A New Approach of Vertical Handoff in the Heterogeneous Wireless Networks

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ABSTRACT
The fast and seamless vertical handoff (VHO) is the one of the major requirements for moving mobile terminal (MT) among heterogeneous networks. The vertical handoff decision should be carefully executed if there is a network preferred; it is based on many factors such as the wireless channel state, network layer characteristics and QoS requirements. In this paper, the performance of the vertical handoff algorithm was evaluated under two different consideration approaches for handoff process; one approach for MT's moving from Wireless Local Area Network (WLAN) to Cellular Network (CN), and inversely form MS's moving from CN to WLAN. In this work, a new hybrid algorithm is proposed to evaluate the performance of VHO process. This work is done by combining two previous algorithms with some modifications taking into account the effect of an Application Signal Strength Threshold (ASST) on an adaptive preferred network. This hybrid algorithm showed that the number of handoff will be reduced as compared with the traditional handoff algorithm. The decreasing percentage was about (62-37) %. This reducing behavior is seen when the velocity of MS becomes low. This result is satisfactory and can be used in low user mobile for more attention and increasing the dependency on the WLAN given to provide the optimal system resource utilization.

General Terms
WLAN, Cellular Network, Mobility Management and Vertical Handoff Process.

Keywords
Heterogeneous Wireless Networks (HWN), Vertical Handoff (VHO), Horizontal Handoff (HHO) and Signal Strength Threshold (SST).

1. INTRODUCTION
Communications networks are now a combination of different Heterogeneous wireless and wired networks that are based on an enriched set of technologies. The major problem for seamless mobility is a handoff, where handoff (or handover) is the process of maintaining a mobile user in active connection when it changes its point to another point of attachment. There are two types of handoff according to MT technologies used; Vertical Handoff (VHO) and Horizontal Handoff (HHO). Handoffs that occur between different access-points or base stations belonging to different networks are referred to as vertical handoffs or inter-system handoffs, while the classical handoffs occurred in any same wireless networks are called horizontal handoffs. So the HHO is a symmetry process, while VHO is an asymmetric process in which the MT moves between two different networks with different characteristics [1-3].

The handoff process is divided into three phases [4-6]: Network Discovery, Handoff Decision and Handoff Implementation. Periodically the system monitor for discovering a better network which the mobile terminal can be handed off. The handoff considerations include several different criteria depending on the algorithms and the goals set for handoff. The handoff decision uses an algorithm that optimizes based on a selected set of criteria to decide when to handoff. The decision is very crucial and several different interesting solutions have been proposed to address the problem [6-7]. The last phase in any handoff procedure determines messages that are exchanged between the two networks to reroute the user call to the new network.

Wireless technologies are evolving toward broadband information access multiple networking platforms, to provide continuous availability of multimedia application. Thus vertical handoffs are implemented across heterogeneous cells of access systems, which differ in several aspects such as bandwidth, data rate, frequency of operation, and butter QoS etc.[5-7].

Traditionally, handoff research has been based on an evaluation of the received signal strength (RSS) at the mobile. There are five traditional handoff initiation techniques mentioned in [2,3]. These traditional RSS comparisons are not sufficient to make a vertical handoff decision with these heterogeneous networks, as they do not take into account the heterogeneous between the wireless networks such as monetary cost, network conditions, user preferences, battery lifetime, congestion in the network, network coverage, velocity of mobile users and the number of users in the network etc,.

The author of [1] studied the performance of vertical handoff using the integration of 3G cellular and wireless local area networks and showed that the adaptive VHO approach was improving the system resource. The author of [4] focused on a mobile controlled vertical handoff management scheme. The proposed scheme in this work shows a good interesting answer to interworking mobility management. Mark Stemm [5] explored a method which enables seamless mobility in wireless LAN networks with using 802.11 networks configured to work like a single umbrella network. He established mathematical relationship that allowed a vertical handoff.

In this work, we will investigate the analytical framework to study a hybrid handoff algorithm that combine from two previous algorithms of vertical handoff process [1,2] between WLAN and CN with some modification. We study the effect of this hybrid algorithm in order to reduce the number of vertical handoff as compared with the traditional algorithm, and the effect of Application Signal Strength Threshold (ASST) to optimize VHO decision comparable with traditional algorithm. We define few variables and a control mechanism to determine the vertical handoff.

This paper is organized as follows; Section two introduces the VHO in heterogeneous wireless system, VHO procedure, and system model. Section three describes the analysis of a proposed VHO algorithm, the handoff probabilities and number of handoffs. Section four shows our numerical results. Finally, Section five concludes our work.

2. VHO in Heterogeneous Wireless Networks

In heterogeneous wireless networks, the initiation VHO requirements should satisfy the following:

- Minimizing the numbers of VHO (included unnecessary handoffs) to avoid network overload, and
- Minimizing the Handoff delay, and
- Using MI (Moving Into WLAN) to avoid the congestion network, and
- Achieving fast handoffs and QoS guarantees and keeping fast users connected to the overlay network.

In this paper, we will investigate the hybrid vertical handoff process between WLAN and cellular networks using an adaptive lifetime VHO algorithm with some modification combining with the absolute and relative RSS handoff algorithm. Our work consists of two scenarios which we will introduce in the next section.

2.1 VHO Procedure in WLAN and CN

Now, we discuss and analyze two main scenarios in VHO: MI and MO that represent the MT moving into the preferred network and moving out of the preferred network respectively as shown in Figure 1. When the MT is connected to the Cellular network and it realizes that a WLAN is available (moving in), the following steps occur in MI scenario:

1. MT's home network is the CN as a first case. Then MT detects a WLAN AP beacon which in feasible range.
2. The HO algorithm decides or MT decides to handoff to WLAN and it starts with a set of L1/L2 handoff procedures.
3. MT sends a standby message to home network to prevent the CN detaches the MT when it's moving.
4. Then, MT can access the IP network and sends an Agent Solicitation to locate FA (foreign agent), FA replies the MT.
5. The MT can send Registration Request to its HA (home agent). After updating the address in the HA, the downward HO is occur.

In the reverse situation, when the MT moves away from the coverage of WLAN within the Cellular coverage, (moving out) , we can illustrated these following occur in MO scenario:

1. Signal received from the Access Point (AP) in the WLAN is strong and its represented HA, then becomes weak;
2. MT decides or the network decides to handoff to a CN if there is no another AP available and it starts with a set of L1/L2 handoff procedures.
3. Start/update Mobile IP: Foreign Agent (FA) in the MT gets activated using the Mobile IP protocol and MT uses new IP address by using the second part of MT the universal subscriber identity mobile (USIM).
4. If the MT did not attach the network or activate the session before, it should attach the network and activate a session before getting the service.
5. The Home Agent (HA) in the WLAN is informed about the new IP address through the Mobile IP protocol and the upward VHO is occurring.
6. The HA encapsulates and tunnels any packets arriving for the MT to the FA of the CN.

The Mobile-IP provides only one IP tunnel, the MT can connect to one network only at any time. In addition, multi-interface mobility client software is installed on the MT that performs Mobile-IP signaling with the foreign and home agents. It periodically scans (discovers) the available interfaces, and measures the relative RSS. Then in high accuracy selects the best access network that matches with the predefined vertical handoff algorithm.

2.2 System Model

The topology model used in study of theoverlapping of heterogeneous WLAN and cellular networks is shown in Figure 1. Both types of cells are assumed to have base station or access points at the center of the cells, and the distance between two BSs is two kilometers. Two different scenarios are used to visualize two mobile users. The cellular network is assumed to provide universal coverage, while WLAN availability is referred as the presence of the WLAN beacons that are continuously transmitted by the WLAN APs and the Mobile-IP is assumed for mobility management purpose.

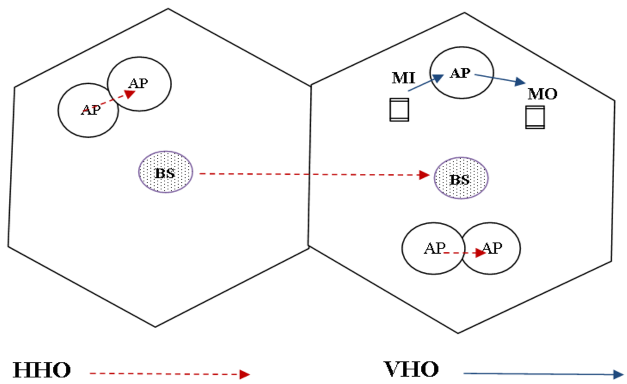

Figure1: Vertical & Horizontal Handoff in Heterogeneous Wireless System

In urban area the received signal strength from any BS or AP is namely, RSS (d) expressed in dBm, log-linear path loss channel propagation model with shadow fading is used in [8]. Formulated as:

$$RSS(d) = P_T - L - 10n\log(d) + f\ (\mu, \sigma\ ) \quad (1)$$

Where PT is the transmitted power, L is a constant power loss, n is the path loss exponent and usually has values between (2−4), d represents the distance between the MT and the WLAN AP, and f (μ, σ) represents shadow fading which is modeled as Gaussian with mean μ = 0 and standard deviation σ with values between (6–12) dB depending on the environment. We can use autocorrelation function for the shadow fading that assumed exponential, taken in [9];

$$E[u(d_1)\,u(d_2)] \;=\; E[\,u(d_1)\,v(d_2)]$$
$$=\sigma_s^2\,exp\,(-|d_2-d_1|/d_o)(2)$$

Where do is the correlation distance. We also assume that when the RSS is below a certain sensitivity level or (threshold value α) the MT is unable to communicate with the AP.

3. Hybrid Vertical Handoff Algorithm Analysis

We assume two scenarios MO and MI: in MO scenario, when the MT is within a WLAN, VHO to CN occur if the average RSS is less than MOT (moving out threshold), which the MT is unable to maintain its connection with the WLAN otherwise the MT is Stay in WLAN. We must take into consideration the handoff delay due to MIP tunneling, authentication, and initiation. The adaptive received signal threshold (ASST) is an application dependent parameter which represents a composite of the quality of service QoS requirements and bit error rate that can make an important effect in analysis and optimizes the hybrid algorithm as we will show in results.

Now we used two handoff algorithms; the first algorithm MO is based on [1] with few modifications. We used a variable length, weight and size of rectangular window. This algorithm based on ASST and lifetime estimation as the criteria to start handoff, as shown in Figure 2. To reduce the number of handoffs and the impact of shadow fading, we measured averaged signal strength samples over a variable rectangular window before they were used to trigger the handoff initiation algorithm as follows:

$$\overline{Rss_i}(k)=\frac{1}{N_w}\sum_{n=0}^{N-1}Rss_i(k-n)W_n \;(3)$$

Where i= WLAN or CN and $N_w=\sum_{n=0}^{N-1}W_n$, Wn is the weight assigned to the sample taken at the end of (k − n)thinterval [10] .

The second algorithm is based on absolute and relative signal strength in the handoff decision. We use it in the second case of (MI) when we make the decision of vertical handoff from Cellular to WLAN. Figure 2 illustrates Handoff procedures for MO and MI.

Now, in discrete time, RSS is expressed as:

$$\mathrm{RSS(d(k))=PT-L-10n\,log(d(k))+f(\mu,\sigma\,)}\quad(4)$$

Let $\quad \mathrm{RSS(k)\;=\;\mu RSS\;(k)\;+N\;(k)}$ (5)

$$\mathrm{\mu RS\;S(k)=PT-L-10n\,log\big(d(k)\big)}$$

$$\text{and}\qquad \mathrm{N\;(k)=f(\mu,\sigma\;)}$$

Where k is the time index and d is the distance between BS and AP. To check improvement of handoff performance we assume using averaging rectangular or exponential window which is dependent on the mobile velocity.

We know the better estimates is a result of using larger windows that obtained in slower users and that improve of the handoff performance, so we obtain maximizing benefits of WLANs.

3.1 Handoff Probabilities and Number of Handoffs

First, we assume two types of heterogeneous networks WLAN and 4G/3G CN network; The following probabilities are used to calculate the proposed handoff algorithm which is based on recursive computation of the handoff probabilities.

$$\mathrm{Pb}[\big(\overline{\mathrm{RSS}}(\mathrm{k})-\mathrm{T_{HO}\;S(k)}<\gamma\big(\overline{\mathrm{RSS}}(\mathrm{k}-1)-\;\mathrm{T_{HO}\;S(k-1)}\big)\geq\gamma\big)](6)$$

Let $\mathrm{Z(k)}=\big(\overline{\mathrm{RSS}}(\mathrm{k})-\mathrm{T_{HO}\;S(k)}\big)$ (7)

Then we have

$$\mathrm{PC/W(k)=\;Pb[Z(k)<}\;\gamma,Z(k-1)\geq\gamma]/\,Pb[Z(k-1)\geq\gamma]\qquad(8)$$

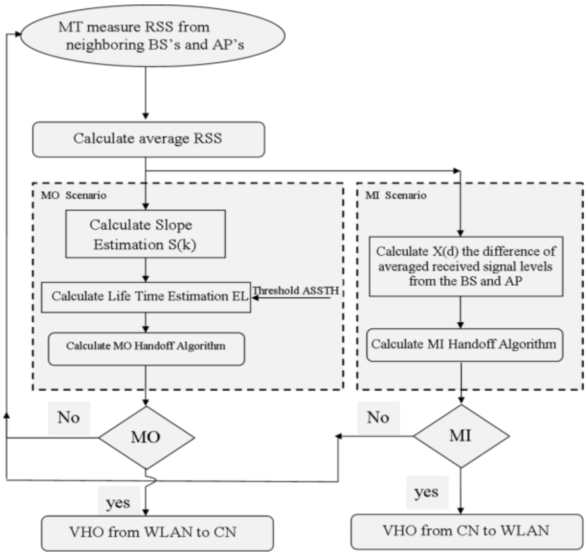

Figure 2: VHO Algorithms Implementation

Where *PW(k)* is the probability of MT that is being assigned with the WLAN at instant , *PC(k)* is the probability of MT that is being assigned with the CN at instant *k*, *PW/C(k)* is the probability of MT that is being assigned with the WLAN at instant but at instant *(k−1)* it is assigned with the CN and *PC/W(k)* is the probability of MT that is being assigned with the CN at instant k, but at instant *(k−1)* it is assigned with the WLAN. The calculation of these probabilities can be computed in a recursive way as the following:

$$\mathrm{Avg.\,no.\,of\,HO=\;NMO+NMI}$$

$$=\sum_{\mathrm{k=1}}^{\mathrm{kmax}}\mathrm{(PMO(k)+\;PMI(k))(9)}$$

$$\mathrm{PMO(k)=PC/W(k)\;PW(k-1)},(10)$$

$$\mathrm{PMI(k)=\;PW/C(k)\;PC(k-1)},\qquad(11)$$

$$\mathrm{PHO(k)}=\frac{\mathrm{PC}}{\mathrm{W(k)PW(k-1)}}$$
$$+\,\mathrm{PW/C(k)\;PC(k-1)\;(12)}$$

$$\mathrm{PW(k)=PW(k-1)}\left(1-\frac{\mathrm{PC}}{\mathrm{W(k)}}\right)$$
$$+\,\mathrm{PC(k-1)PW/C(k)},(13)$$

$$\mathrm{PC(k)=PC(k-1)}\left(1-\mathrm{P}\frac{\mathrm{W}}{\mathrm{C(k)}}\right)$$
$$+\,\mathrm{PW(k-1)PC/W(k)\;(14)}$$

Clearly, we must compute these terms *PW/C(k)* and*PC/W(k)* to calculate the handoff probability and number of handoff assuming the initial conditions as *PW(0)=1* and *PC(0)=0* and k is the time index.

To obtain maximum benefit from WLAN resources, the MO condition becomes more significant for low mobility [11] users and hence, the MO condition can reduce the lifetime estimation EL(k) less than the time ofhandoff threshold, assuming the WLAN is always in good condition.

Remember that we must choose MIWLAN threshold value greater than MOWLAN threshold value to decrease the number of unnecessary HO that is cause by ping-pong eff ect. Now the calculation of the term PMO(k) is based on the first algorithm with modification, while the calculation of the term PMI(k) is based on the second algorithm as we explained previously. While we assume RSS(k) is a Gaussian distribution for simplified, the average received signal, lifetime estimated signal, El(k)and slope estimated signal, S(k) are Gaussian too.

The derived conditional probability PW/C(k) can be computed using the jointly Gaussian PDF with the shadow correlation function. We compute the Conditional probabilities PC/W(k) as follows:

$$\mathrm{PC/W(k)} = \mathrm{Pb}\,[\mathrm{EL(k)} < \mathrm{T_{HO}} /\, \mathrm{EL(k-1)} \geq \mathrm{T_{HO}}] \quad (15)$$

Where γ is the ASST, which is assumed -90dB as a specific parameters in our simulation given in Table 1.

Table 1: Simulation Parameters

arameter	Value	Parameter	Value
P_T	100mW	α	0.99
n	3.3	S	28.7dB
D	2km	d_o	20m
D_{av}	500m	d_s	1m
D_s	5m	MOT_{WLAN}	-85dBm
γ	-90dB	MIT_{WLAN}	-80dBm
σ	6dB	THO	1sec
$CN_{coverage}$	2.5km	$WLAN_{coverage}$	100m
T_s	0.015		

The autocorrelation function ρ between Z(k) and Z(k-1) can be defined their joint probability density function of f Z (k) f Z(k−1) (z1 , z2) [12].

$$\mathrm{PC/W(k)} = \frac{\mathrm{PDF\ f\,Z\,(k)\ f\,Z(k-1)}}{\mathrm{Prob(\,z(k-1)\geq\gamma)}} \quad (16)$$

$$\mathrm{PC/W(k)} = \frac{\int_{-\infty}^{\gamma}\int_{\gamma}^{\infty} \mathrm{f\,Z\,(k) f\,Z(k-1)(z1\,,z2\,)dz1dz2}}{\mathrm{Prob(\,z(k-1)\geq\gamma)}} \quad (17)$$

Where $\mathrm{Pb}\ (\mathrm{Z(k-1)} \geq \gamma) \ = \mathrm{Q}\left(\frac{\gamma-\mu_{z(k-1)}(k)}{\sigma_{z(k-1)}(k)}\right)$

We know the complementary function defined as

$$\mathrm{Q(\,\beta)} = \frac{1}{\sqrt{2\pi}}\int_{\beta}^{\infty} e^{-x^2/2}dx \quad (18)$$

Clearly, we know the autocorrelation coefficient is defined by this equation

$$\rho z(k)z(k-1) = \frac{\mathrm{Cov(Z(k),Z(k-1)}}{\sigma_{z(k)}\sigma_{z(k-1)}}, \quad (19)$$

We can compute the term of $\mathrm{Cov(Z(k), Z(k-1))}$ with using variable rectangular window with $W_{average}$ and W_{slop}. We can calculate the covariance as follows:

$\mathrm{Cov(Z(k), Z(k-1)})=$

$$\frac{\sum_{hys=1}^{Wn_{av}-1}(Wn_{av} - |hys|)\,[T_s W_s^2(4Ws - 6|hys|) + 8T_{HO}]}{T_s W_s^2} + \frac{4\,\sigma^2 T_{HO}^2\,(Wn_{av}(W_s-6))}{Wn_{av}^2 W_s^4 T_s^2} \quad (20)$$

4. Numerical Results

In this work , the suggested hybrid algorithm for VHO in previous section has been tested and evaluated by using MATLAB R2008a simulation with the following parameters that were chosen for application in two algorithms in the (Table 1). Two scenarios MO and MI had been evaluated using the two algorithms which we referred to earlier. Thus, the average number of vertical handoff verses mobile terminal velocity were calculated and compared with traditional handoff algorithm which using RSS and threshold with hysteresis level.

The results is shown in Figure 3 illustrates the decreasing of number of vertical handoff in hybrid algorithm compared with traditional algorithm. That explains the effect of selection the type and size of window. In Figure 4 and 5, the effect of adaptive signal strength threshold had been studied using the combining algorithm. Three different values of ASST were used and the results show the increase of ASST decreases the average number of VHO. In Figure 6 we see the decreasing percentage between our algorithm and the traditional algorithm in number of vertical handoff. The percentage is about (62-37)% in linear trend line of decreasing. We show that the level of decreasing reduce when the velocity becomes high. This algorithm can be satisfying and useful in low user mobile for more attention.

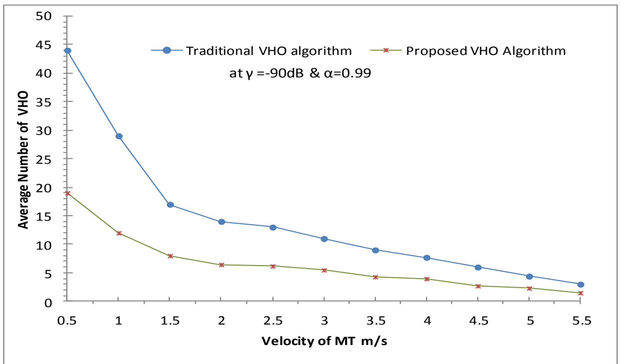

Figure 3: The comparision in two Handoff algorithms

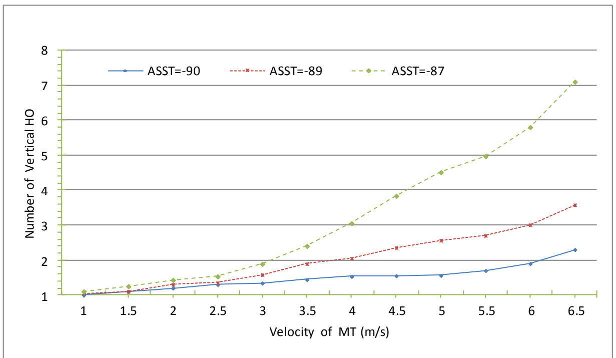

Figure 4: Number of Vertical Handdoff with Velocity

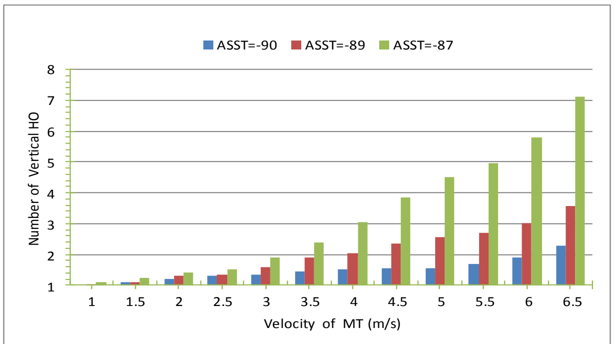

Figure 5: Number of Vertical Handdoff with Velocity at different values of ASST

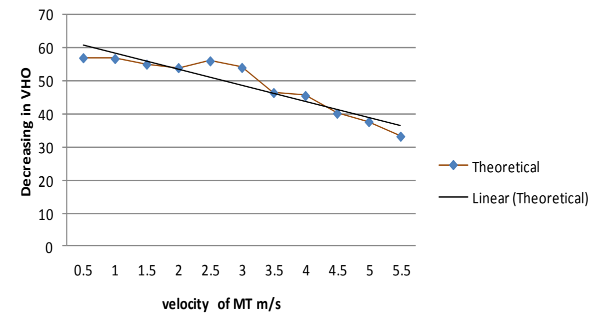

Figure 6 : The Decreasing percentage of VHO between two algorithms

5. Conclusions

The suggested vertical handoff algorithm uses adaptive VHO algorithm with rectangular window (variable length, weight and size) as a first algorithm. The second algorithm based on absolute and relative signal strength shows good results that can be used effectively to reduce the number of vertical handoff compared with traditional algorithm in heterogeneous wireless networks. In the hybrid VHO approach we show that increasing of dependency on the WLAN that given the provides an optimal system resource, as well as keeping the resources of the heterogonous network for users located outside the WLAN. The value of ASST important role factor determines the number of handoff.

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