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A COST-BASED VERTICAL HANDOFF WITH COMBINATION PREDICTION OF SINR IN HETEROGENEOUS WIRELESS NETWORKS

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ABSTRACT

It is well known that to provide seamless mobility and transmission in heterogeneous wireless networks, a vertical handoff technique is required to guarantee an Always Best Connected. This paper thus presents a cost-based vertical handoff algorithm with combination prediction of SINR (CPSVH) in heterogeneous wireless networks to make handoff decision. Our approach involves two steps, first SINR is predicted by combining GM (1,1) and BP neural network for accurate timing to trigger handoff, and then a handoff decision on the optimal network is made by way of a cost function. The cost function, on basis of multi-attribute QoS consideration, is composed of SINR, user preference, user traffic cost and available bandwidth from accessible networks, with the weight of each attribute in the cost function calculated by a fuzzy judgment matrix constructed for this purpose. Meanwhile, the stability period (defined as the waiting time before handoff) is also taken into regard to reduce unnecessary handoffs. The simulation results in this study reveal that the proposed handoff scheme outperforms other approaches in terms of system throughput, dropping probability, and vertical handoff numbers.

Keywords: *Vertical Handoff, SINR, Combination Prediction, Cost Function*

1. INTRODUCTION

The coexistence of different access technologies is one of the most prominent features of the fourth-generation wireless networks (4G) [1]. Consequently, one of the popular trends in heterogeneous systems is to integrate wireless local area networks (WLANs) and cellular networks, e.g. WCDMA system. To guarantee seamless roaming and the best Quality of Service (QoS) for users in heterogeneous networks, an efficient and accurate vertical handoff is essential and indispensible.

Nowadays, various works have appeared covering the vertical handoff algorithm (VHA) concerning heterogeneous technologies. In many of previous studies on vertical handoff, the Received Signal Strength (RSS) was taken as a basic decision indicator. According to the role RSS plays therein, these works can be categorized into two groups: 1) the handoff decision is made by comparing RSS with the predefined threshold [2]; and 2) RSS is used only to initiate the handoff [3,4]. In [2], a vertical handoff decision algorithm is formulated by adopting Markov decision process (MDP) to maximize the expected total reward per connection. The proposed approach in [3] determines the optimal target network through two phases: 1) the polynomial regression RSS prediction and MDP analysis; and 2) the TCP sender can accurately predict the available bandwidth and increase the network throughput by using the cross-layer information. In [4] the algorithm, targeting the non-real and real time services, selects the optimal network from WLAN/WiMAX/UMTS on basis of fuzzy logic. These vertical handoff schemes mentioned above using RSS as a basic indictor have their advantages. However, as the attainable data rate of a mobile terminal is a function of received Signal to Interference plus Noise Ratio (SINR), so the using of SINR in integrated wireless networks as handoff indicator, unlike RSS-based vertical handoffs, can provide a higher average throughput for users and achieve the best possible performance of the system. In addition, a SINR-based vertical handoff is more desirable to support better multimedia QoS. Expectedly, the combined SINR based vertical handoff (CSVH) discussed in [5] does acquire a higher throughput compared with the

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RSS based vertical handoff, but the algorithm gives no consideration to other QoS parameters. In order to provide a seamless vertical handoff supporting multi-attribute QoS, a multi-dimensional adaptive SINR based vertical handoff (MASVH) algorithm is thus proposed [6], while the value of optimal parameter k in its handoff decision is not determined; though the predictive SINR vertical handoff (PSVH) using GM (1,1) is suggested in [7], the performance of the proposed algorithm is not analyzed in depth.

With these problems concerning vertical handoff in mind, we formulate a cost-based adaptive vertical handoff algorithm with combination prediction of SINR (CPSVH) in integrating WLAN and WCDMA networks to make handoff decision. In regard to the four service classes defined by the Third Generation Partnership Project (3GPP), the vertical handoff algorithm gives consideration to SINR, user traffic cost, user preference and available bandwidth of each WLAN access point (AP) and WCDMA base station (BS). The optimal network can be determined through cost function in which the weight of each attribute is calculated by fuzzy judgment matrix. The proposed scheme here consists mainly of two steps: 1) the combination prediction of SINR by GM (1,1) and back-propagation (BP) neural network to fix the accurate timing of triggering handoff; 2) the decision of the optimal network by cost function. In addition, the stability period is also considered to reduce unnecessary handoff during the decision-making process. The simulation results in this paper indicate that our handoff approach not only selects the optimal network through considering the user preference and network conditions, but also outperforms other approaches regarding system throughput, system dropping probability, and vertical handoff numbers.

The remainder of this paper is organized as follows. Section 2 describes the combination prediction of SINR using GM (1,1) and BP neural network, while the cost function and handoff decision are specified in Section 3. Section 4 evaluates the performance of the three vertical handoff algorithms – PSVH, MASVH, and CPSVH (our approach) – by way of several important metrics and compares their results with one another. In the last section, the conclusion is drawn.

2. THE COMBINATION PREDICTION OF SINR

2.1. Advantages Of Prediction

At present, prediction technique is applied widely in communication field for its advantage [8]. In this paper, we use it to obtain SINR at the next time. The overall system throughputs can be improved by using non-predictive SINR based vertical handoffs (e.g. CSVH and MASVH) against the RSS based vertical handoff, but this approach results in lower data rate since SINR for terminal user is far below the pre-established threshold of the current network at handoff point. Given the predictive SINR, the handoff process then will start off before the SINR falls below the threshold. Therefore, the prediction-based scheme can achieve higher data rate.

2.2. The Combination Prediction Of Sinr By Gm (1,1) And Bp Neural Network

The accuracy of predictive SINR exerts great influence to handoff event, and a wrong handoff decision will be made if the SINR estimation is not accurate, yet it is difficult to achieve a higher accuracy using single prediction methods. Consequently, a combination of different single prediction methods can make full use of the information acquired by each single prediction method, reducing randomness and improving prediction accuracy significantly [9]. Although the grey model GM (1,1) is quite suitable for prediction of highly noisy data such as SINR [10], the results obtained by using GM (1,1) prediction cannot meet the requirements in actual situation as the SINR change is highly nonlinear because there are many factors that affect SINR due to the complex wireless environment. The BP neural network, capable of self-learning and parallel distribution processing, can approximate any complex nonlinear function without determining the relationship between neurons in advance [11]; nonetheless, it produces residual error. Considering the fact that GM (1,1) model is highly suitable for correcting residual error, so the coupling of the two models, benefiting from their complementary effect, can enhance the reliability of prediction results. By combining the advantages of both GM (1,1) and BP neural network, this paper then presents a nonlinear model to predict SINR and improve predictive accuracy, and the architecture of the combination prediction model is illustrated in Fig. 1.

2.3. The Process Of Combination Prediction

In this paper, GM (1,1) and a four-layer BP neural network are used to predict SINR. The modeling and prediction go according to the following steps:

Step 1: The time series prediction of SINR is

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accomplished by GM (1,1);

Step 2: The establishment of BP neural network, initialization of weight and offset value;

Step 3:To train the neural network to update its weight and offset value repeatedly until the error between output value and target value drops below the certain fixed value;

Step 4: Application of the combination prediction model by using the predicted values of GM (1,1) as the input data of BP neural network to acquire the output data.

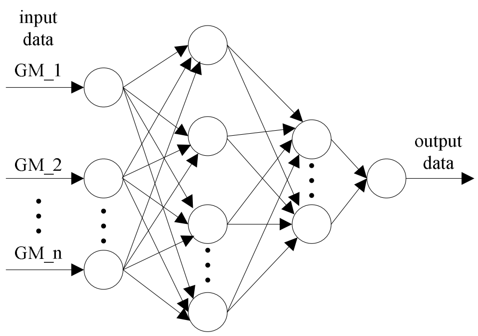

Fig. 1 Combination Prediction Model

3. VERTICAL HANDOFF ALGORITHM BASED ON COMBINATION PREDICTION OF SINR AND COST FUNCTION

In this study, only the downlink traffic that requires a higher bandwidth than the uplink traffic is considered, which suits the multimedia services in particular. Here a heterogeneous wireless network with m base stations (BSs) and n access points (APs) is assumed, where all candidate BSs and APs can be indexed by 1 to m+n in a set A:

$$A=[BS_1, BS_2, \dots, BS_m, AP_1, AP_2, \dots, AP_n] \quad (1)$$

When SINR obtained by combination prediction is lower than the predefined threshold, the handoff is then triggered. The optimal network from the candidate set A for each user will be determined by cost function based vertical handoff algorithm in regarding to the following attributes: SINR, user preference, cost to user traffic, and available bandwidth. The following assumptions are used in our study:

1. Each BS or AP transmits with the maximum power allowed;
2. Each mobile terminal is served by one BS or AP from all candidate BSs and APs;
3. The thermal noise power at any receiver is P_0 in WCDMA, and the background noise power at any receiver is P_B in WLAN.

3.1. Decision Attribute

1. Signal to Interference plus Noise Ratio (SINR)

The maximum attainable data rate for the given carrier bandwidth and SINR can be determined with the help of Shannon capacity formula. The maximum attainable data rate RAP from WLAN and RBS from WCDMA for a connected user can be represented by the receiving SINR from these two networks γ_{AP} and γ_{BS} respectively as [12,13]:

$$R_{AP}=W_{AP}\log_2(1+\frac{\gamma_{AP}}{\Gamma_{AP}}) \quad (2)$$

$$R_{BS}=W_{BS}\log_2(1+\frac{\gamma_{BS}}{\Gamma_{BS}}) \quad (3)$$

Where Γ_{AP} and Γ_{BS} are the two channel coding loss factors for WLAN and WCDMA respectively. When WLAN and WCDMA offer users the same downlink data rate, i.e. $R_{AP}=R_{BS}$, the relationship between γ_{AP} and γ_{BS} is expressed as:

$$\gamma_{BS}=\Gamma_{BS}((1+\frac{\gamma_{AP}}{\Gamma_{AP}})^{\frac{W_{AP}}{W_{BS}}}-1) \quad (4)$$

The SINR values a user *i* received from all BSs ($S_{BS,i}$) and all APs ($S_{AP,i}$) at a certain time are defined as two sets:

$$S_{BS,i}=[\gamma_{BS_1,i},\gamma_{BS_2,i},\cdots\cdots,\gamma_{BS_m,i}] \quad (5)$$

$$S_{AP,i}=[\gamma_{AP_1,i},\gamma_{AP_2,i},\cdots\cdots,\gamma_{AP_n,i}] \quad (6)$$

The SINR $\gamma_{BS_j,i}$ received by a user *i* from WCDMA BS_j can be represented as [14]:

$$\gamma_{BS_j,i}=\frac{G_{BS_j,i}P_{BS_j,i}}{P_0+\sum_{k=1, k\neq j}^{m}(G_{BS_k,i}P_{BS_k})+G_{BS_j,i}\alpha(P_{BS_j}-P_{BS_j,i})} \quad (7)$$

For WLAN, The SINR $\gamma_{AP_j,i}$ received by a user *i* from WLAN AP_j can be represented as:

$$\gamma_{AP_j,i}=\frac{G_{AP_j,i}P_{AP_j}}{P_B+\sum_{k=1, k\neq j}^{n}(G_{AP_k,i}P_{AP_k})} \quad (8)$$

The SINR received from APs ($S_{Ap,i}$) is converted to be equivalent SINR $S'_{AP,i}$ through (4) to achieve the same data rate via BS as:

$$S'_{AP,i}=\Gamma_{BS}((1+\frac{S_{AP,i}}{\Gamma_{AP}})^{\frac{W_{AP}}{W_{BS}}}-1) \quad (9)$$

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S_i denoting the set of SINR value of all BSs and APs for the user i can be represented by:

$$S_i = S_{BS,i} \cup S'_{AP,i} \quad (10)$$

This paper adopts a macro-cell propagation model for urban and suburban areas to determine propagation condition [14]. For an antenna 15 meters high, the path loss is:

$$PL(\text{dB}) = 58.8 + 21\log_{10}(f) + 37.6\log_{10}(d) + S(\text{dB}) \quad (11)$$

Where f is the carrier frequency, d is the distance between the user and BS or AP, and S corresponds to the log-normal shadowing with s=10 dB standard deviation.

2. User preference

The selection of optimal network should consider better trade-off between user preference and network condition, so the user preference vector P is introduced:

$$P = P_{BS} \cup P_{AP} \quad (12)$$

Where the sets P_{BS} and P_{AP} denote the user preference vector of BSs and APs respectively:

$$P_{BS} = [P_{BS_1}, P_{BS_2}, \cdots\cdots, P_{BS_m}] \quad (13)$$

$$P_{AP} = [P_{AP_1}, P_{AP_2}, \cdots\cdots, P_{AP_n}] \quad (14)$$

The two sets indicate degree of user preference for BSs or APs in terms of service type. The preference vector P is set by the user.

3. User traffic cost

The set C represents the cost of user traffic transmission through each BS or AP:

$$C = C_{BS} \cup C_{AP} \quad (15)$$

Where the sets C_{BS} and C_{AP} denote the cost of each candidate BS and AP:

$$C_{BS} = [C_{BS_1}, C_{BS_2}, \cdots\cdots, C_{BS_m}] \quad (16)$$

$$C_{AP} = [C_{AP_1}, C_{AP_2}, \cdots\cdots, C_{AP_n}] \quad (17)$$

4. Available bandwidth of access network

Let B be the system available bandwidth vector, represented by residual bandwidth of each candidate BS and AP:

$$B = B_{BS} \cup B_{AP} \quad (18)$$

Where the sets B_{BS} and B_{AP} are the available bandwidth of the candidate BSs and APs:

$$B_{BS} = [B_{BS_1}, B_{BS_2}, \cdots\cdots, B_{BS_m}] \quad (19)$$

$$B_{AP} = [B_{AP_1}, B_{AP_2}, \cdots\cdots, B_{AP_n}] \quad (20)$$

3.2. Cost Function Based Approach For Optimal Network Selection

1. Cost function

The cost function measures the benefit obtained by handoff to a candidate network [15] and can be used to evaluate each network available in the vicinity of the user. In this paper, the cost function of one network n at a certain time is defined by SINR (S_n), user preference (P_n), user traffic cost (C_n) and access network available bandwidth (B_n) as follows:

$$f_n = w_s \ln(1/S_n) + w_p \ln(1/P_n) + w_c \ln(C_n) + w_b \ln(1/B_n) \quad (21)$$

Where w_s, w_p, w_c, and w_b ($\sum w_i = 1$) stands for the respective weight of S_n, P_n, C_n, and B_n. Note that the lower the value of fn, the lower the cost of network n is, and the better is network n. Consequently, the network with the lowest cost function value is regarded as our optimal choice.

2. Weight vector

To weigh each decision attribute, traditional AHP method usually constructs a judgment matrix containing the pairwise comparison results, with the numbers 1 to 9 or their reciprocals to indicate the relative importance of the two sub-elements in the judgment matrix [16]. However, this method fails to solve fuzzy problems arising in decision process. But a fuzzy judgment matrix integrating the judgment matrix in AHP and the fuzzy theory can be built to obtain reasonable and reliable weight of the four decision attributes.

Suppose the number of the decision attributes is n, the attribute set {q_1, q_2, … , q_n} can be compared with each other based on service characteristic. Multiple pairwise comparisons are based on a standardized evaluation method, as shown in Table 1.

The pairwise matrix comparison is then used to build a square fuzzy judgment matrix $D = (d_{ij})n\times n$ denoted as follows:

$$D = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nn} \end{bmatrix} \quad (22)$$

Where $d_{ij}= q_i/q_j$, d_{ji}=1- d_{ij}, and d_{ii}=0.5 (i, j=1,2,…, n).

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Table 1. Definition of Relative Importance

Scale **(q_i/q_j)**	***Relative*** **importance**
0.5	equal importance
0.6	moderate importance
0.7	obviously importance
0.8	strong importance
0.9	extremely importance
0.1,0.2, 0.3,0.4	Opposite comparison

3GPP has defined four service types, namely conversational (Ω_1), streaming (Ω_2), interactive (Ω_3) and background (Ω_4). The optimal network selection should consider different service types because each type has different Qos requirements. Consequently, the weights of the four attributes in each type also differ greatly, thus we construct four fuzzy judgment matrixes respectively according to the scale in Table 1, and qi in decision attribute set represents P_n, C_n, B_n and S_n in turn. The fuzzy judgment matrixes are then constructed as follows:

$$D_{\Omega_1} = \begin{bmatrix} 0.5 & 0.1 & 0.2 & 0.3 \\ 0.9 & 0.5 & 0.7 & 0.8 \\ 0.8 & 0.3 & 0.5 & 0.6 \\ 0.7 & 0.2 & 0.4 & 0.5 \end{bmatrix} \quad (23)$$

$$D_{\Omega_2} = \begin{bmatrix} 0.5 & 0.7 & 0.6 & 0.3 \\ 0.3 & 0.5 & 0.4 & 0.1 \\ 0.4 & 0.6 & 0.5 & 0.2 \\ 0.7 & 0.9 & 0.8 & 0.5 \end{bmatrix} \quad (24)$$

$$D_{\Omega_3} = \begin{bmatrix} 0.5 & 0.6 & 0.3 & 0.2 \\ 0.4 & 0.5 & 0.2 & 0.1 \\ 0.7 & 0.8 & 0.5 & 0.4 \\ 0.8 & 0.9 & 0.6 & 0.5 \end{bmatrix} \quad (25)$$

$$D_{\Omega_4} = \begin{bmatrix} 0.5 & 0.5 & 0.2 & 0.1 \\ 0.5 & 0.5 & 0.2 & 0.1 \\ 0.8 & 0.8 & 0.5 & 0.3 \\ 0.9 & 0.9 & 0.7 & 0.5 \end{bmatrix} \quad (26)$$

According to the above fuzzy judgment matrixes, we can calculate the weight of each decision attribute to obtain the weight vector and execute satisfied consistence check using method described in our previous literature [17]. The weighting results and the satisfied consistence index ρ are shown in Table 2, and the judgment matrix D constructed is then regarded reasonable if $\rho<0.1$.

Table 2. Values of Weights and Satisfied Consistence Index

Service	w_p	w_c	w_b	w_s	ρ
Ω_1	0.1259	0.3814	0.2748	0.2179	0.05
Ω_2	0.2638	0.1531	0.2085	0.3746	0
Ω_3	0.1936	0.1373	0.3064	0.3627	0
Ω_4	0.1475	0.1475	0.3018	0.4032	0.05

3.3. Handoff Decision

Being one of the most critical phases during whole process, handoff decision determines when and where to trigger the handoff. The proposed vertical handoff scheme mainly consists of two steps: 1) QoS monitoring decides whether handoff event should be triggered; 2) network selection determines which candidate network should be chosen.

1. Stability period

The stability period (T_s) is defined as a waiting period before handoffs, and T_{makeup} is defined as the amount of time needed to compensate for the loss due to handoff latency $l_{handoff}$, which are represented below [18]:

$$T_{makeup} = \frac{l_{handoff}}{e^{f_{better} - f_{current}} - 1} \quad (27)$$

$$T_s = l_{handoff} + \frac{l_{handoff}}{e^{f_{better} - f_{current}} - 1} \quad (28)$$

Where f_{better} and $f_{current}$ are cost function values of the better and current network respectively. As a result of the instability of wireless link and the mobility of terminal users, f_{better} and $f_{current}$ may change dramatically over a short period of time, so Ts defined above cannot reflect the real dynamic situation of the access network accurately. Bearing this in mind, this paper then modifies T_s (specifics of modification in the next section) to achieve an adaptive handoff that can deal with harsher network environment.

2. Handoff decision process

(1) Handoff event is triggered when SINR obtained by combination prediction in current network is lower than predefined threshold.

(2) The optimal BS or AP from candidate set A for each user will be determined by calculating cost

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function of each network. If its cost function value is lower than that of the current network, then it will be evaluated in modified stability period T_s'. The result of evaluation determines whether the mobile terminal should handoff to the target network or not. The detailed evaluation includes the following steps:

Initialization of the total evaluation number N, the current evaluation number k and the stability period T_s'. Let k = 0 and T_s ' = 0.

Define $\Gamma = e^{f_{current} - f_{better}}$, let Γ_k denote the kth evaluation result, and the time interval between kth evaluation and the next evaluation is defined by:

$$t_k = \frac{l_{handoff}}{N} + \frac{l_{handoff}}{N(\Gamma_k - 1)} \qquad (29)$$

The following process are executed repeatedly until k=N.

If Γ_k >1, calculate the next evaluation time according to formula (29) ;

a) Update the stability period: $T_s^{'} = T_s^{'} + t_k$;

b) Update he current evaluation number: k=k+1;

Otherwise turn to ③;

③ The evaluation process ends. If Γ_k >1 at the moment, handoff is executed at once, otherwise mobile terminal remains in current network.

According to the above handoff decision process, the modified stability period $T_s^{'}$ before handoff execution is represented below:

$$T_s^{'} = \sum_{k=0}^{N} \left[\frac{l_{handoff}}{N} + \frac{l_{handoff}}{N(\Gamma_k - 1)} \right] \qquad (30)$$

4. RESULTS AND DISCUSSION

The performance of the proposed vertical handoff algorithm (CPSVH), predictive SINR using GM (1,1) vertical handoff algorithm (PSVH) and multi-dimensional adaptive SINR based vertical handoff algorithm (MASVH) are evaluated with a simulation scenario as shown in Fig. 2, in which there are 7 BSs and 12 APs placed at each WCDMA cell boundary [5]. The WCDMA cell has a radius of 1200 meters. 600 randomly generated terminals are used within the simulation area. In the random waypoint mobility model, the position of each terminal, depending on its moving speed and direction, changes during the interval. The maximum moving speed of the terminal is 80 km/h, the arrival of user traffic obeys Poisson distribution, and the duration of traffic obeys exponential distribution with mean session holding time 60 seconds.

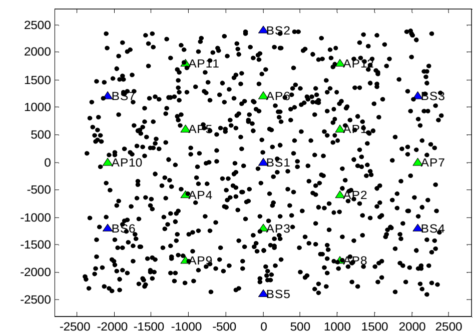
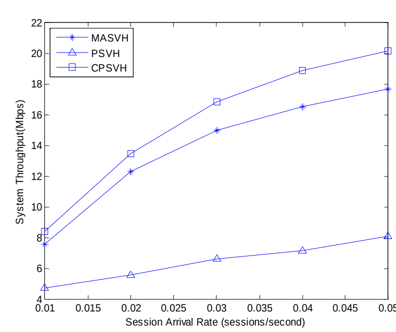


Fig. 2 Simulation Scenario

The respective cost of the BS and AP is assumed to be 0.8 and 0.4. To calculate the system dropping probability, the maximum capacity of BS and AP are limited to 2 Mbps and 11Mbps. In addition, the transmitting power and the power allocation of BS and AP are specified according to the reference in [5, 6].

Considering four service types, the overall system throughput against different session arrival rates based on different services are shown in Fig. 3. In CPSVH, w_S is the highest among the four service types with exception of the conversational service. In other words, S_n plays a rather important role in network selection, thus the mobile terminal can obtain a higher throughput. Meanwhile, the fact that w_b is relatively high means the algorithm tends to select a network with a much higher available bandwidth. In regard to the stream service, users prefer to select WLAN due to its high bandwidth embodied through P_n. Moreover, the proposed predictive scheme will initiate handoff process before SINR drops below the threshold, thus obtaining a higher throughput. To sum up, the proposed algorithm achieves higher system throughput than the two other algorithms.



(a) Ω_1

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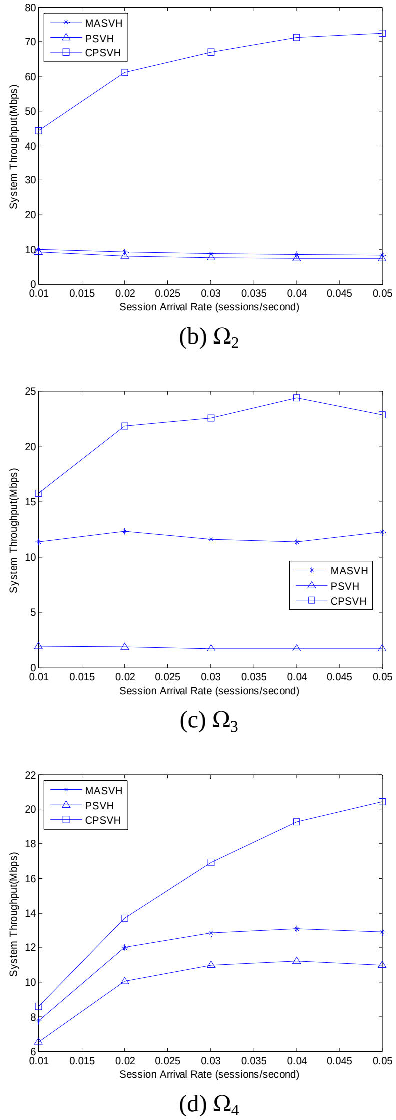


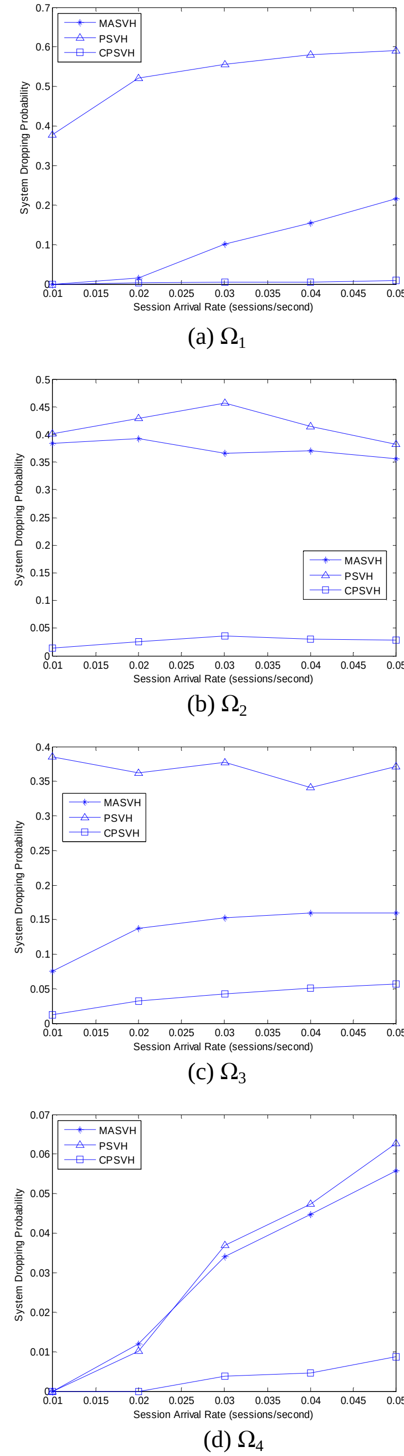
(b) Ω_2

(c) Ω_3

(d) Ω_4

Fig. 3 The System Throughput of Different VHAs

The system dropping probability against different session arrival rates are shown in Fig. 4. The results show that compared with other algorithms the dropping probability in CPSVH is lowest, as the consideration of the decision attribute Bn helps to maintain the load balancing among networks, which in turns reduces dropping probability for mobile terminals. Although the cost vector *C* has certain load balancing effect in MASVH and PSVH, its effect is not significant enough to guarantee a lower dropping probability, especially for stream service.



(a) Ω_1

(b) Ω_2

(c) Ω_3

(d) Ω_4

Fig. 4 The System Dropping Probability of Different VHAs

Fig.5 shows the number of vertical handoffs against different session arrival rates in four service types, and the vertical handoff number is smaller in CPSVH than in PSVH and MASVH. From the

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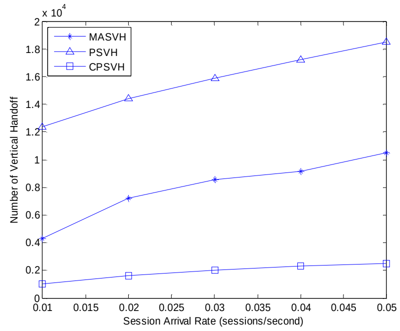
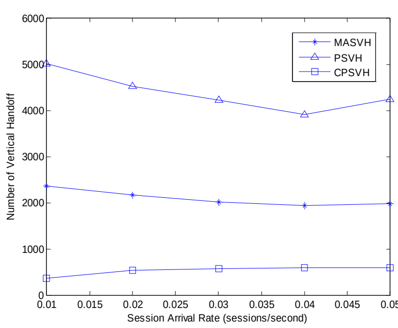
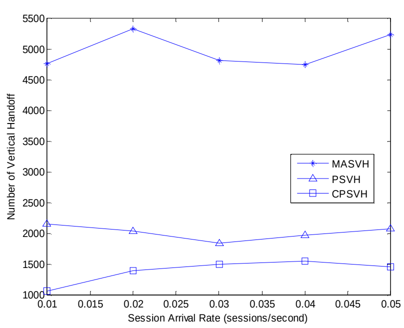
point of view of prediction, the proposed scheme can avoid unnecessary handoffs through given future values of the SINR. In addition, only one network is "consistently" better than the current network, then the mobile terminal handoffs the better network. T_s' applied in proposed CPSVH determines whether the handoff is worthwhile in terms of the cost incurred, thus reducing unnecessary handoffs to a larger extent.



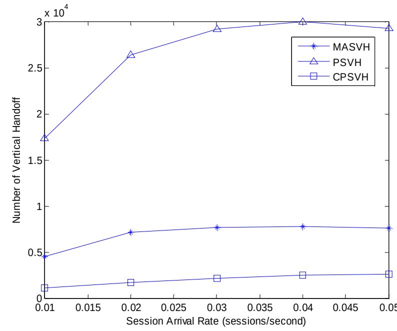
(a) Ω_1



(b) Ω_2



(c) Ω_3



(d) Ω_4

Fig. 5 Number of Vertical Handoff of Different VHAs

5. CONCLUSION

In this paper, we have presented a cost-based vertical handoff algorithm with combination prediction of SINR (CPSVH) for mobile users to roam seamlessly between different access networks. The proposed combination predictive scheme can improve prediction accuracy to guarantee the reliability of results and obtain a better QoS as it ensures a higher throughput for users at the same time. The cost function formulated in the proposed scheme achieves a better trade-off between user preference and network condition and guarantee a better QoS for different services, this allows the users to participate in the selection of the optimal network thus improves their satisfaction. Moreover, the stability period is modified to make adaptive handoff decision in order to ensure that a handoff is worthwhile and reduce the vertical handoff number. The numerical results indicate that the proposed approach outperforms other approaches, thus our scheme can provide better QoS for users and optimize the utilization of the whole network resources.

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