Research on Vertical Handover Strategy in Heterogeneous Vehicular Networks on Expressway

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***Abstract*—Due to the different coverage of different access technologies and network properties, it is one of the fundamental problems how to ensure that users can choose the most suitable network in the case of multi network selection, and can switch between different networks seamlessly, so as to get high-quality user service.This paper focuses on the heterogeneous Internet of Vehicles environment composed of LTE, WiFi, and DSRC, and combines single-user and group handover schemes according to the different states of the vehicle. When the vehicle is in an isolated state, the single-user vertical switching algorithm is adopted; when the vehicle is in the cluster head or cluster member state, the vertical switching algorithm of "fleet" users is adopted. The simulation experiment is carried out by MATLAB, and the better performance of switching is obtained.**

Keywords—heterogeneous internet of vehicles; vertical handoff; single user handoff; fleet handoff

I. INTRODUCTION

At present, the Internet of Vehicles occupies an important position in the construction of Intelligent Traffic System and the heterogeneous Internet of Vehicles has emerged, which can include many different networks. The most typical ones are LTE, DSRC and WiFi, these three networks have their shortcomings, but if these types of networks are integrated to serve users together, they can achieve complementary advantages and provide users with a higher level of service, meet the needs of users of different business types. Fig.1 shows the three states of the vehicle.

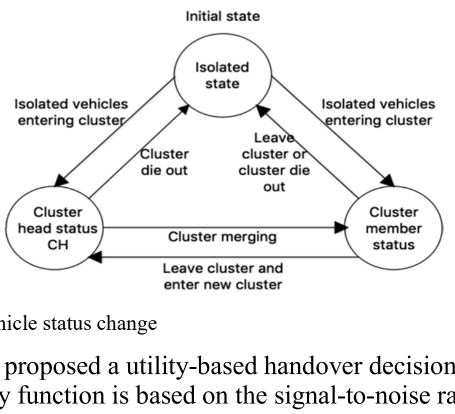

Fig. 1. Vehicle status change

In [1] proposed a utility-based handover decision method. The utility function is based on the signal-to-noise ratio value and the network load. In [2] used the method of travel time calculation and threshold time prediction to estimate the throughput and bandwidth of the RSU in the network and optimized the vertical handover decision process.

However, in group switching, a large number of handover requests may occur at the same time, it may cause GVHO scenarios Network congestion phenomenon. in [3] proposed a fuzzy clustering method, the user can choose the network with the smallest empirical deviation after fuzzy clustering. In [4] proposed a fuzzy logic-based GVHO scheme using gray prediction method. The proposed scheme can reduce the number of handovers, ensure QoS, reduce network load, and has a good handover effect. However, there is basically a lack of congestion-based game and network demand that considers user preferences and different services. In addition, the research involving clustering algorithms does not consider the influence of social attributes on network selection.

II. SINGLE USER VERTICAL SWITCHING STRATEGY

A. Subjective weight calculation-expert

Consider the following six decision factors: Bandwidth, Delay, Jitter, Packet Loss Ratio, Safety, and Price, the fuzzy complementary judgment matrix R_1 of real-time business and the fuzzy complementary judgment matrix R_2 of non-real-time business judged by experts.

B. Subjective weight calculation-users

Before the user enters the expressway, the user feedback form shown in Table I is formed according to the user's historical trajectory, preference information and user driving habits.

TABLE I. USER FEEDBACK FORM

Indicator name	**Real-time business selectable range**	**Non-real-time business selectable range**
Acceptable network transmission rate	2500-7200kbps	2500-7200kbps
Acceptable waiting time	30-400ms	60-3200ms
Acceptable jitter time	10-50ms	30-80ms
Acceptable packet loss rate	0.04%-0.20%	0.02%-0.10%
Acceptable degree of safety	2，3	1，2，3
Acceptable cost	10-30	5-20
Consider filling in the user feedback form?	0 considered, 1 not considered	0 considered, 1 not considered

Infrastructure (such as roadside units, cellular base stations, etc.) calculate the degree of deviation from the value of the judgment factor to obtain the degree of deviation judgment matrix.

1.Obtain a real-time business deviation matrix, Each entry of the matrix is denoted as r_{ij}.

where $r_{ij} = \left|\frac{x_i - y_i}{y_i}\right|$, $i \in [1,6]$. r_{ij} represents the degree of deviation between the value of the $i-th$ decision factor in the user feedback table and the value of the decision factor corresponding to the $j-th$ network, where x_i is the value of the decision factor i in the user feedback table, and y_i is the value of the same network decision factor.

2. Find $\min|r_{ij}|$ in the matrix and preprocess the deviation value. Then find $\max|r_{ij}|$, obtain the boundary value of deviation ratio by calculating R, then map it to the 0.5-0.95 scale, treat r as an absolute value, and compare two by two through the same network column vector elements to obtain three deviation judgment matrix, the three network judgment matrices are added and averaged to obtain the final real-time business deviation judgment matrix R_1'.

3. Obtain the non-real-time service deviation judgment matrix R_2' through the same steps 1 and 2.According to the FAHP calculation of the deviation degree of the user feedback table and network parameters, two sets of weight vectors of real-time and non-real-time can be obtained.

C. Objective weight calculation

The objective weight of this paper uses the fusion method of entropy weight method and CRITIC algorithm in (2.3):

$$\omega_j = \frac{(S_j + EV_j)\sum_{i=1}^{n}(1-c_{ij})}{\sum_{j=1}^{m}\left[(S_j + EV_j)\sum_{i=1}^{n}(1-c_{ij})\right]} \tag{2.3}$$

Where S_j represents the standard deviation of each value of the $j-th$ decision factor, EV_j represents the entropy value of the $j-th$ decision factor, and $(1-c_{ij})$ represents the conflict between the decision factors i and j.

D. Comprehensive weight calculation

This paper selects the integrated weighting method based on game theory.The comprehensive weight shown in (2.4) is obtained.

$$W^* = \sum_{k=1}^{2}\alpha_k^* \varphi_k^T \tag{2.4}$$

Among them, α_k represents the weight coefficient, and φ_k represents the weight value of the subjective weight or the objective weight.

E. Calculate the chi-square distance

The weighted norm matrix wnm is a matrix obtained by multiplying each element of the normalized matrix $R=(r_{ij})_{n\times m}$ by the weight of the decision factor corresponding to W^* in the comprehensive weight.Calculate the chi-square distance between the $i-th$ network and the ideal network in (2.5).

$$chisqr\_dist_i = \sum_{j=1}^{m}\frac{(wnm_{ij} - ideal\_network_j)^2}{wnm_{ij} + ideal\_network_j}, i = 1,2,...,n \tag{2.5}$$

The network with the smallest chi-square distance is selected for switching.

F. Switching control unit optimization

In order to avoid the ping-pong effect as much as possible, two judgments should be made before the execution of the handover decision:

First, determine whether the speed changes frequently, then determine whether the movement direction is regular to avoid invalid switching, and finally determine whether to perform the switching according to the judgment result.

III. Vertical Handoff Strategy for fleet users

First, cluster a large number of vehicle terminals in the network and perform maintenance and update. The vehicle selects and executes the corresponding algorithm during the handover process according to its current network status. When the vehicle is in the cluster head or cluster member state, the "fleet" user switching algorithm is executed. In the handover algorithm for "fleet" users, when the network is not congested, the vehicle terminal adopts the priority "fleet" network switching; when the network may be congested, the blocking rate constraint method is adopted to select the switching network.

A. Clustering process

The multi-attribute social relationship strength function $f_{ij}(t)$ as shown in (3.1),where $\sum_{i=1}^{3}\omega_i = 1$.

$$f_{ij}(t) = \omega_1 h_{ij}(t) + \omega_2 t_{ij}(t) + \omega_3 \chi_{ij}(t) \tag{3.1}$$

The vehicle driving similarity measurement function $R_{ij}(t)$ of the vehicle terminal at time t can be expressed as the following in (3.5).

$$R_{ij}(t)=\begin{cases} 0, & d_{ij}(t)\ge D_{\max}\ or\ \theta_{ij}(t)\in\left[\frac{\pi}{2},\pi\right] \\ \omega_1 f_{ij}(t)+\omega_2\frac{D_{\max}-d_{ij}(t)}{D_{\max}}+\omega_3 v_{ij}(t)+\omega_4\theta_{ij}(t), & d_{ij}(t)<D_{\max}\ or\ \theta_{ij}(t)\in\left[0,\frac{\pi}{2}\right] \end{cases} \tag{3.5}$$

Where $d_{ij}(t)$ represents the relative distance, $v_{ij}(t)$ represents the relative speed, $\theta_{ij}(t)$ represents the angle between the two vehicles' movement directions . The vehicles are clustered according to the similarity measurement function of the vehicles.

B. The network is not congested-user side

For vehicle end users, the service quality value of the access network increases with the increase of the network resources obtained by the user. The S function [9] as shown in (3.6) is introduced to evaluate the service quality of different networks to be switched.

$$SQ_i = \frac{F}{1+\exp\left\{-\varphi\sum_{k=1}^{K}\left[\omega_k(\bar{r}_{ik} - N_{ik})\right]\right\}} \tag{3.6}$$

The parameters in (3.6) are defined as follows: SQ_i represents the utility value of the network; F represents the service quality correction value of the access network, the value of φ can affect the slope of the function, and the slope of the function increases monotonically as the value of φ increases; ω_k Represents the weight of the $k-th$ decision factor obtained by the integrated weighting method; $\overline{r}_{ik}$ represents the normalized value of the $k-th$ decision factor of the network to be switched; N_{ik} represents the QoS requirements of vehicle end users for decision factor K.

Further, each access network can be evaluated by establishing a model based on $\frac{SQ_i}{chisqr\_dist_i + c_{ij}}$, and the accessible networks can be prioritized.

C. The network is not congested-network side

Considering the actual situation, different service types should have different priorities. The initial priority of RT service(θ_{rt}), the initial priority of NRT service(θ_{nrt}) and the initial $\theta_{rt} > \theta_{nrt}$, and the vehicle with the highest priority must be selected for each time slice.According to the different delay tolerance of RT services, the tolerance is mapped to n time slices, and the user priority is updated in this time slice.

D. Network congestion

Assuming there are N available networks, the available bandwidth of each network is $AB_i(t)$Mbps, and the round-trip time is RTT_i. At the same time, it is assumed that the vehicle terminal user can obtain the available bandwidth and the number of users of each network from the network broadcast. Assuming that the bandwidth required by each vehicle end user is B_j Mbps.

The formula for evaluating transmission delay in real-time services is defined as shown in (3.9).

$$TD_{ij} = \frac{B_j \cdot RTT_i}{2 \cdot AB_i^*} \tag{3.9}$$

Where AB_i^* represents the remaining available bandwidth resources.

The formula definition of the non-real-time service evaluation packet loss rate is shown in (3.10).

$$PLR_{ij} = \delta_i \exp\left(-\frac{TD_{\max}}{TD_{ij}}\right) \tag{3.10}$$

$TD_{\max}$ represents the maximum network delay that the vehicle end user can tolerate, δ_i is the load balance factor.

For RT users, the optimization goal is to minimize the average TD of the system. k^* represents the maximum number of users who initiate vertical handover at the same time. The network selection problem is expressed as a nonlinear programming problem as shown in (3.12).

$$\min \frac{1}{k^*} \sum_i \frac{R_i \cdot RTT_i}{2 \cdot AB_i^*}$$

$$s.t. \begin{cases} AB_i^* = AB_i - R_i = AB_i - \sum_j c_{ij} \cdot B_j \\ c_{ij} \in \{0,1\} \\ AB_i^* \geq 0 \end{cases} \tag{3.12}$$

For NRT users, except for the optimization goal, the decision-making process is the same. The optimization goal can be expressed as: $\min \frac{1}{k^*} \sum_i \sum_j PLR_{ij}$ .By solving the above-mentioned nonlinear programming problem, the decision result can be obtained, and the network switching can be performed.

IV. EXPERIMENTAL RESULT

The simulation experiment is carried out by MATLAB. In the experiment, the setting scene is a highway with a length of 12,000 meters and two-way six lanes. The cellular base station covers the whole process. The roadside unit is deployed on the infrastructure such as speed measurement equipment in the highway. One is deployed at a location with a road length of 5,000 meters. The network attribute parameters of the three networks are shown in Table II[10].

TABLE II. NETWORK PARAMETER TABLE

parameter	DSRC	LTE	WiFi
Bandwidth/Mbps	10	20	100
Coverage radius/m	300	1200	500
Delay/ms	12	90	35
Jitter/ms	1	13	10
Packet loss rate	0.0493	0.0010	0.0770
safety	3	2	1
Price/yuan	20	30	10

A. Single user experiment results

Comparing the scheme proposed in this paper with the schemes in [9], [10], [11] and [12]. Fig.2-4 shows the change of delay, packet loss rate and throughput with the increase of the number of vehicle terminals.

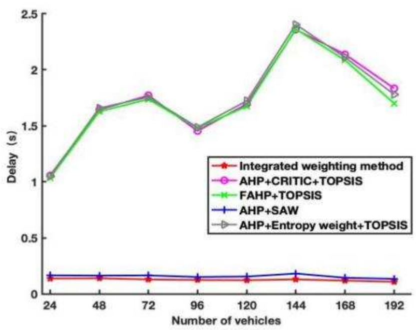

Fig. 2. Switching delay varies with the number of vehicles

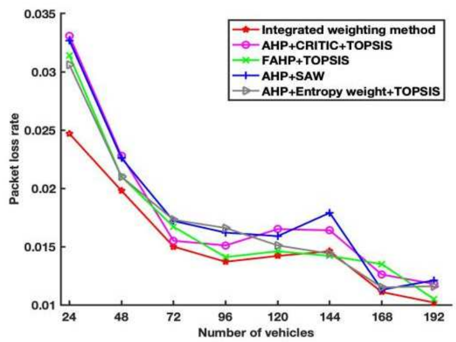

Fig. 3. Switching Packet loss rate varies with the number of vehicles

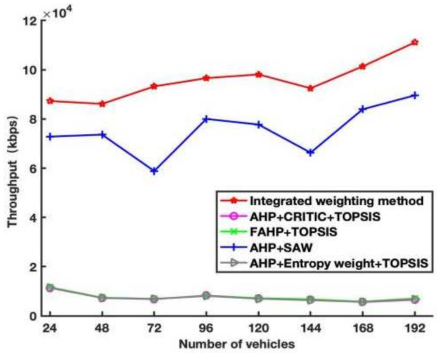

Fig. 4. Comparison scheme throughput partial enlarged diagram

B. *Fleet user experiment results*

Comparing the scheme proposed in this paper with the scheme [15].

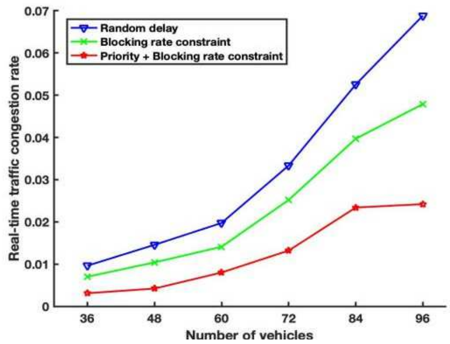

Fig. 5. Real-time traffic congestion rate

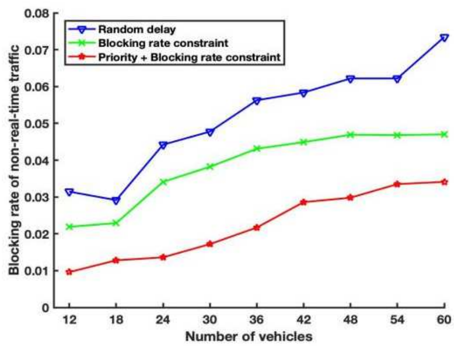

Fig. 6. Blocking rate of non-real-time traffic

Fig.5 and Fig.6 show the change curves of the blocking rate of real-time and non-real-time services respectively. For real-time and non-real-time services, the network switching blocking rate of the proposed algorithm is significantly lower than the blocking rate of the random delay scheme and the blocking rate constraint scheme.

V. SUMMARY

This paper proposes a Vertical Handoff Strategy for single user travel in Expressway scenario. We use bandwidth, delay, jitter, packet loss rate, security and price as handoff indicators to calculate the subjective and objective weights and then select the most appropriate handoff network by using the calculation of network chi square distance. Besides a Vertical Handoff Strategy for fleet users in freeway scenario is introduced.

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