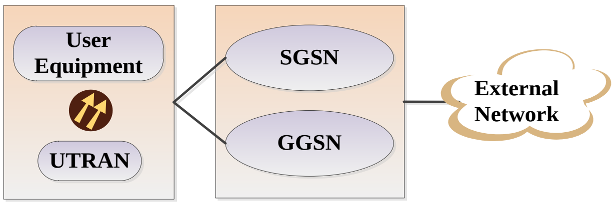

FIGURE 3 The structure of UMTS network

3G communication mode is suitable for communication scenarios with long distance and less traffic load. The advantage of 3G communication mode has less demand on the moving velocity of the node, and the disadvantage of 3G is the data transfer rate and limited capacity.

2.2 WLAN COMMUNICATION MODE

WLAN is a type of wireless communication system, with characters of flexibility, mobility, easy scalability, and low cost and used for providing wireless connectivity between moving vehicles [12]. Wi-Fi which is the widely application of WLAN is a brand of wireless communication technology, and its main communication protocol is the IEEE 802.11 series of protocol. Wi-Fi adopts the IEEE 802.11b protocol generally. There are many available routing protocols, including AODV, DSR, TORA routing protocol. Channel access protocols such as DCF (Distributed Coordination Function), PCF (Point Coordination Function) and HCF (Hybrid Coordination Function) are available. Other kinds of IEEE 802.11 series protocol for different application scenarios have different applicability. The typical routing protocol, channel access protocol and MAC protocol are listed in the following figure.

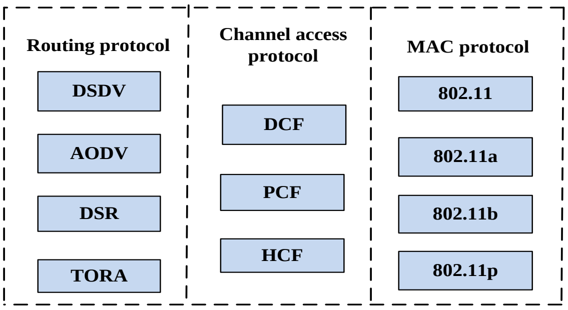

Figure 4 The networking architecture of Internet of Vehicles

WLAN communication mode is suitable for the communication scenario in which the number of vehicles, vehicle velocity, and communication distance are moderate. Overall, WLAN technology proved to work also at vehicular velocity [13].

2.3 WAVE COMMUNICATION MODE

WAVE technology is an efficient short-range wireless communication mechanism after the generation of cooperative vehicle infrastructure system in order to solve the vehicle-to-vehicle communication, vehicle-roadside communication problems. The advantage of WAVE is mainly reflected in the message transmission latency, node mobility, communication frequency of anti-interference. The applicability of the IEEE 802.11p for Internet of Vehicles, its comprehensive evaluation of network performance and cost of implementation and complexity aspects are superior to ordinary wireless communication technology.

The data Link layer includes LLC (Logical Link Control) and MAC, the IEEE 802.11p of MAC layer is the concentrated reflection of the performance advantages in the protocol architecture as shown in Figure 5. The IEEE 1609.4 standard sets rules on the multi-channel multiplexing technique and channels can be divided into SCH and CCH time slot by using the method of time slot, and the channel time is divided into synchronization intervals with a fixed length of 100ms [14, 15]. MAC layer provide services for data transmission channel and coordination control, and make more efficient exchange of data through reliable channel access protocol. The WAVE mode is more suitable for traffic scenarios with plenty of vehicles and high velocity.

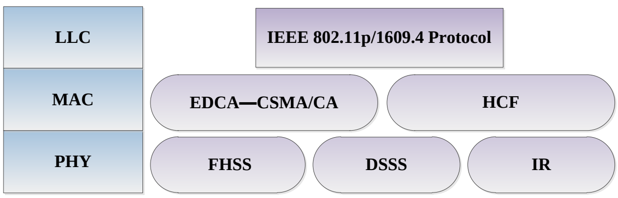

FIGURE 5 The protocol architecture of WAVE

3 Selection method for wireless communication modes based on support vector machine

The main function of proposed selection method for wireless communication modes is to select the most suitable wireless communication mode for the current traffic scene. Support vector machine can learn the rule of optimal communication mode according the learn simples. As vehicle density and vehicle velocity are the regular characters of transportation system, so they regard as the input of the support vector machine network. Support vector machine (SVM) network model is adopted in selection method proposed in this paper.

3.1 SUPPORT VECTOR MACHINE MODEL

Support vector machine (SVM) method is built on the basis of statistical learning theory based on VC dimension theory and structure risk minimum principle and seek the best compromise between the limited sample information in the complexity of the model and learning ability to get the best generalization ability. The decision function of support vector machine (SVM) is similar to a support vector machine network, and the output is several linear combinations of the middle layer nodes. Each layer node corresponds to the inner product between input sample and a support vector, and then which is also called support vector networks. The structure of support vector machine network is shown as Figure 6. x_1 and x_2 represent vehicle density and vehicle velocity respectively. The essence of SVM is mapping the low-dimensional input space to a high-dimensional feature vector space. y is the output of support vector machine network model and its range of value is $(0,1,2,3)$ which represent random mode, 3G mode, WLAN mode and WAVE mode respectively.

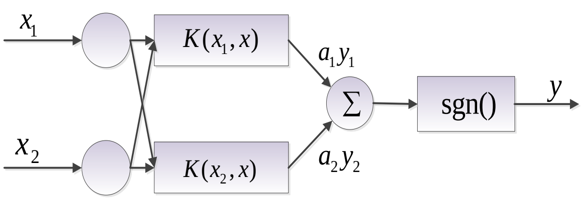

FIGURE 6 Structure of SVM network

$K(x_i,x_j)$ is the inner product function which satisfies condition of Mercer. sgn() is the threshold function of this selection method.

$$K(x_i,x_j)=[(x_i \cdot x_j)+1]^q, \quad q=1, \tag{1}$$

$$\text{sgn}=\begin{cases}1,(0.5\le y<1.5)\\2,(1.5\le y<2.5)\\3,(2.5\le y<3.5)\\0, \quad other\end{cases} \tag{2}$$

3.2 LEARNING SAMPLE

The learning samples consist of optimal simulation results of plenty of traffic scenes. Simulation scenarios with different vehicle densities and vehicle velocities are simulated using different communication modes in OPNET Modeler, and then communication mode with the best communication performance is chose as the learning sample. The transmission delay and packet loss rate are the main communication performance evaluation indexes. The transmission delay means the time difference between the time of creating packet and the time of receiving packet. The packet loss rate means the proportion of lost packet in the whole packets. This paper puts forward a system evaluation factor C which integrates the transmission delay and packet loss rate as formula (3).

$$C = 0.5\cdot(1-\frac{D}{D_{\max}}) + 0.5\cdot(1-\frac{L}{L_{\max}}) \quad (3)$$

D and L are the average transmission delay and packet loss rate during current simulation scene. We think that the transmission delay and packet loss rate have the same importance for the performance of Internet of Vehicles nearly, so their scaling factor are 0.5 as well. $D_{\max}$ and $L_{\max}$ indicate the maximum value of them respectively. System evaluation factor C can reflect the performance of the network communication basically and $0 \le C < 1$. The performance of communication change for the better as the value of C becomes larger.

System evaluation factor C regards as the reference standard which is put forward by the above paper. A number of different traffic simulation scenarios were finished and the communication mode with maximum of C was selected for learning samples. The whole learning samples of selection method based on SVM network model is described in Table 1.

TABLE 1 Learning samples of selection method

Input(veh, km/h)	Evaluation Factor	Optimal Mode
100,20	0.654	3G
100,40	0.702	3G
100,60	0.745	WAVE
200,20	0.723	WLAN
200,40	0.695	WLAN
200,60	0.821	WAVE
400,20	0.795	WLAN
400,40	0.765	WAVE
400,60	0.732	WAVE

3.3 LEARNING ALGORITHM

The process of learning algorithm for solving the problem of classification with support vector machine (SVM) is described in the following paper.

Step 1: One group of learning sample (x_1, x_2) and desired output (y_1, y_2) are given. There are 9 groups of learning samples in whole.

Step 2: Constraint condition are described in following Equation.

$$\sum_{i=1}^{2} y_i a_i = 0,\ \ a_i \ge 0 (i = 1,2)\,. \quad (4)$$

Then calculate the maximum value of $W(a)$ from the Equation (5) and obtain a_i^*.

$$W(a) = \sum_{i=1}^{2} a_i - \frac{1}{2}\sum_{i,j=1}^{2} a_i a_j y_i y_j (x_i \cdot x_j) \quad (5)$$

Step 3: Calculate the value of w^* and b^* as following Equation. x_s is a specific support vector.

$$w^* = \sum_{i=1}^{2} a_i^* x_i y_i\ , \quad (6)$$

$$b^* = \frac{1}{y_s} - w^* \cdot x_s\,. \quad (7)$$

Step 4: For the vector x without classification, it can be calculated by $K(x_i, x_j)$ and $f(x)$.

$$f(x) = \mathrm{sgn}\{\sum_{i=1}^{2} y_i a_i^* K(x_i, x) + b^*\}\,. \quad (8)$$

Although the performance of the SVM algorithm is verified in the application in many actual problems, but there are some problems on the calculation of the algorithm, which include slow training algorithm, the complex algorithm that is difficult to implement and test phase with heavy computation. The memory size during training process is shown is Figure 7 and the memory size increase rapidly with the increase of sample size, and in the final it reaches 24M. When the above four steps are finished, the SVM network is constructed and it can be used for selection of communication mode.

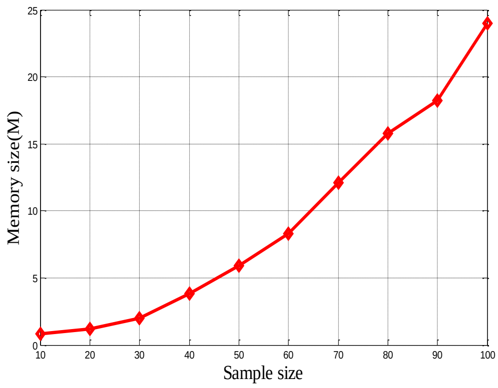

FIGURE 7 The relationship between memory size and sample size inSVM network

3.4 SIMULATION RESULTS OF SVM NETWORK

In order to verify the accuracy in the choice of communication mode in Internet of Vehicles by above designed support vector machine network model, the authors have designed more complex traffic simulation scenarios in which more elaboration of vehicle densities and vehicle velocities regard as the input of support vector machine network. Through support vector machine learning algorithm, and the output of the communication mode by selection method is collected as follows Table 2.

TABLE 2 Result of support vector machine network model

Input(veh, km/h)	Output
150,20	3G
150,30	3G
150,40	3G
150,50	3G
150,60	WAVE
250,20	WLAN
250,30	WLAN
250,40	WLAN
250,50	WAVE
250,60	WAVE
300,20	WLAN
300,30	WLAN
300,40	WAVE
300,50	WAVE
300,60	WAVE

4 Performance evaluation

The purpose of evaluation of selection method for wireless communication mode based on support vector machine network is comparing the different choice results between the real optimal communication mode and the output of the selection method. At the same time, authors make research for the effect of performance with different communication mode in different traffic simulation environments.

4.1 ESTABLISHMENT OF SIMULATION SCENARIO

The simulation scenarios are constructed in OPNET Modeler. OPNET which is based on the time driving mechanism has good time management strategy. OPENT provide According to the particularity of communication process in Internet of Vehicles, the MANET model of OPNET Modeler model library is selected as vehicle equipment simulation experiments when WLAN and WAVE are selected as the communication modes. As the main information carrier, MANET node plays a decisive role to the entire network environment simulation.

Vehicle information is sent and received from the WLAN transceiver and in turn goes by the MAC layer, data link layer, IP, UDP, routing layer, application layer to complete the whole message communication process. The quantity of MANET model represents the vehicle density and the attitude of velocity represents the vehicle velocity. As the motion model is not essential for this selection method, so it is set as random mobility. Routing protocol, packet size and interval, channel access protocol parameters and other settings can be set by the user interface in OPNET Modeler. The number of MANET during simulation is placed according the input of Table 2 and simulation process with WLAN mode is shown as Figure 8.

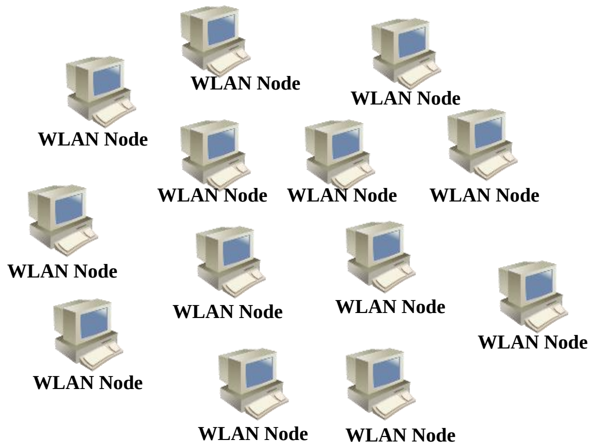

FIGURE 8 WLAN simulation process in OPNET Modeler

As the WAVE mode is based on 802.11p and OPNET Modeler don't provide its interface, so we need to modify the node internal code to simulate the communication process with WAVE communication mode. The focus of modification is the MAC layer and multi-channel operation.

The simulation process with WAVE mode is show as Figure 9.

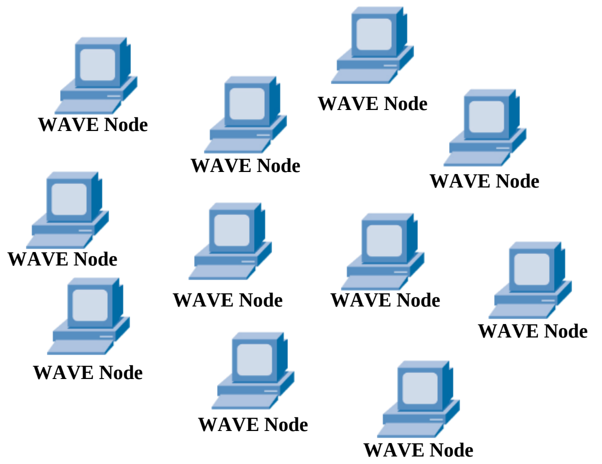

FIGURE 9 WAVE simulation process in OPNET Modeler

The simulation network topology of UMTS in OPNET Modeler is shown in Figure 10. UE represents the mobile user equipment, and Node_B represents the node B in UMTS. The RNC represents the radio network controller of UMTS, and CN represents the core network in UMTS. The quantity of UE is equal to the vehicle density. In order to generate UMTS data flow, an external network and the FTP server are built.

The simulation scenario needs to switch among different communication modes. The range of simulation scenario is one square kilometer. OPNET Modeler perform a variety of communication modes, which including 3G (UMTS), WLAN and WAVE.

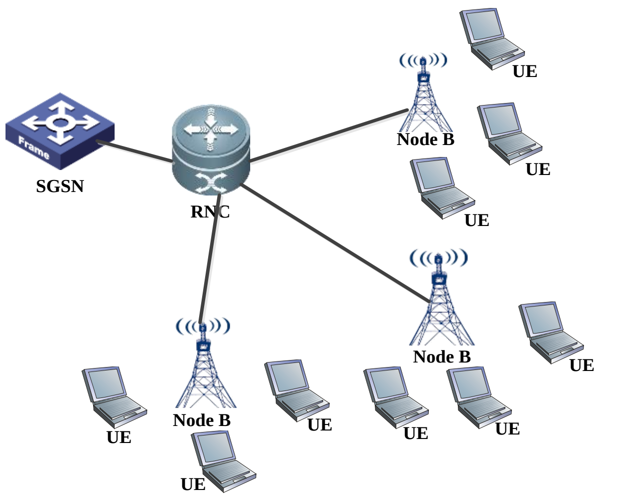

FIGURE 10 UMTS simulation process in OPNET Modeler

The attitudes of communication mode and above simulation scenario are set as the default settings which are described in Table 3. The simulation time lasts 10 minutes. The simulation results are managed by the statistics processing of OPNET Modeler during simulation and can export when simulation finished.

TABLE 3 The default settings of simulation

Settings	Value
Simulation range	1000m^2
Simulation time	10minutes
Packet size	1000 bytes
Packet interval	Exponential(1)
MAC protocol	802.11p/802.11b
Data rate	11M/s
Wireless transmission mode	TwoRay Ground
Network interface type	Wireless PhyExt
Interface queue model	PriQueue
Mobility model	Random
Channel access protocol	EDCA/DCF
Link layer	LL
Routing protocol	AODV

4.2 VERIFICATION OF SVM NETWORK

Through the simulation according to the input of support vector machine network and the system evaluation factor C, the optimal communication modes are obtained precisely. The verification results of support vector machine network model are described in Table 4. We can see from the results that only when the vehicle density and velocity are 150 and 50, the output of selection method and real optimal mode is different. This is because when 3G mode behaves well when the number of vehicles is small and WAVE mode behaves well when the vehicle velocity is high. Then the wrong judgment is made as the miscalculation of transport properties and different traffic applicability. The probability of correct is 93.3%. In order to get higher accuracy of selection of communication mode, the failure output can be joined in the learning samples as the new condition, then the feedback loop is constructed.

TABLE 4 Verification result of support vector machine network model

Input(veh, km/h)	Output	Optimal Mode
150,20	3G	3G
150,30	3G	3G
150,40	3G	3G
150,50	3G	WAVE
150,60	WAVE	WAVE
250,20	WLAN	WLAN
250,30	WLAN	WLAN
250,40	WLAN	WLAN
250,50	WAVE	WAVE
250,60	WAVE	WAVE
300,20	WLAN	WLAN
300,30	WLAN	WLAN
300,40	WAVE	WAVE
300,50	WAVE	WAVE
300,60	WAVE	WAVE

4.3 VERIFICATION OF NETWORK PERFORMANCE

The system evaluation factor can reflect the wireless network performance. In order to show the different network performance of simulation scenario with various vehicle densities and velocities visually, we stat the transmission delay and packet loss rate during simulation time. In order to make a fair comment for network performance, we calculate the average parameter of transmission delay and packet loss rate in specific simulation environment. The unit of transmission delay is sec and the unit of packet loss rate is %. The simulation result of transmission delay and packet loss rate in different simulation scenarios are shown in Figure 11 and Figure 12.

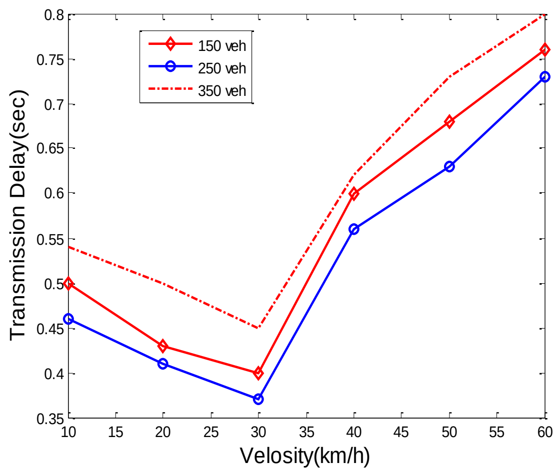

FIGURE 11 Results of transmission delay in different simualtion senarios

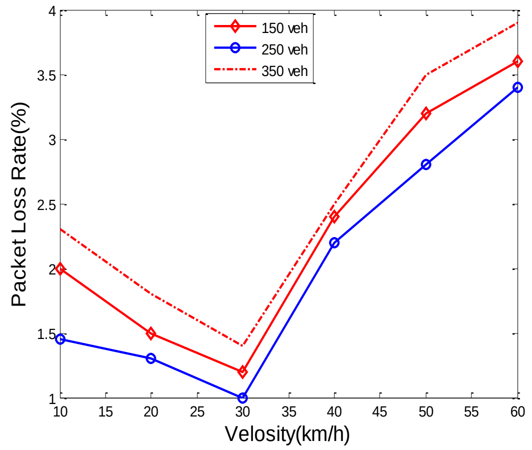

FIGURE 12 Results of packet loss rate in different simualtion senarios

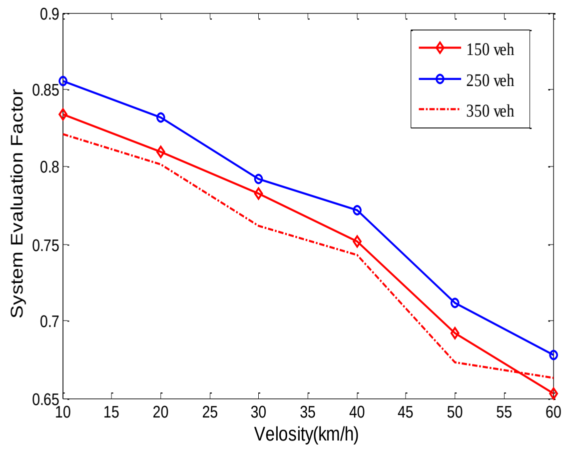

FIGURE 13 Results of system evaluation factor in different simualtion senarios

It can be seen from the above result of transmission delay and packet loss rate that they have the similar variation tendency with the increase of velocity value. The velocity stands for average velocity of all the vehicles. When the velocity is low, vehicle nodes is equal to the fixed nodes and the miscellaneous function of movement has no show, so the network performance is not very good. When the velocity is high, network topology changes in frequent and the path of data packet transmission is unstable, then it leads to bad network performance. When the velocity is moderate, the communication performance is optimal relatively.

The effect of vehicle density on the performance of communication is also similar. When the vehicle density is small, the path that reaches the destination node is less and when the vehicle density is large, the possibility of traffic jams increase, so above conditions lead to the increase of transmission delay and packet loss rate. The system evaluation factor integrates the transmission delay and packet loss rate reasonably.

Figure 13 shows the system evaluation factor C in all simulation scenes. From it we can see that when the density is modest and velocity is low, the performance of network is better and the reason of it is that when the topological structure and routing of network is relatively stable, the path between source node and destination node is unblocked and the probability of sending failure is small relatively. As the selection method can choose the optimal communication mode, their network performances have little difference in the changing process of velocity.

5 Conclusion

Through the study of the 3G, WLAN and WAVE communication mode applied in the Internet of Vehicles and analyzing the applicability of the communication mode, and then the selection method for wireless communication mode based on support vector machine network was proposed. The learning samples are created through plenty of simulation scenarios built in OPENT Modeler. After support vector machine learning algorithm, it forms a complete support vector machine network model to make choice of communication mode. More complex simulation scenes are built for the verification of selection method based on support vector machine network. The verification results show that the applicability of the selection method based on support vector machine network is great and basically can find out the optimal communication mode. The network performance factors which include transmission delay and packet loss rate reflect the variation tendency with different traffic simulation scene and the system evaluation factor integrate the transmission delay and packet loss rate reasonably.

This paper also has shortcoming, for example, the reasonability of support vector machine network has no strict mathematical reasoning; the learning samples have no integrity; the selection of evaluation parameters have no argument whether they are justice. In the future, we will search for more accurate selection methods of wireless communication mode in Internet of Vehicles.

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