Vertical handover algorithm for Internet of vehicles based on dynamic scanning period and grey prediction

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ABSTRACT

In order to enable Internet of vehicle users to discover the surrounding available wireless networks in time and reduce the energy consumption caused by network scanning in a heterogeneous network environment, this paper proposes a vertical handover algorithm based on dynamic scanning period and grey prediction method. In the network discovery phase of vertical handover, this method dynamically changes the scanning period according to the speed of the vehicle, so as to achieve a balance between the activate times of the interface and the timely discovery of the network. In the network selection phase, this paper uses the grey prediction algorithm to predict received signal strength of the current access network, so that Internet of vehicles users can make decisions and switch in advance. The simulation results show that compared with existing algorithms, dynamic scanning period method proposed in this paper can discover the network in time and reduce the energy consumption of the terminal. The use of grey prediction algorithm enables Internet of vehicles users to effectively predict the received signal strength and make handover decisions more timely, and the handover call drop rate is improved.

Keywords: Internet of vehicle, heterogeneous network, dynamic scanning period, grey prediction

1. INTRODUCTION

The concept of Internet of vehicles[1] is gradually known by people in recent years. Also, with the fast advance of wireless communication technology, various wireless network technologies came into being, forming a coexistence situation of multiple networks. These networks have their own advantages and disadvantages in network performance such as bandwidth, delay and coverage. In order to make Internet of vehicles users maintain a good connection at all time, the integration of heterogeneous wireless networks under the Internet of vehicles is an inevitable trend. At present, heterogeneous networks of Internet of vehicles mainly include LTE, DSRC (dedicated short range communication) and WLAN[2]. In the heterogeneous network environment, vertical handover is one of the most important technology. The key problem of vertical handover under the Internet of vehicles is how to find new available networks and choose among multiple available networks. Yu uses fixed scanning period for network discovery[3], but the fixed scanning period is obviously not suitable for the different scenes of vehicle networking. A periodic hierarchical scanning mechanism was proposed[4]. The mechanism adjusts the scanning period of the terminal according to the current network quality and the surrounding environment change speed. However, the classification method only divided two scanning period of 1s and 0.1s. A multi-attribute vertical handover algorithm based on dynamic scanning period is proposed[5]. Although the algorithm is able to reduce the energy consumption of mobile terminals, it overlooks the importance of ensuring the quality of service for Internet of vehicle users.

Considering the problems of existing algorithms, we proposed a vertical handover algorithm for Internet of vehicles based on dynamic scanning period and grey prediction. Firstly, in the network discovery phase, the scanning period is dynamically adjusted according to the current speed of the vehicle; which can achieve a balance between timely network discovery and reducing energy consumption. In the network selection phase, we use grey prediction algorithm to predict the RSS (received signal strength) of current access network based on the historical values, which enables the users to know the network RSS changes in time, prepare for switching, and improve the switching efficiency and success rate. The results demonstrate that the algorithm used in this paper not only improve the energy consumption of terminals, but also reduce the network discover time of users. Besides, by predicting the received signal strength of current access network, switching efficiency and switch success rate are enhanced, which ensures the service quality of Internet of vehicles users.

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2. VERTICAL HANDOVER FOR INTERNET OF VEHICLES

2.1 Network discovery

Vertical handover process can be roughly divided into three phases: network discovery phase, network selection phase and network handover phase[6]. In network discovery phase, vehicle scans the surrounding networks to find the network that can be used. Vehicles with multiple network interfaces must activate these interfaces to obtain the surrounding available network information. If interfaces are always active, it will consume a lot of terminal power. Therefore, for Internet of vehicles users, timely discovery of available networks and reduction of energy consumption of vehicle terminals are two important aspects to be considered. In this paper, we proposed a dynamic scanning mechanism based on vehicle speed. We determine the scanning period as

$$\Delta T = T_{max} + (T_{max} - T_{min})(1 - \frac{V}{Vmax}) \tag{1}$$

where T_{min} is the minimum scanning period, which is set as 1s in this paper. T_{max} is the maximum scanning period, which is set as 9s in this paper. V is the current vehicle speed, V_{max} is the maximum speed of the vehicle, which is set as 120km/h in this paper.

2.2 Network selection

Network selection phase is the second phase of vertical handover process. In this phase, by analyzing the surrounding network information, the most suitable network for Internet of vehicle users is selected. A good handover decision algorithm can determine the most appropriate handover time, avoid unnecessary handover, and improve the user's quality of service.

Received signal strength (RSS) is an important evaluation basis of wireless network link quality; It is also an important judgment standard that users need to consider in the process of vertical handover. If the vehicle terminal can know the RSS of current access network in advance, the vehicle can determine the best switching time and switch to a better network to prevent call drop, switching failure, etc. In this paper, we use grey prediction algorithm to predict the RSS of the current access network.

2.3 Grey prediction method to predicts RSS in Internet of Vehicle

GM (1,1) prediction model is widely applied in grey theory system. The model can well predict the future signal strength, and the steps are as follows:

(1) Construct a sequence containing historical RSS values:

$$R^{(0)} = \left(r^{(0)}(1), r^{(0)}(2), \dots, r^{(0)}(n)\right) \tag{2}$$

(2) Construct a new sequence $R^{(1)}$:

$$R^{(1)} = (r^{(1)}(1), r^{(1)}(2), \dots, r^{(1)}(n)) \tag{3}$$

$$r^{(1)}(k) = \sum_{i=1}^{k} r^{(0)}(i), k = 1,2,\dots,n \tag{4}$$

(3) Get the grey differential equation:

$$\frac{dr^{(1)}}{dt} + ar^{(1)} = b \tag{5}$$

a and b are obtained by equation (6):

$$\hat{\alpha} = (a, b)^T = (B^T B)^{-1} B^T Y_n \tag{6}$$

where $B=\begin{bmatrix} -r^{(1)}(2) & 1 \\ -r^{(1)}(3) & 1 \\ \cdots & \cdots \\ -r^{(1)}(n) & 1 \end{bmatrix}, Y_n=\begin{bmatrix} r^{(0)}(2) \\ r^{(0)}(3) \\ \cdots \\ r^{(0)}(n) \end{bmatrix}$.

(4) Get predicted RSS:

After obtaining a and b, we are able to use the grey differential equation to predict the RSS value at time k+1. The grey prediction model is described as:

$$\hat{r}^{(1)}(k+1) = [r^{(0)}(1) - \frac{b}{a}]e^{-ak} + \frac{b}{a},\ k = 1, 2, \ldots, n \tag{7}$$

Then the prediction value of RSS can be calculated by the following equation:

$$\hat{r}^{(0)}(k+1) = \hat{r}^{(1)}(k+1) - \hat{r}^{(1)}(k) \tag{8}$$

By using the grey prediction algorithm, Internet of vehicles users can determine the best time to leave the current network, so as to avoid the problems such as call drop caused by not switching in time. Next, the decision method needs to be used to determine which candidate network to switch to. This paper selects Multi-Attribute decision making (MADM) algorithm, which is simple, efficient and widely used in vertical handover algorithm[7].

2.4 Analytic hierarchy process (AHP) to determine the attribute weight

The idea of AHP method is to decompose the complex decision-making problem into sub-problem hierarchies that are easier to understand[8]. The typical hierarchical structure model for AHP is shown in Figure 1. According to the requirements of Internet of vehicle users for the network, delay (D), bandwidth (B), packet loss rate (P) and price (C) are selected in this paper. Assuming that the Internet of vehicle user is running the information business type, this type of service has high requirement for price while low requirement for delay and bandwidth.

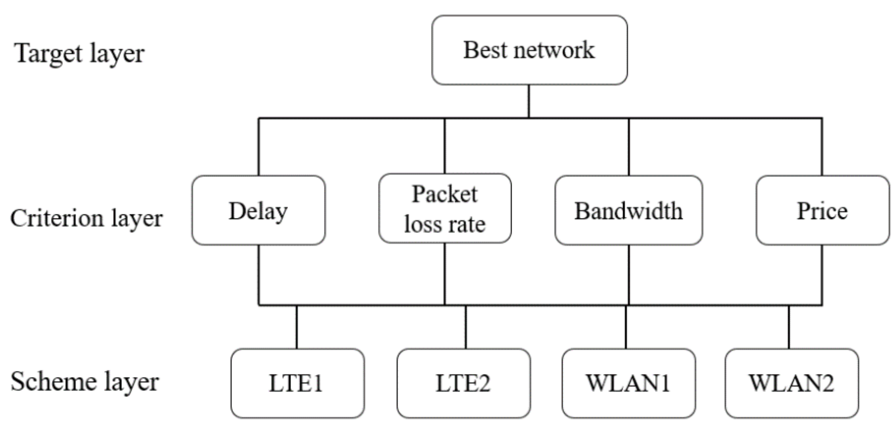

Figure 1. Hierarchical structure model for AHP.

According to the steps of the AHP method, the corresponding weight vector can be obtained as:

$$\omega = \begin{matrix} D & B & P & C \\ (0.07 & 0.243 & 0.149 & 0.537) \end{matrix} \tag{9}$$

2.5 TOPSIS method to select the network

TOPSIS method is an MADM method that use the idea of finding the candidate network that is closest to the positive ideal network, and furthest from the negative ideal network. After getting the attribute weights by AHP method, the weight vector is used in TOPSIS method to evaluate the most appropriate network for the current service type, and the best network is selected.

3. SIMULATION ANALYSIS

3.1 Simulation scenario

We verify the feasibility and accuracy of the proposed algorithm on OPNET simulation platform. The simulation scenario consists of two LTE networks and two WLAN networks. The overlapping coverage scenario is shown in Figure 2. LTE 1 covers the whole simulation area with a coverage radius of 3000m. The coverage radius of LTE 2 is 1000m. The coverage radius of WLAN 1 is 300m and that of WLAN 2 is 500m. Internet of vehicle user cross these four networks according to the trajectory shown in the figure. Assuming that the current business type of the vehicle is information service, the vehicle moves at the speed of 30km/h before point A, after point A, it moves at the speed of 60km/h.

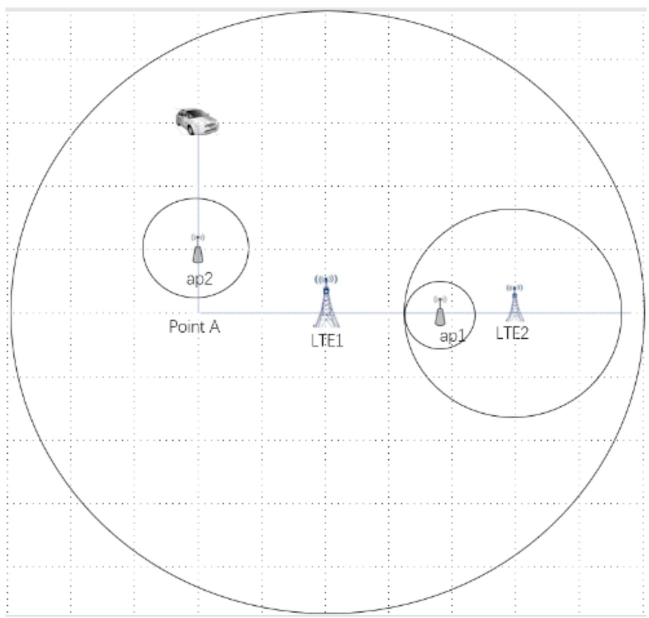

Figure 2. Simulation scenario.

The parameters of the networks are set as shown in Table 1.

Table 1. Parameters of the candidate networks.

Network	Delay (ms)	Bandwidth (MHz)	Packet loss rate (%)	Price
LTE1	10-20	8-10	3-5	9
LTE2	20-30	9-11	5-7	6
WLAN1	50-80	10-20	8-10	3
WLAN2	60-90	15-30	9-12	2

3.2 Analysis of simulation results

In this paper, we use the activate times of terminal interface to represent terminal power consumption, and compares the dynamic scanning period method with the fixed scanning period of 5s and 7s. The results shown in Figure 3 are the comparison of interface activate times when the vehicle moves at variable speed shown in Figure 2. Figure 4 shows the comparison of network discovery time under three scanning methods. We can see from the result that the dynamic scanning period method has less interface activate times than the fixed scanning period of 5s. Although it has more interface activate times than the 7s scanning period, it performs significantly better in network discovery time than 7s scanning period. Therefore, the method based on dynamic scanning period proposed in this paper achieves the balance between discovering the network in time and reducing the activate times of terminal interface.

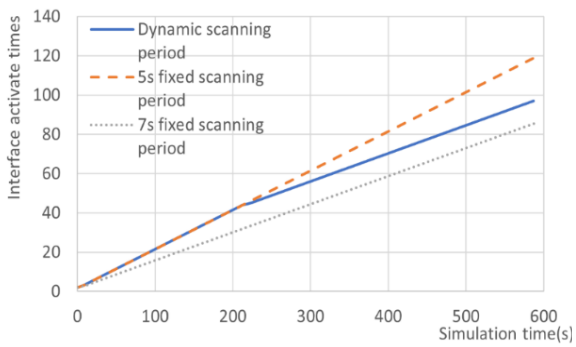

Figure 3. Interface activate times.

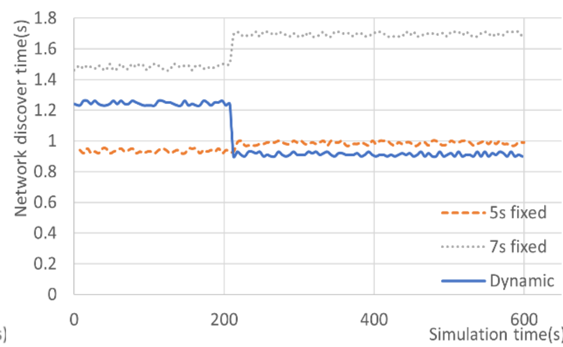

Figure 4. Network discovery time.

The simulation results in Figure 5 compare the network selection results during the whole simulation period when the vehicle uses the grey prediction algorithm and does not use the prediction algorithm. We can see from the figure that after using the Grey prediction algorithm, the vehicle terminal can predict the received signal strength of current access network effectively, and switch to a better network in advance. At the same time, due to the application of prediction algorithm, the vehicle terminal can prepare to switch in advance, and the handover call drop rate is improved. Figure 6 shows the simulation result.

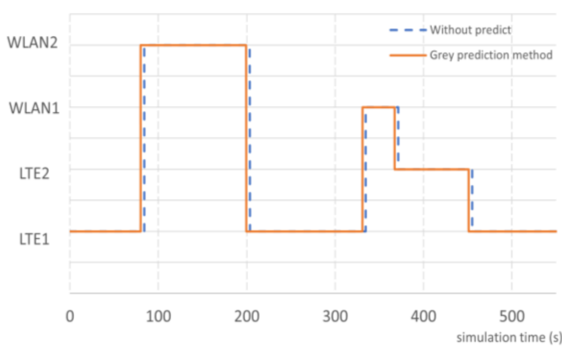

Figure 5. Network selection result.

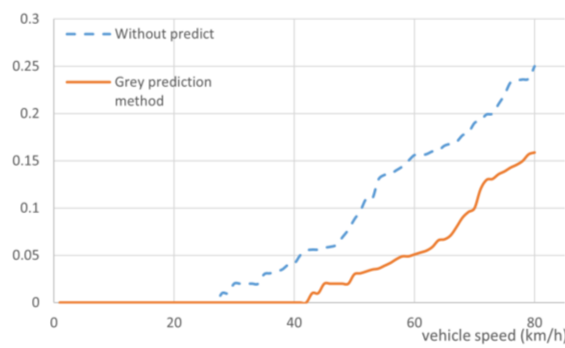

Figure 6. Handover call drop rate.

4. CONCLUSION

In this paper, a vertical handover algorithm based on dynamic scanning period and grey prediction algorithm is proposed. Firstly, in the network discovery phase, in view of the disadvantages that the traditional fixed scanning period is not suitable for the complex scene of vehicle environment, the scanning period is dynamically adjusted according to the speed of vehicles. In the network selection phase, we use the grey prediction algorithm to predict the received signal strength of the current access network, so as to make the handover decision more timely. The simulation shows that dynamic scanning period method is able to discover the network in time and reduce power consumption of terminal. The grey prediction algorithm can effectively predict the change of received signal strength, making vehicle determine the best switching time in advance, and improve the success rate of switching.

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