Optimum Threshold for Velocity Considered-SINR Based Vertical Handoff Decision in HetNet

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ABSTRACT

A heterogeneous network (HetNet) that consists of various wireless networks is being massively studied. Integration of the networks should be error free to achieve seamless communication. The seamless vertical handoff (VHO) remains a challenging problem in HetNet studies. Several criteria for VHO decision have been studied 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 compare to RSS based VHO. However, there are some limitations in SINR based VHO scheme. This study aims to overcome those limitations by considering user velocity as an additional criterion for SINR based VHO decision. User velocity is represented in the value of additional SINR threshold. 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. Simulation results show that there is a trade-off between average throughput and the number of unnecessary handoffs per call. In this study, optimum threshold is obtained when the high percentage of unnecessary handoffs reduction is reached with an acceptable value of average throughput for multimedia data transfer.

Keywords: Vertical Handoff, User Velocity, Optimum Threshold, SINR

1. INTRODUCTION

A HetNet that consists of various wireless networks, including Worldwide Interoperability for Microwave Access (WiMAX), Wireless Fidelity (Wi-Fi), and mobile communications, is being developed to achieve high speed transmission [1]. Mobile communications include Wideband Code Division Multiple Access (WCDMA) and High Speed Downlink Packet Access/High Speed Uplink Packet Access (HSDPA/HSUPA). To complement them, wireless personal area networks (WPANs), e.g., Bluetooth and Zigbee, are developed for short-range coverage [2].

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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 [3]. 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 [4]. Several criteria for VHO decision have been studied in the literature and the main criteria are Received Signal Strength (RSS), Signal to Interference plus Noise Ratio (SINR), and available bandwidth [5].

There have been many studies that consider user velocity in the VHO decision, but not in the study of SINR based VHO algorithm. There is a VHO algorithm based on the mobility profiles, cost, transfer time [6]. The access cost and transmission time are defined as a function of velocity. Ylianttila designed system architecture for VHO in location-aware heterogeneous wireless networks [7]. He performed analysis of VHO algorithm sensitivity to various mobility parameters including velocity, handoff delay, and dwell time using Mobile IP with a fuzzy logic algorithm for VHO. Dynamic factors such as RSS and velocity of mobile station simultaneously with static factors like usage expense, link capacity (offered bandwidth), and power consumption have been studied to make the right VHO decision by determining the best network at best time among available networks [8]. Cha et al. suggested mobile velocity adaptive VHO in integrated WLAN and Wireless Broadband Internet (WiBRO) according to exact estimation of Dwell Time (DT) for downward handoff only [9]. A new multi-region mobility model has been studied by Ben Ali and Pierre in their work entitled On the Impact of Mobility and Soft Vertical Handoff on Voice Admission Control in Loosely Coupled 3G/WLAN Networks [10]. This study defined RSS model as a function of mean velocity. VHO algorithm for HetNets based on 2-level Analytic Hierarchy Process (AHP) has been studied by Radhika and Reddy [11]. The optimal target network is decided by considering a set of decision parameters (Available bandwidth, Velocity, Throughput, Cost, Security, and User Preference) with AHP. Two classes of user mobility model, pedestrian and fast, have been defined in load balancing algorithm by VHO [12]. Pedestrian is forced to perform downward VHO and stay in WLAN, while fast mobile user is forced to perform upward VHO and stay in WWAN.

There have been massive studies in SINR based VHO in recent years. 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. studied combined-SINR based VHO [3]. In this study, the VHO is triggered while the user is getting higher equivalent SINR from another access network resulting in higher throughput. This study has been developed to consider other parameter metrics to perform better VHO [13,14]. Other parameters to be considered in this study are the required bandwidth of user, user cost, maximum downlink bandwidth of each neighbour BS and AP, and network utilization. The same method with [3] also has been suggested by Ayyappan et al. [15]. El Fadeel also studied a combined-SINR based VHO using predictive SINR. The SINR prediction is done by Gray Model, GM (1, 1) [16]. A Simple Additive Weighting (SAW) VHO based on SINR and Analytic Hierarchy Process (AHP) has been studied to make VHO decisions for multi-attribute QoS consideration according to the features of traffic [17]. This study used the combined effects of SINR, user required bandwidth, user traffic cost, and available bandwidth of the participating access networks. New parameter that is called as Interference to other Interference plus Noise Ratio (IINR) has been introduced in order to have a better VHO decision [4]. In this study, VHO will be performed only when there is a throughput gain. A new decision criterion based on IEEE 802.21 Media Independent Handover (MIH) signalling among WLAN and WiMAX networks which depend on the received SINR has been studied in [18]. VHO Combined with local route repair based on SINR matrix to improve performance of 4G-multiradio mesh network has been studied in [19]. SINR based novel VHO procedure to facilitate the Long Term Evolution (LTE)-WLAN interworking is introduced in [20]. This study illustrated the significance of other handover parameters in addition to SINR in achieving improved system performance, such as time-to-trigger (TTT), offset, and moving average of SINR. The latest identification of suitable parameters for predicting VHO in heterogeneous wireless networks has been presented in [21] and user velocity was not shown as an additional criterion in SINR based VHO decision.

Some studies showed some limitations in SINR based VHO scheme. Ahmed summarized most of the limitation [22]. Major drawback of SINR based VHO is its dependent on the velocity of the mobile users and the performance degrades with the increase in velocity. Also, this scheme provides high latency and number of unnecessary handoffs. Excessive handoffs come up due to the variation of the SINR and causing Ping-Pong effect. Choi implies in his study that SINR-only based VHO will increase feedback overhead [4].

This study will consider user velocity in the SINR based VHO algorithm and divide the velocity into two groups to overcome the limitations that are mentioned above. These two groups are slow speed user and high speed user. The user velocity is considered as an additional criterion for SINR based VHO decision. The basic handoff decision based on the SINR value in [4] will be used as the foundation to build up the algorithm in this study. In the rest of this report, the basic handoff decision based on the SINR value will be called basic SINR based VHO algorithm. Consideration of user velocity will be represented in the value of additional threshold in the basic SINR based VHO.

The basic principle of the VHO algorithm in this study is that slow speed user should stay longer in WLAN and high speed user should stay longer in WCDMA. There are some advantages of this basic principle. This approach assigns user to appropriate cells so that frequent call handoff from fast-speed users in small cells can be avoided [23] and signalling overheads and processing load were reduced [6,24]. The VHO blocking probability is reduced while maintaining reasonable throughput in the WLAN [24]. It will also reduce ping-pong effect [9,25] and dropping probability [26].

2. VELOCITY-CONSIDERED SINR BASED VHO DECISION ALGORITHM

2.1 VHO Decision Algorithm

The VHO decision algorithm is depicted as a flow chart in Fig. 1. When MS is categorized as low speed user (lower than velocity threshold) and starts to make a call in WLAN coverage area, the system will force MS to stay longer in WLAN until SINR of the neighbour WCDMA cell has higher value than the pre-set additional threshold. When the pre-set threshold is reached, the handoff is triggered. If the pre-set threshold is not reached, VHO will not be triggered and MS will stay in the current serving cell until the call is finished. The low speed MS will stay in WCDMA cell until SINR of the neighbour WLAN cell has higher value than SINR of serving WCDMA cell. The next handoff will be triggered without any pre-set threshold. If the SINR of the neighbour WLAN cell never gets higher value than SINR of serving WCDMA cell, the next VHO will not be triggered and MS will stay in the current serving cell until the call is finished.

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 SINR of the neighbour WLAN cell has higher value than the pre-set threshold and the handoff is triggered. If the pre-set threshold is not reached, VHO will not be triggered and MS will stay in the current serving cell until the call is finished. The high speed MS will stay in WLAN cell until SINR of the neighbour WCDMA cell has higher value than SINR of serving WLAN cell. The handoff will be triggered without any pre-set threshold. If the SINR of the neighbour WCDMA cell never gets higher value than SINR of serving WLAN cell, then the next VHO will not be triggered and MS will stay in the current serving cell until the call is finished.

2.2 Optimum SINR Threshold

Handoff decision algorithms have been designed mainly to guarantee the continuity of service [4]. 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 neighbour BS. The SINR based handoff decision algorithm can be simply expressed as

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

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

Neighbour 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, 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.

The SINR received by user from its associated WLAN Access Point (AP) i^{th} or WCDMA Base Station (BS) i^{th} is [3]

$$\gamma_i = \frac{G_iP_i}{N+I_i} = \frac{G_iP_i}{N+\sum\limits_{\substack{k \neq i \\ k \in AP/BS}} G_kP_k} \quad (2)$$

where G_i is the channel gain between user and its associated AP or BS, Pi 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 neighbour APs or BSs.

Path loss model that is used in this study is a macro-cell propagation model for urban and suburban areas. For the antenna height of 15 meters, the path loss is [3]

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

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 of σ=10dB.

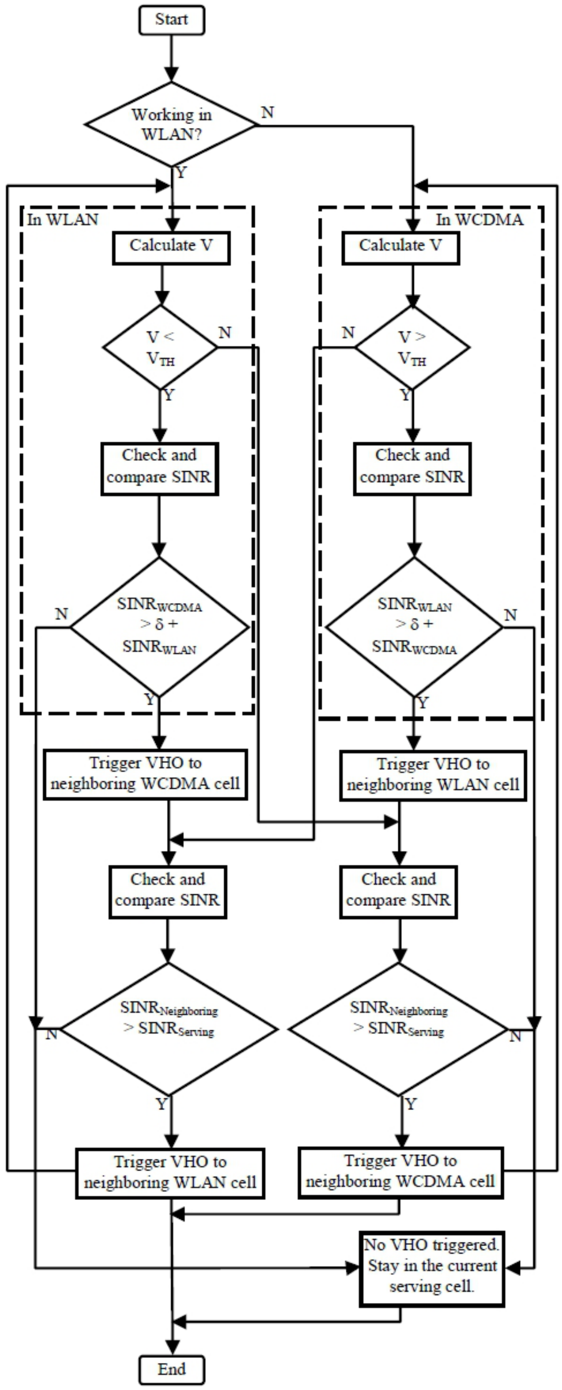

Fig.1: *VHO Decision Algorithm.*

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

$$\delta = \gamma_{n_i} - \gamma_{s_i} \quad (4)$$

Substituting (2) to (4), then

$$\delta = \frac{\mathrm{G_{n_i}P_{n_i}}}{\mathrm{N_{n_i}+I_{n_i}}} - \frac{\mathrm{G_{s_i}P_{s_i}}}{\mathrm{N_{s_i}+I_{s_i}}} \quad (5)$$

where notation s is indicating serving cell, notation n is indicating the neighbour cell, and i is representing i^{th} user. Substituting (3) in the ratio (antilog) form, it will become

$$\delta = \frac{10^{((37.6\log_{10}(D_{n_i})+G_n)/10)} \times P_{n_i}}{N_{n_i}+I_{n_i}} - \frac{10^{((37.6\log_{10}(D_{s_i})+G_s)/10)} \times P_{s_i}}{N_{s_i}+I_{s_i}} \tag{6}$$

where $G_n = 58.8 + 21\log(f_n) + \text{LogF}$ and $G_s = 58.8 + 21\log(f_s) + \text{LogF}$.

Additional SINR threshold, δ, is used as forcing parameter for user to stay longer in the appropriate cell according to its velocity. Velocity will come up in the calculation of $\mathrm{D_{n_i}}$ and $\mathrm{D_{s_i}}$ in (6). System model in Fig. 2 is used to define the relation between δ and user velocity.

The $\mathrm{AP_1/BS_1}$ is a serving cell with the coordinate $(x1, y1)$ and the $\mathrm{AP_2/BS_2}$ is a neighbor cell with the coordinate $(x2, y2)$. The $\mathrm{UE_0}$ is the starting point of user movement. The UE_S is the point when user receives the same SINR form the serving and the neighbor 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 between UE_S and UE.$\mathrm{D'_{s_i}}$is the distance from the serving AP1/BS1 to UE_S.

$\mathrm{D'_{n_i}}$is the distance from the neighbor AP2/BS2 to UE_S.$\mathrm{D'_{n_i}}$is the distance between UE point to neighbor candidate cell and $\mathrm{D'_{s_i}}$ is the distance from UE point to serving cell and define as

$$\begin{aligned} D_{n_i} &= \sqrt{(x_2 - x)^2 + (y_2 - y)^2} \\ &= \sqrt{(x_2 - (x_s + D\cos\theta))^2 + (y_2 - (y_s + D\sin\theta))^2} \\ &= \sqrt{(x_2 - (x_s + (v.t_\delta)\cos\theta))^2 + (y_2 - (y_s + (v.t_\delta)\sin\theta))^2} \end{aligned} \tag{7}$$

and

$$\begin{aligned} D_{s_i} &= \sqrt{(x_1 - x)^2 + (y_1 - y)^2} \\ &= \sqrt{(x_1 - (x_s + D\cos\theta))^2 + (y_1 - (y_s + D\sin\theta))^2} \\ &= \sqrt{(x_1 - (x_s + (v.t_\delta)\cos\theta))^2 + (y_1 - (y_s + (v.t_\delta)\sin\theta))^2} \end{aligned} \tag{8}$$

where v is user velocity and t_δ is the time needed to travel from UE_S point to UE point.

Relation between δ and user velocity can be directly understood when (7) and (8) are substituted in (6). Equation (6) 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 the serving and the neighbour cell or when

$$\delta = 0 \tag{9}$$

$$\gamma_{n_i} - \gamma_{s_i} = 0 \tag{10}$$

$$\gamma_{n_i} = \gamma_{s_i} \tag{11}$$

$$\frac{G_{n_i}P_{n_i}}{N_{n_i} + I_{n_i}} = \frac{G_{s_i}P_{s_i}}{N_{s_i} + I_{s_i}} \tag{12}$$

Substituting (3), it become

$$\frac{10^{\left(\left(37.6\log_{10}\left(D'_{n_i}\right)+G_n\right)/10\right)} \times P_{n_i}}{N_{n_i}+I_{n_i}} = \frac{10^{\left(\left(37.6\log_{10}\left(D'_{s_i}\right)+G_s\right)/10\right)} \times P_{s_i}}{N_{s_i}+I_{s_i}} \tag{13}$$

Where

$$\begin{aligned} D'_{n_i} &= \sqrt{(x_2 - x_s)^2 + (y_2 - y_s)^2} \\ &= \sqrt{(x_2 - (x_0 + D_0\cos\theta))^2 + (y_2 - (y_0 + D_0\sin\theta))^2} \\ &= \sqrt{(x_2 - (x_0 + (v.t)\cos\theta))^2 + (y_2 - (y_0 + (v.t)\sin\theta))^2} \end{aligned} \tag{14}$$

and

$$\begin{aligned} D'_{s_i} &= \sqrt{(x_1 - x_s)^2 + (y_1 - y_s)^2} \\ &= \sqrt{(x_1 - (x_0 + D_0\cos\theta))^2 + (y_1 - (y_0 + D_0\sin\theta))^2} \\ &= \sqrt{(x_1 - (x_0 + (v.t)\cos\theta))^2 + (y_1 - (y_0 + (v.t)\sin\theta))^2} \end{aligned} \tag{15}$$

$$\begin{aligned} &\left(37.6\log_{10}\left(\sqrt{(x_1 - (x_0 + (v.t)\cos\theta))^2 + (y_1 - (y_0 + (v.t)\sin\theta))^2}\right) + G_s\right) \\ &- \left(37.6\log_{10}\left(\sqrt{(x_2 - (x_0 + (v.t)\cos\theta))^2 + (y_2 - (y_0 + (v.t)\sin\theta))^2}\right) + G_n\right) \\ &= 10\log\left(\left(\frac{P_{n_i}}{N_{n_i}+I_{n_i}}\right) / \left(\frac{P_{s_i}}{N_{s_i}+I_{s_i}}\right)\right) \end{aligned} \tag{16}$$

where t is the time for user to travel from point $\mathrm{UE_0}$ to point UE_s. Substituting (14) and (15) to (13) and rearrange it, finally it can be seen that UE_S point is the point when (16) is satisfied.

3. RESULTS AND DISCUSSION

3.1 Simulation Scenario

The calculation of system performance in this study has been evaluated with the same scenario in many studies, such as presented in [3], [13-16]. 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 parameters as presented in [3]. The simulation parameters for WCDMA cells, WLAN cells, and user are shown in Table 1.

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 [6, 9]. 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 [12]. It is well known that fast speed MS cause high Doppler spread while slow speed MS cause low Doppler spread. The authors in [12] classify user's mobility model into two classes, pedestrian and fast. They used path loss model for microcellular structure.

The average throughput under different noise power of WLAN with velocity threshold $\mathrm{V}_{th} = 11$ m/s are shown in Fig. 3. This V_{th} value will separate users into two groups, slow speed users and high

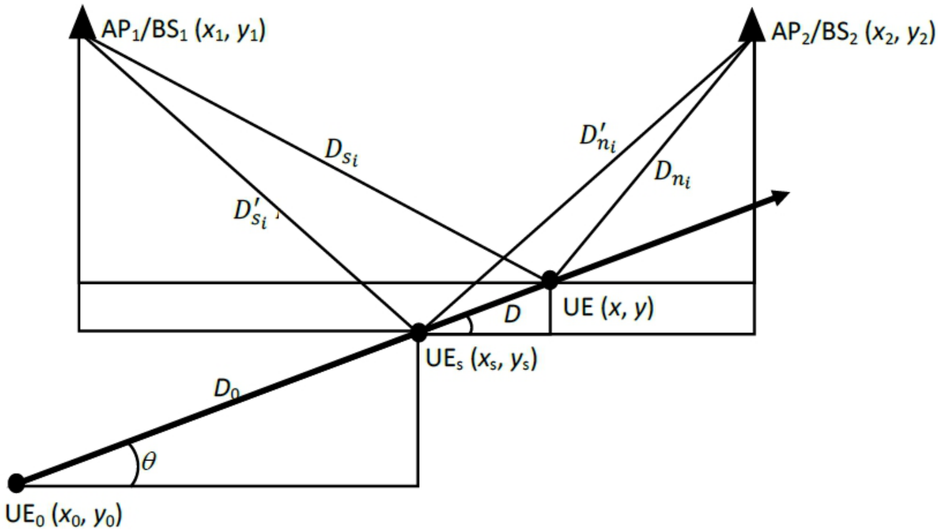

Fig.2: *System Model to Define the Relation Between δ and User Velocity.*

Table 1: *Simulation Parameters*

WCDMA	WLAN	USER
•Maximum BS transmitting power is 40dBm •The ratio of total allocated BS transmits power to HSDPA channel is 50%. •Average downlink load factor is 75% •User end background noise power equals to 7.66*10-14W. •Carrier frequency is 2GHz •Channel bandwidth is 5MHz •Gap between uncoded QAM and channel capacity is 16 dB	•Maximum AP transmitting power is 20dBm. •Background noise power equals to 96 dBm •Carrier frequency is 2.4GHz •channel bandwidth is 1MHz •Gap between uncoded QAM and channel capacity is 3 dB	•Number of user is 200. •User velocity is randomly generated (1 m/s - 22.2 m/s) or (3.6 km/h - 80 km/h)

speed users. Slow speed users are users that have velocity below 11 m/s. This V$_{th}$ value was also used in [8].

The average throughput becomes lower with higher noise power. The average throughput of proposed algorithm with different time threshold t_δ is always lower than the average throughput of basic-SINR based VHO based on (1), denoted as δ. The VHO algorithm will force low velocity users to stay connected in WLAN longer and high velocity users to stay connected in WCDMA longer. In this simulation, the SINR thresholds have four values of t_δ (5 sec, 10 sec, 30 sec, and 50 sec) that will result in different δ for each velocity. The higher the t_δ, the longer the users stay in the cells according to their velocity, even if the received throughput is lower than the throughput from the neighbour candidate cell.

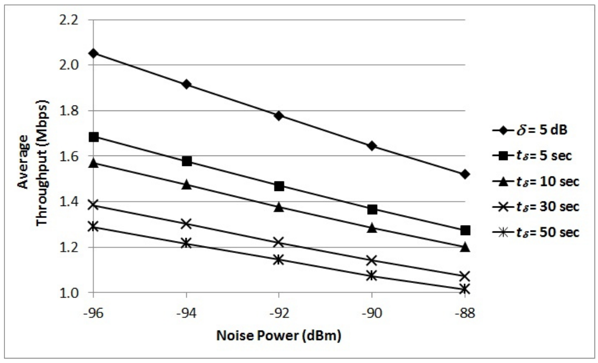

Fig.3: *Average Throughput for 200 UEs at V_{th} = 11m/s.*

For the basic-SINR based VHO, the user will perform VHO whenever SINR from candidate neighbor cell is higher than SINR from serving cell. The throughput received in this algorithm will not drop too low before it gets higher throughput after performing VHO. Since δ = 0 dB, there is no forcing parameter to consider user velocity in this algorithm.

The degradation of average throughput is acceptable according to the minimum requirement of throughput for transferring multimedia data, such as video streaming. For lowest video quality that has 240p and resolution of 426x240, the video bit rate range is 300-700 Kbps. It means that the lowest average throughput in this study still more than enough for transferring process, even in the high noise power environment at -88 dBm. The highest video quality that can be handled by the system is video that has 480p, resolution of 854x480, and the video bitrate range is 500 - 2,000 Kbps. In this case, t_δ should be set at 10 second to give minimum average throughput 1.2 Mbps which is in the video bitrate range.

The impact of different t_δ on the average number of handoffs per call is depicted in Fig. 4. It shows that by applying t_δ, the system has the lower value of the average number of handoffs per call or superior performance compares to basic-SINR based VHO. This threshold value will force user to stay in the appropriate cell, according to its velocity; longer until the condition is satisfied and might be missed many cells before the user perform VHO. If the neighbor candidate cell has a coverage that will be passed by the user in a shorter time than additional staying period, user will not handoff in this cell, but directly handoff to the next candidate cell. In this case, one handoff process will be missed.

Fig. 4 shows that t_δ = 30 second has the best performance or the lowest value of average number of handoffs per call. In many cases during simulation, t_δ = 50 second is too long for user to perform handoff and when the time to perform handoff comes, there is another condition satisfied to perform another handoff in a short time, such as horizontal handoff or even vertical handoff as the same condition in lower part of flowchart in Fig. 1.

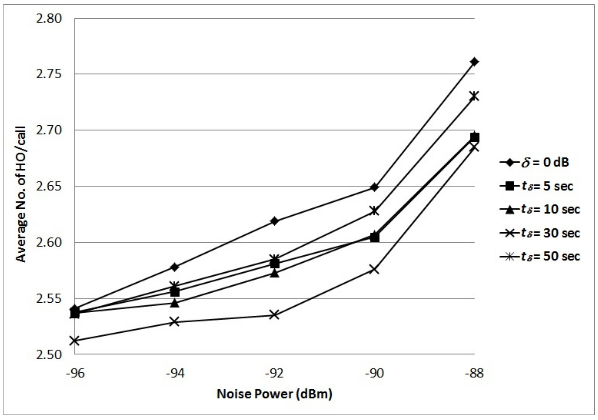

Fig.4: *Average Number of Handoffs per Call for 200 UEs at V_{th} = 11m/s.*

Fig. 5 shows the average number of unnecessary handoffs per call. The proposed algorithm significantly reduces the number of unnecessary handover compare to the basic-SINR based VHO. In the basic-SINR based VHO, user will initiate handoff process whenever neighbour SINR is higher than current serving cell or in other words. This handoff will be repeated as long as the condition is satisfied, even the last handoff just performed in a short period. This is the cause of very high number of unnecessary handoffs in the basic-SINR based VHO. At noise power -88 dBm, the average number of unnecessary handoffs in the basic-SINR based VHO is 320 per call, while in the proposed algorithm at t_δ = 5 second is 28.7 per call, at t_δ = 10 second is 9.3 per call, at t_δ = 30 second is 0.9 per call, and at t_δ = 50 second is 0 per call (no unnecessary handoff is occurred).

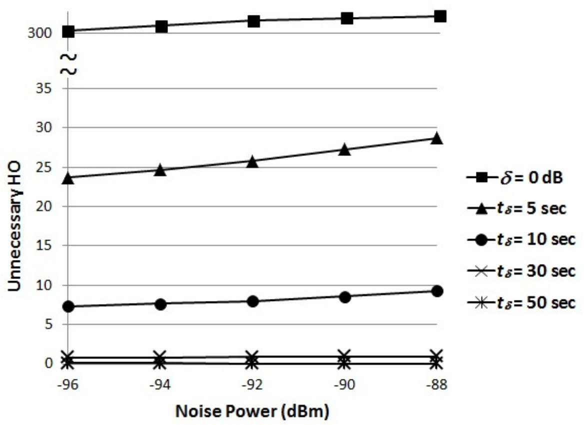

Fig.5: *Average Number of Unnecessary Handoffs per Call for 200 UEs at V_th = 11m/s.*

Fig. 6 shows the percentage of unnecessary handoffs reduction per call versus average throughput at the worst condition where the noise power is -88 dBm. This graph can be used to recommend the optimum threshold for optimum systems performance. If the system is required to handle video quality that has 480p, then the optimum recommended threshold is t_δ = 10 second. It will give minimum average throughput 1.2 Mbps with maximum unnecessary handoffs reduction 97%.

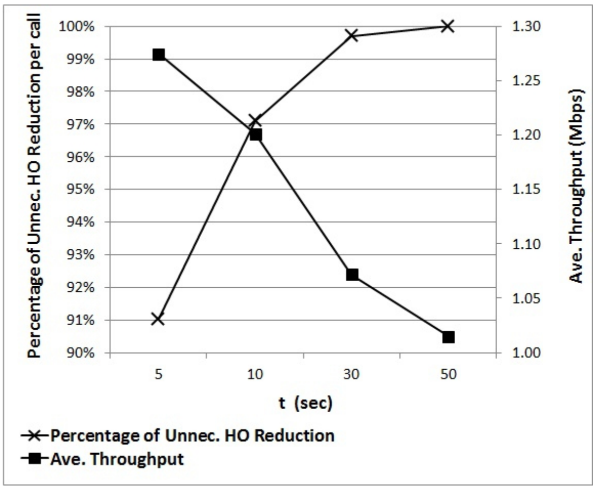

Fig.6: *Percentage of Unnecessary Handoffs Reduction per Call versus Average Throughput.*

4. CONCLUSION

The relation between user velocity and SINR threshold has been formulated. The simulation for implementing the proposed algorithm has been designed. The simulation results have been compared with basic SINR based VHO. The simulation results shows that the velocity consideration makes the average throughput slightly drop, but give a better performance on the average number of handoffs per call and significant unnecessary handoffs reduction. This study also defined the optimum SINR threshold to give the best performance in terms of average number of unnecessary handoffs per call with an acceptable average throughput.

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