DYNAMIC THRESHOLD STRATEGY TO REDUCE UNNECESSARY HANDOFF FOR SINR BASED VERTICAL HANDOFF DECISION

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ABSTRACT

A heterogeneous network (HetNet) that consists of various wireless networks is being developed to achieve high speed transmission. 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, such as Received Signal Strength (RSS) and Signal to Interference plus Noise Ratio (SINR). It has been shown that SINR based VHO has superior performance in terms of throughput. However, there are some limitations in SINR based VHO scheme. Several problems always arise during VHO process. Unnecessary handoff (UHO) is one of the challenging problems that still occur in many proposed VHO algorithm in the previous studies. In this paper, we propose a dynamic threshold of SINR based VHO to reduce the number of UHO, while maintaining an acceptable throughput for multimedia data transfer. Dynamic threshold is defined as a function of user velocity. The user velocity is considered as an additional criterion for SINR based VHO decision. The basic principle of the proposed algorithm is that slow speed user should stay longer in WLAN cells and high speed user should stay longer in WCDMA cells. The simulation results have been compared with previous study and it shows that the velocity consideration makes the average throughput slightly drop, but give a better performance on the average number of handoff per call and significant UHO reduction.

KEYWORDS: *dynamic threshold, SINR, vertical handoff, user velocity, unnecessary handoff*

1. INTRODUCTION

The fifth generation (5G) environment will be so complex as it will integrate all the existing technologies, such as third generation (3G), long term evolution (LTE) system embodying fourth generation (4G), Wifi, and WiMax and combine it with 5G base stations (BS) to provide ubiquitous high-rate and seamless communication service as in Qiang, et al. (2016) and Andrews, et al. (2014). To complement them, wireless personal area networks (WPANs), e.g., Bluetooth and Zigbee, are developed for short-range coverage (Wang & Kuo, 2013). The overlapping coverage deployment of all networks will form a hybrid or heterogeneous wireless networks.

The seamless and efficient handoff between different access technologies, known as Vertical Handoff (VHO), is essential and remains a challenging problem. VHO schemes provide not only service continuity in the entire network area, but also an effective solution for enhancing cell edge throughput, which is a major issue in 4G standardization (Choi, 2010). Moreover, the data rate in 5G is expected to be roughly 1000× compared with current 4G technology, hence the VHO requires a faster processing (Qiang, et al., 2016). Hybrid 5G environment need a fast, distributed, privacy-preservation and user-centered handoff scheme.

The VHO operation should provide a minimum overhead, authentication of the mobile users, and the connection should be maintained to minimize the packet loss and transfer delay (Bhuvaneswari & Prakash Raj, 2012; Stevens-Navaro & Wong, 2006). A decision algorithm gives a better performance when several parameters are considered. The trade-off is with the increase in decision time and complexity of the algorithm. Up to now, many methodologies have been used on VHO, such as policy-enabled schemes, fuzzy logic, neural networks concepts, etc (He, et al., 2011). Although some of these methods are quite successful, they are not particularly suitable for real-time applications in the real world applications, since the reliability of them usually depends on complex procedure. Most of the previous works make handoff decision based on received signal strength (RSS), but yield serious ping-pong effect when a mobile node moves around the overlay area of several heterogeneous wireless networks. The ping-pong effect causes unnecessary handoff and brings some weaknesses, including low network throughput, long handoff delay, and high dropping probability. RSS with hysteresis based VHO has been proposed in many studies to prevent ping-pong effect (Zeng & Agrawal, 2002). However, the first handoff maybe unnecessary if the serving base station (BS) is sufficiently strong.

Another criterion that has been extensively studied is Signal to Interference plus Noise Ratio (SINR) based VHO decision. However, 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 (Ahmed, et al., 2014). Also, this scheme provides high latency and a 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).

Unnecessary handoff (UHO) is one of the challenging problems that still occur in many proposed VHO algorithm in the previous studies. UHO usually is caused by the terminals dwelling at the edge of cell coverage (Lin, et al., 2014). Minimizing UHO is as important as handover triggering condition estimation and optimization of handover execution (Hussain, et al., 2012). If the UHO are not checked, the phenomenon will have adverse effect on the system performance. Not only overhead involved in UHO would consume network resources, but it would also increase the probability of handover failure.

In this paper, we propose a dynamic threshold of SINR based VHO to reduce the number of handoff per call and UHO, while maintaining an acceptable throughput for multimedia data transfer. In this study, the user velocity is considered as an additional criterion for SINR based VHO decision. Consideration of user velocity will be represented in the value of additional SINR threshold in the basic SINR based VHO. User velocity, given its importance in VHO decision, will become the main agenda of this study. The simple approach used in this study is expected to bring the research outcomes applicable in the real life networks. Finding the value of dynamic SINR threshold will further help the system to improve their VHO performance.

We choose WLAN and 3G WCDMA as a heterogeneous network in this study. The basic principle of the proposed algorithm is that slow speed user should stay longer in WLAN and high speed user should stay longer in WCDMA. From the previous works, this basic principle gives some advantages. This approach assigns user to appropriate cells so that frequent call handoff from fast-speed users in small cells can be avoided (Huang, et al., 2011) and signalling overheads and processing load were reduced (Kim, et al., 2010; Shafiee, et al., 2011). The VHO blocking probability can be reduced while maintaining reasonable throughput in the WLAN (Kim, et al., 2010). It will also reduce ping-pong effect (Rizvi, et al., 2010; Cha, et al., 2008) and dropping probability (Dan, et al., 2012). In this study, combining the user velocity and SINR as VHO decision criterion will give better performance, especially in ping-pong effect reduction.

The remainder of this paper is organized as follows. Section 2 provides the development of proposed algorithm and formulation of mathematical equation of additional dynamic SINR threshold. Section 3 presents' simulation scenario and simulation results. The simulation results of the proposed algorithm will be compared with other algorithms that have been previously proposed. Section 4 provides the conclusion of the study.

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, V_{TH} = 5 m/s) and starting make a call in WLAN coverage area, then the system will force MS to stay longer in WLAN until the SINR of the neighbor WCDMA cell has a higher value than the pre-set additional threshold. When the pre-set threshold is reached, then the handoff is triggered. The low speed MS will stay in WCDMA cell until the SINR of the neighbor WLAN cell has higher value than the SINR of serving WCDMA cell. The next handoff will be triggered without any pre-set threshold.

The same way will work on high speed user (higher than velocity threshold) that is initially served by WCDMA cell. System will force MS to stay longer in WCDMA until the SINR of the neighbor WLAN cell has a higher value than the pre-set threshold and the handoff is triggered. The high speed MS will stay in WLAN cell until the SINR of the neighbor WCDMA cell has higher value than the SINR of serving WLAN cell. The handoff will be triggered without any pre-set threshold.

In this study, user velocity is randomly generated in the simulation scenario. In practical level, some studies suggested that MS is equipped with digital map and Global Positioning System (GPS) to ease the task of speed estimation (Cha, et al., 2008; Shafiee, et al., 2011). Digital map and GPS can inform the locations, street names, and the velocity of vehicles.

For indoor user with low speed movement, the velocity can be obtained from estimated Doppler spread as suggested in (Pourmina and MirMotahhary, 2012). It is well known that fast speed MS cause high Doppler spread while slow speed MS cause low Doppler spread.

User's mobility model is classified into two classes, pedestrian and fast. They used path loss model for microcellular structure.

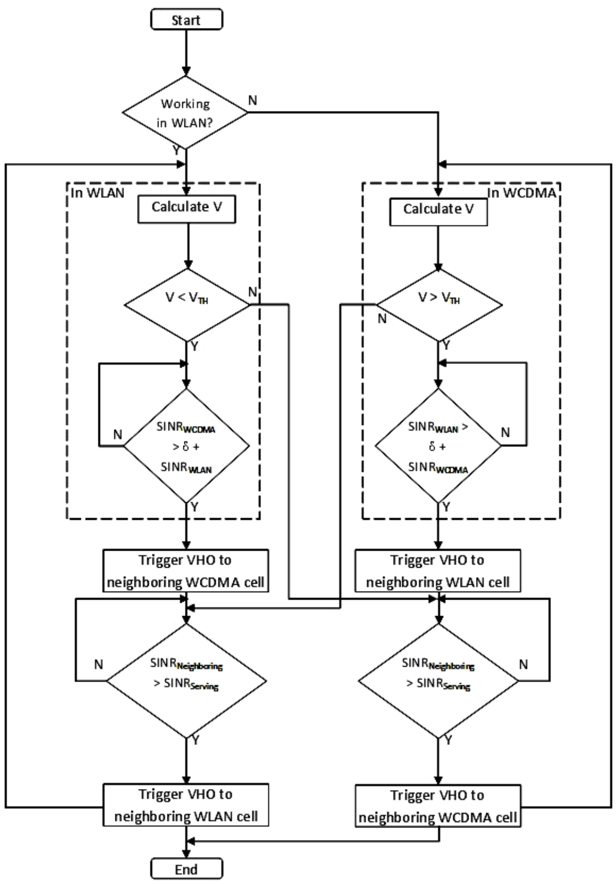


Fig. 1. Proposed VHO algorithm

2.2 Dynamic SINR Threshold

Handoff decision algorithms have been designed mainly to guarantee the continuity of service (Choi, 2010). A basic principle of the algorithms is to use the difference between the quality of the signal received from the serving Base Station (BS) and from the neighbor BS. The Signal to Interference plus Noise Ratios (SINR) based handoff decision algorithm then can be simply expressed as

$$|SINR_o - SINR_i| < \delta \qquad (1)$$

where $SINR_o$ is a received SINR from the serving BS and $SINR_i$ is a received SINR from the neighbor Base Station (BS), and δ is the handoff additional threshold determined by the system.

Neighbor cells that satisfy (1) will be designated by mobile station (MS) as candidate cells for handoff. If the MS reports the identity and SINR information of candidate cells to its serving BS, then the serving BS finally determines a target cell among the reported candidate cells. 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.

Additional SINR threshold, δ, is used as forcing parameter for user to stay longer in the appropriate cell according to its velocity. The relation between d and user velocity can be explained with the system model shown in Fig. 2. The AP_1/BS_1 is a serving cell with the coordinate (x_1, y_1) and the AP_2/BS_2 is a neighbour cell with the coordinate (x_2, y_2). The UE_0 is the starting point of user movement. The UE_S is the point when user receives the same SINR form the serving and the neighbour cell. The UE is the point when additional SINR threshold, δ, is reached. The D_0 is the distance from the initial user movement point to UE_S. The D is the distance from UE_S and UE. D'_{s_i} is the distance from the serving AP1/BS1 to UE_S. The D'_{n_i} is the distance from the neighbor AP2/BS2 to UES. The D_{n_i} is the distance between user (UE) to neighbor candidate cell and the D_{s_i} is the distance from user (UE) to serving cell.

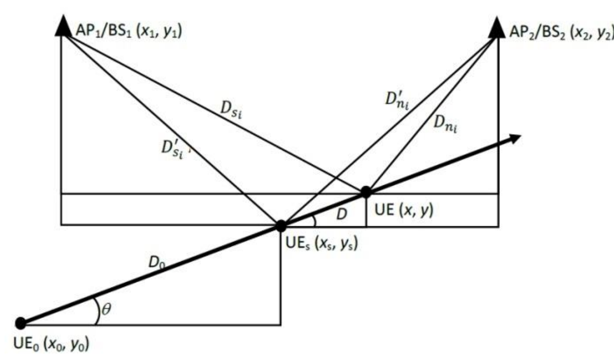


Fig. 2. System model to define the relation between δ and user velocity

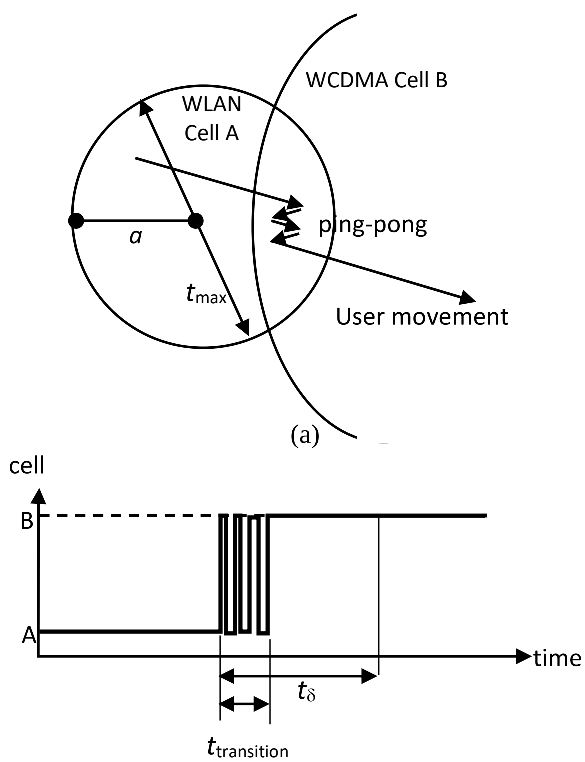
After some geometrical calculations, the relation between δ and user velocity can be expressed as

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

Equation (2) implies that for every value of velocity, v, the same value of t_δ will result in different value of δ. In other words, different δ can be applied for different velocity. In this study, different δ is called as dynamic threshold.

2.3 Probability of Unnecessary Handoff

In this study, the unnecessary handoff number and the probability of unnecessary handoff will be calculated based on the number of pin-pong effect occurrence. The probabilistic model uses the dwell time in the WLAN cell, t_{max}, and time threshold, t_δ, as depicted in Fig. 3. In Figure 3. (a), user move from WLAN cell A to WCDMA cell B. During movement, UE experiences ping-pong effect in the cells border. Figure 3. (b) shows the timing diagram of user movement. UE experiences ping-pong effect at $t_{transition}$ second. Time threshold, t_δ, can be set longer or faster than $t_{transition}$. Maximum value of t_δ is the same as t_{max}.



(b)

Fig. 3. (a). User movement. (b). Timing diagram of user movement.

Referring to Hussain, et al. (2013), the probability density function of traverse time in WLAN coverage region would be

$$f(t) = \frac{2v}{\pi\sqrt{4a^2 - v^2t^2}}, \quad 0 \le t \le t_{max} \tag{3}$$

where v is user velocity, a is cell radius, and $t_{max} = 2a/v$.

Based on Fig. 3. (b), ping-pong effect occurs when $t_{transition}$ exceeds the time threshold t_δ. The probability of ping-pong is

$$P_p = \begin{cases} P_r[t_{transition} > t_\delta], & 0 < t_{transition} < t_{max} \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

If t_δ = 10 second, then

$$\begin{aligned} P_r[t_{transition} > t_\delta] &= P_r[10 < t_{transition} < 2a/v] \\ &= \int_{10}^{2a/v} f(t)\,dt \\ &= \int_{10}^{2a/v} \frac{2v}{\pi\sqrt{4a^2 - v^2t^2}}\,dt \\ &= \frac{2}{\pi}\left(\arctan\left(\frac{v\left(\frac{2a}{v}\right)}{\sqrt{4a^2 - v^2\left(\frac{2a}{v}\right)^2}}\right)\right. \\ &\quad \left. - \left(\arctan\left(\frac{v(10)}{\sqrt{4a^2 - v^2(10)^2}}\right)\right)\right) \\ &= \frac{2}{\pi}\left(\arctan\left(\frac{2a}{\sqrt{4a^2 - 4a^2}}\right)\right) \\ &\quad - \frac{2}{\pi}\left(\arctan\left(\frac{10v}{\sqrt{4a^2 - 100v^2}}\right)\right) \\ &= \left(\frac{2}{\pi} \times \frac{\pi}{2}\right) - \frac{2}{\pi}\left(\arctan\left(\frac{10v}{\sqrt{4a^2 - 100v^2}}\right)\right) \\ &= 1 - \frac{2}{\pi}\left(\arctan\left(\frac{10v}{\sqrt{4a^2 - 100v^2}}\right)\right) \\ &= 1 - \frac{2}{\pi}\left(\arctan\left(\frac{10}{\sqrt{4a^2/v^2 - 100}}\right)\right) \end{aligned} \tag{5}$$

If no SINR threshold is applied or the VHO decision uses basic SINR algorithm, it means t_δ= 0 second, then

$$P_r[t_{transition} > t_\delta] = P_r[0 < t_{transition} < 2a/v] = 1 \tag{6}$$

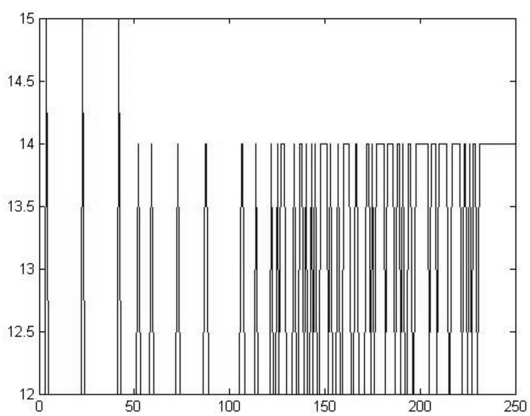
3. PERFORMANCE ANALYSI

3.1 Simulation Scenario

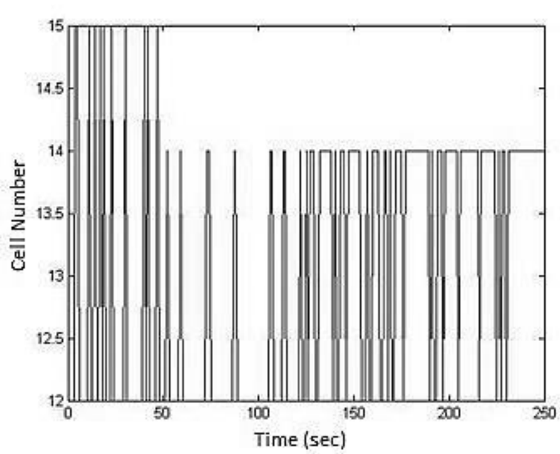
The calculation of system performance of proposed algorithm has been evaluated with the same scenario in many studies, such as presented in (Yang, et al., 2007; Yang, et al., 2008a; Yang, et al., 2008b; Ayyappan, et al., 2009; El-Fadeel, et al., 2012). There are 7 BS and 12 AP at fixed places. The 200 MS are randomly generated inside the simulation area. The MS position changes every time interval, depending on their random moving speed and direction. The simulation employs the same path loss model and parameters as presented in (Yang, et al., 2007). System performance using the scenario in Yang, et al. (2007) is denoted as Comb-SINR. It refers to their algorithm called Combined-SINR.

3.2 Unnecessary Handoff

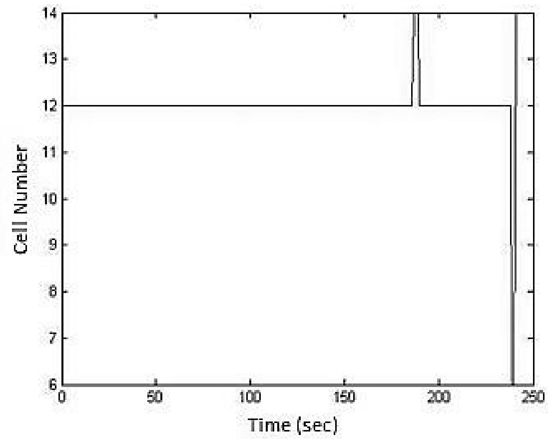
Fig. 4 shows the timing diagram of user movement at the speed of 10 m/s. It is shown to confirm the comprehension depicted in Fig. 3. (b). Three different VHO decision algorithms are applied to the same user, Comb-SINR in Fig. 4. (a)., Basic-SINR algorithm in Fig. 4. (b)., and the proposed algorithm with dynamic threshold at t_δ = 10 sec in Fig. 4. (c). Comb-SINR and Basic-SINR algorithm results in 74 handoffs for 250 seconds. The user changes the serving cells rapidly from cell number 12 to cell number 15 for about 50 seconds then change to cell number 14 for about 200 seconds. It is clear that this phenomenon is ping-pong effect phenomenon.



(a)



(b)



(c)

Fig. 4. Number of handoff using (a). Comb-SINR algorithm. (b). Basic-SINR algorithm. (c). Proposed algorithm with t_δ = 10 sec

In the other hand, the proposed algorithm will maintain the user camp on the serving cell number 12 for about 180 seconds and results in only 4 handoffs. It shows that proposed algorithm can effectively reduce ping-pong effect.

Fig. 5 shows the difference of average number of UHO per call between Comb-SINR, Basic-SINR, and proposed algorithm with t_δ = 10 sec. UHO reduction at low speed users is higher than high speed users. However the number of UHO in high speed users is very low for proposed algorithm implementation, only 1.82 UHO per call at 25 m/s.

Fig. 6 shows the difference of probability of UHO per call between basic-SINR algorithm and proposed algorithm with t_δ = 10 sec. based on (5) and (6). Probability of UHO has the lowest value of 37.25% at user velocity 25 m/s with the cell radius of 150 m. Probability of UHO for basic-SINR algorithm is always at 100% for every user velocity.

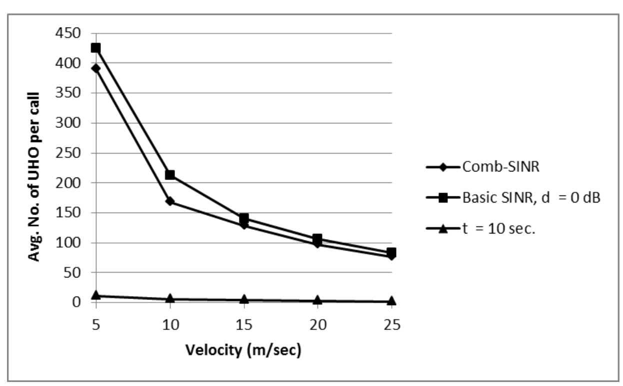


Fig. 5. Average number of UHO for 200 UEs.

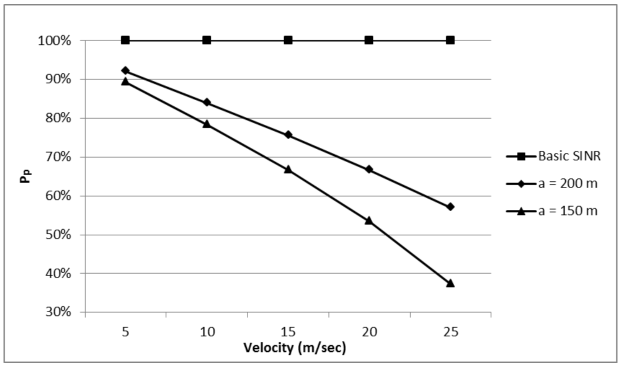


Fig. 6. Probability of UHO for different user velocity and radius of cells.

4. CONCLUSIONS

The dynamic threshold of SINR based VHO has been evaluated in this paper to minimize UHO. The simulation results have been compared with basic SINR based VHO. The simulation results show that the velocity consideration gives significant unnecessary handoff reduction.

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