ANALYTICAL FRAMEWORK FOR VELOCITY-CONSIDERED SINR BASED VERTICAL HANDOFF WITH DYNAMIC THRESHOLD

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ABSTRACT A heterogeneous network that consists of various wireless networks of different technologies is being developed to achieve high speed transmission. Integration of the networks should be error free to achieve the next generation multimedia wireless networks. The seamless and efficient handoff between different access technologies known as vertical handoff (VHO) is essential and remains a challenging problem.
Several criteria for VHO decision have been proposed in the literature. There have been massive studies in Signal to Interference plus Noise Ratio (SINR) based VHO. However, user velocity has never been considered in SINR based VHO decision algorithm. Some studies show that there are some limitations in SINR based VHO scheme. This study aims to overcome those limitations. In this study, the user velocity is considered as an additional criterion for SINR based VHO decision. Consideration of user velocity is represented in the value of additional threshold in the basic SINR based VHO. The proposed algorithm assigns the dynamic threshold based upon the user velocity.
This paper presents an analytical framework for defining relationship between dynamic threshold and user velocity. The relationship has been formulated and the simulation platform to evaluate the performance has been set up. Simulation results show that there is a tradeoff between average throughput and the number of handoff per call. Although the average throughput is slightly dropped, the velocity consideration gives better performance on the number of handoff per call, especially in the high noise power environment.

1. INTRODUCTION

A heterogeneous network that consists of various wireless networks is being developed to achieve high speed transmission (Chang & Chen, 2008). These heterogeneous wireless networks have differences in data rates, transmission range, traffic classes, and access costs (Wang & Kuo, 2013). For seamless communication, the integration of the networks, such as WLAN and 3G WCDMA systems should be error free to achieve the next generation multimedia wireless networks (Yang, et al., 2007). The seamless and efficient handoff between different access technologies, known as Vertical Handoff (VHO), is essential and remains a challenging problem. VHO schemes provide service continuity in the entire network area and an effective solution for enhancing cell edge throughput (Choi, 2010).

Several criteria for VHO decision have been proposed in the literature and the main criteria are Received Signal Strength (RSS), Signal to Interference plus Noise Ratio (SINR), and available bandwidth (Mardini, et al., 2012). It has been proved that SINR based VHO gain a superior average throughput compared to other VHO decision schemes. However, none of these studies combines the SINR value and the user velocity as VHO decision parameters (Yang, et al., 2007), (Choi, 2010). In this study, the user velocity is considered as an additional criterion for SINR based VHO decision and represented in the value of additional threshold in the basic SINR based VHO. The system assign fixed threshold and dynamic threshold depend on the user velocity.

Some studies show that there are some limitations in SINR based VHO scheme (Ahmed, et al., 2014). Major drawback of SINR based VHO is that it is dependent on the velocity of the mobile users and performance of the scheme degrades with the increase in velocity. Also, this scheme provides very high number of unnecessary handoffs. Excessive handoffs come up due to the variation of the SINR and causing Ping-Pong effect. SINR-only based VHO will increase feedback overhead (Choi, 2010). This study will divide the velocity into two groups, slow speed user and high speed user, to overcome the limitations that are mentioned above.

2. PROPOSED ALGORITHM

2.1 Handoff Decision Algorithm

The basic principle of the proposed algorithm is that slow speed MS should stay longer in WLAN and high speed MS should stay longer in WCDMA. The proposed VHO decision algorithm is depicted as a flow chart in Fig. 1. When MS is categorized as low speed user (lower than velocity threshold, Vth) and starting make a call in WLAN coverage area, then the system will force MS to stay longer in WLAN until the SINR of neighboring WCDMA cell has a higher value than the preset additional threshold. When the preset threshold is reached, then the handoff is triggered. The low speed MS will stay in WCDMA cell until the SINR of neighboring WLAN cell has higher value than the SINR of serving WCDMA cell. The next handoff will be triggered without any preset threshold. The same way will work on high speed user (higher than Vth) that is initially served by WCDMA cell.

2.2 Dynamic SINR Threshold

The Signal to Interference plus Noise Ratios (SINR) based handoff decision algorithm then can be simply expressed as (Choi, 2010)

$$|\mathrm{SINR}_o - \mathrm{SINR}_i| < \delta \quad (1)$$

where $SINR_o$ is a received SINR from the serving BS, $SINR_i$ is a received SINR from the neighboring Base Station (BS), and δ is the handoff additional threshold determined by the system. Neighboring cells that satisfy (1) will be designated by mobile station (MS) as candidate cells for handoff. In this study, the handoff additional threshold, δ, will be used to force the MS with the certain velocity value to stay longer in the certain cell according their velocity.

The SINR received by user from its associated WLAN Access Point (AP) i^{th} or WCDMA Base Station (BS) i^{th} is

$$\gamma_i = \frac{G_i P_i}{N_i + I_i} = \frac{G_i P_i}{N + \sum_{\substack{k \neq i \\ k \in AP/BS}} G_k P_k} \quad (2)$$

where G_i is the channel gain between user and its associated AP or BS, P_i is the transmit power of AP or BS, N is the background noise power at user receiving end, and I_i is the interference from other neighboring APs or BSs. Path loss model uses a macro-cell propagation model for urban and suburban area with antenna height of 15 meters (Yang, et al., 2007)

$$G_{(dB)} = 58.8 + 21\log_{10}(f) + 37.6\log_{10}(D) + \mathrm{LogF} \quad (3)$$

where f is the carrier frequency (2GHz for WCDMA, 2.4GHz for WLAN), D is the distance in meters between the user and the BS or AP, and LogF is the log-normal distributed shadowing with standard deviation σ=10dB.

Based on (2), SINR received by the user in the serving cell can be expressed as

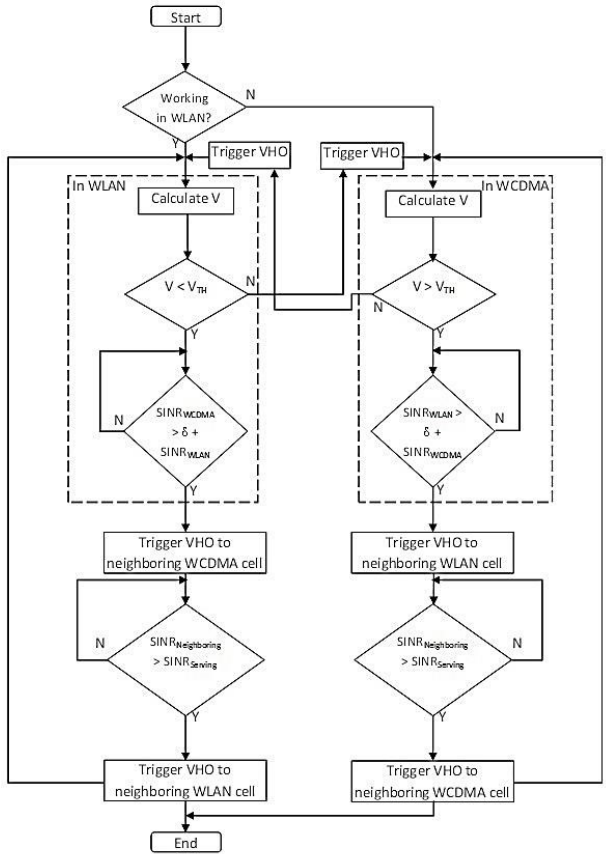

Fig. 1. The proposed VHO algorithm.

$$\gamma_{s_i} = \frac{G_{s_i} P_{s_i}}{N_{n_i} + I_{n_i}} = \frac{G_{s_i} P_{s_i}}{P_B + \sum_{\substack{k \neq i \\ k \in \frac{AP}{BS}}} G_{s_k} P_{s_k}} \quad (4)$$

where notation s is indicating serving cell, n is indicating neighboring cell, and i is representing i^{th} user.

Based on the equation (1), the additional threshold for SINR based VHO, δ, can be defined as

$$\delta = \gamma_{n_i} - \gamma_{s_i} \quad (5)$$

Substituting (4) to (5), then

$$\delta = \frac{G_{n_i} P_{n_i}}{N_{n_i} + I_{n_i}} - \frac{G_{s_i} P_{s_i}}{N_{s_i} + I_{s_i}} \quad (6)$$

Substituting path loss equation (3) in the ratio (antilog) form, it will become

$$\delta = \frac{10\hat{}\left(\left(37.6\log_{10}\left(D_{n_i}\right) + G_n\right)/10\right) * P_{n_i}}{N_{n_i} + I_{n_i}} - \frac{10\hat{}\left(\left(37.6\log_{10}\left(D_{s_i}\right) + G_s\right)/10\right) * P_{s_i}}{N_{s_i} + I_{s_i}} \quad (7)$$

where G_n = 58.8 + 21log(f_n) + LogF and G_s = 58.8 + 21log(f_s) + LogF.

Relation between δ and user velocity can be explained with the system model in Fig. 2.

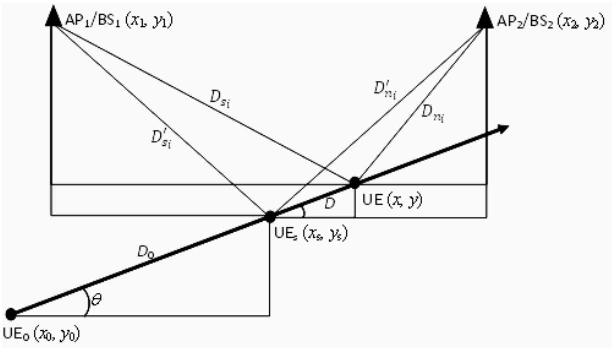

Fig. 2. System model to define the relation between δ and user velocity.

AP_1/BS_1 is a serving cell with the coordinate (x_1, y_1) and AP_2/BS_2 is a neighboring cell with the coordinate (x_2, y_2). UE_0 is the starting point of user movement. UE_S is the point when user receives the same SINR form serving and neighboring cell. UE is the point when additional SINR threshold, δ, is reached. D_0 is the distance from the initial user movement point to UE_S. D is the distance from UE_S and UE. D'_{s_i} is the distance from the serving AP_1/BS_1 to UE_S. D'_{n_i} is the distance from neighboring AP_2/BS_2 to UES. D_{n_i} is the distance between user (UE) to candidate neighbor cell and D_{s_i} is the distance from user (UE) to serving cell. After some geometrical calculation, the relation between δ and user velocity can be expressed as (8). Equation (8) implies that for every value of velocity, v, the same value of t_δ will result in different value of δ.

The coordinate of UE_s point is needed to start applying t_δ and it can be found when user receives the same SINR form serving and neighboring cell. In other words, when

$$\frac{G_{n_i}P_{n_i}}{N_{n_i}+I_{n_i}} = \frac{G_{s_i}P_{s_i}}{N_{s_i}+I_{s_i}} \quad (9)$$

Substituting (3), it will become

$$\frac{10\hat{}\left(\frac{37.6\log_{10}(D'_{n_i})+G_n}{10}\right)*P_{n_i}}{N_{n_i}+I_{n_i}} = \frac{10\hat{}\left(\frac{37.6\log_{10}(D'_{s_i})+G_s}{10}\right)*P_{s_i}}{N_{s_i}+I_{s_i}} \quad (10)$$

Expanding D'_{n_i} and D'_{s_i}, and rearrange it, it will become (11).

3. PERFORMANCE EVALUATION

3.1 Simulation Scenario

The calculation of system performance of proposed algorithm has been evaluated with the same scenario in (Yang, et al., 2007). There are 7 BS and 12 AP at fixed places and 200 MS randomly generated inside the simulation area. The MS position changes every time interval, depending on their random moving speed and direction. In this study, simulation is applying the fixed additional threshold. All users will have the same additional threshold. The simulation is also applying the dynamic threshold depend on user velocity.

To simplify the simulation, the dynamic threshold will be calculated with simple equations such that the δ value will be in the range around 0 to 20 like in (Choi, 2010). There are two types of simple dynamic defined as

$$\delta_1 = \frac{v}{3600} \text{ and } \delta_2 = \frac{v}{7200} \quad (10)$$

Since the user velocity is randomly generated from 3,600 m/hrs to 80,000 m/hrs, then (10) will give δ_1 value from 1 to 22.22 dB and δ_2 value from 0.5 to 11.11 dB.

3.2 Simulation Results

Fig. 3 and Fig. 4 show the system performance comparison between dynamic threshold algorithm and other algorithms, basic SINR based VHO according to (1), δ_S, fixed threshold velocity considered-SINR based VHO, δ_V, and combined-SINR based VHO (Yang, et al., 2007), Comb-SINR. In term of average throughput, dynamic threshold algorithm δ_1 has superior performance compare with the others, except with combined-SINR based VHO and velocity considered-SINR based VHO with δ_V = 0 dB.

$$\delta = \frac{10\hat{}\left(\left(37.6\log_{10}\left(\sqrt{\left(x_2-(x_s+(v.t_\delta)\cos\theta)\right)^2+\left(y_2-(y_s+(v.t_\delta)\sin\theta)\right)^2}\right)+G_n\right)/10\right)*P_{n_i}}{N_{n_i}+I_{n_i}} - \frac{10\hat{}\left(\left(37.6\log_{10}\left(\sqrt{\left(x_1-(x_s+(v.t_\delta)\cos\theta)\right)^2+\left(y_1-(y_s+(v.t_\delta)\sin\theta)\right)^2}\right)+G_s\right)/10\right)*P_{s_i}}{N_{s_i}+I_{s_i}} \quad (8)$$

$$\left(37.6\log_{10}\left(\sqrt{\left(x_1-(x_0+(v.t)\cos\theta)\right)^2+\left(y_1-(y_0+(v.t)\sin\theta)\right)^2}\right)+G_s\right) - \left(37.6\log_{10}\left(\sqrt{\left(x_2-(x_0+(v.t)\cos\theta)\right)^2+\left(y_2-(y_0+(v.t)\sin\theta)\right)^2}\right)+G_n\right) = 10\log\left(\left(\frac{P_{n_i}}{N_{n_i}+I_{n_i}}\right)/\left(\frac{P_{s_i}}{N_{s_i}+I_{s_i}}\right)\right) \quad (11)$$

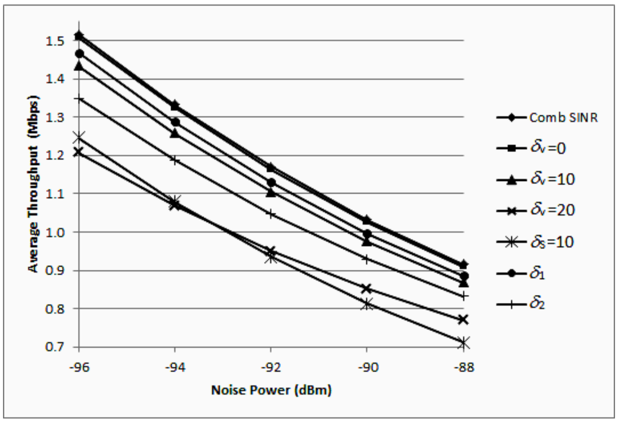

Fig. 3. Average throughput comparison at V_{th} = 5m/s.

The same thing happen with basic SINR based with velocity consideration with δ_v = 0 dB because there is no forcing parameter for considering user velocity. User will perform VHO whenever SINR from candidate neighbor cell is higher than SINR from serving cell. Throughput received will not drop too low before it gets higher throughput after performing VHO.

The basic SINR based VHO with additional threshold δ_S = 10 dB has the worst average throughput, since user will always perform VHO whenever the threshold is reached, whether the candidate cell is WCDMA or WLAN. The user will always extend their stay in current cell longer, with very low throughput before it gets higher throughput after performing VHO.

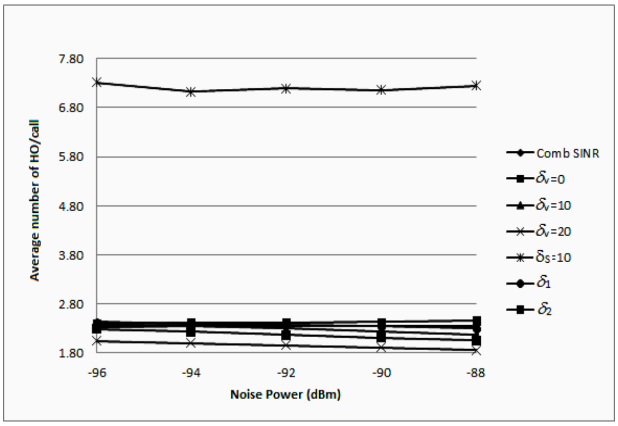

Fig. 4. Average number of handoff per call comparison at V_{th} = 5m/s.

In term of average number of VHO per call, δ_2 has superior performance compare to other algorithm, except velocity considered-SINR based VHO with δ_v= 20 dB. This threshold value will force the user to stay in the current cell so long and might be missed many cells that should make the user perform VHO.

CONCLUSION

The relation between user velocity and SINR threshold has been formulated and the simulation platform has been set up. Two approaches in implementing the proposed algorithm, fix and dynamic threshold, have been designed. The simulation results show that the velocity consideration makes the average throughput slightly drop, but give a better performance on the average number of handoff per call, especially in the high noise power environment.

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