Vertical Handoff Algorithms in WLAN/3G Integrated Networks

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***Abstract*—With the development of various heterogeneous wireless technologies, which are for different purposes, the integration of these networks will provide good service, connectivity and high date rates to users. In this paper we consider the integration of WLAN and 3G networks. We evaluate performance of two vertical handoff (VHO) algorithms for an integrated 3G and WLAN network. The number of handoffs and decision delay are estimated as the MT (mobile terminal) moves from the centre of 3G network towards the AP of WLAN.**

***Keywords*— VHO-algorithm, wireless area network (WLAN), 3G network, decision delay, seamless handover, bandwidth conversion.**

I. Introduction

Vertical Handoffs refer to handoff between two network access points, which are usually using different network connection technology. In next-generation heterogeneous wireless systems, one of the major challenges is seamless vertical handoff. Seamless handover is challenge due to following heterogeneities: 1) Next Generation Wireless Systems integrate Bluetooth, GPRS, and IEEE 802.11 based WLANs, WiMAX, UMTS. All these systems have different cell sizes of radii ranging from few meters to few kilometers and may have overlapping or partially overlapping coverage areas [1]. 2) Different network architectures have different transport, routing and mobility management protocols. 3) They are optimized for specific service demands like Bluetooth provides very small coverage area for personal use, IEEE 802.11based WLANs for local area internet connectivity, limited ability, VoIP calls, UMTS provides full mobility, Teleservices, SMS, MMS, Packet data, E-mail, VoIP, Internet WiMAX provides very limited mobility, P2P, Point-to-Multipoint, Internet connection, VoIP etc [1],

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In this paper, we consider Received signal strength (RSS) based vertical handoff taking two wireless systems in concern: 3G cellular network and WLAN. when a mobile device has access to both WLAN and 3G cellular network, the mobile directly switches to WLAN because it provides higher data rate(1 to 11 Mbps) in a local area (<100m). As the mobile moves away from the access point of WLAN, its data rate decreases and 3G networks, which provides global coverage at limited data rate becomes dominant and thus network access can be transferred from WLAN to 3G cellular network. Vertical handoff includes three sequential steps namely handoff initiation, handoff decision and handoff execution. Handoff initiation is concerned with measurement of received signal strength.

Received signal strength is the measurement of power present in a received radio signal. Signal must be strong enough between base station (BS) and MT to maintain signal quality at receiver. The signal gets weaker as mobile moves far away from BS/AP and gets stronger as it gets closer to BS/AP. Handoff decision is based on received signal strength from current BS to neighbor BS of 3G cellular network or AP of WLAN. The vertical handoffs from WLAN to 3G cellular network are different from those from 3G cellular network to WLAN. Similar to horizontal handoff, vertical handoff from WLAN to 3G cellular network are mainly initiated when the user is not in coverage area. As WLAN user is moving away from AP, RSS decreases. When user detects that RSS from WLAN is below threshold, mobile will initiate a handoff request. If 3G cellular network has sufficient resources to accommodate, it will accept the request, otherwise it will drop the request. In this case, user is totally disconnected from interworking system. The handoffs from 3G cellular network to WLAN are triggered to seek low-cost or high-speed services or to reduce 3G cellular network congestion. Since WLAN has rather small coverage and usually locates within a single 3G cell, the user requesting a vertical handoff from 3G to WLAN is always within the coverage area of 3G cellular network. If WLAN accepts the handoff request, the user will break the connection with 3G network and start to communicate with WLAN. Even if WLAN denies the handoff request, the user can still remain in the original connection with 3G as it is still within the coverage of 3G cell. That is, user is always connected to the interworking system. There is no real blocking for the vertical handoff from 3G cellular network to WLAN. RSS from WLAN and 3G network cannot be directly compared with each other due to their heterogeneity. So another QOS parameter is consider as in [10]. As network bandwidth is most preferable QOS parameter to the user so we take this QOS parameter for mapping purpose.

II. System Model

In our network model, we consider the mobile station (MT) is moving from center of 3G network to WLAN.

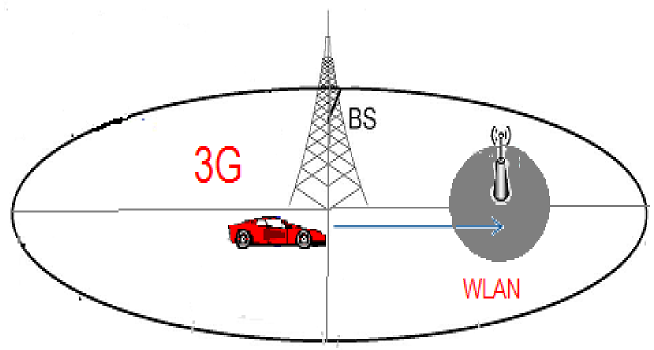

Figure 1. system model

For our proposed model, while moving from 3G to WLAN, only one vertical handoff will occur in the absence of shadowing term. But practically in the presence of shadowing term, signal fluctuates at MT. Due to this we will get two different types of vertical hand offs i.e 3G network to WLAN and WLAN to 3G network. So we have measured the number of handoff and decision delay as a performance measure for moving MT from 3G to WLAN. The figure represents the overall scenario. WLAN is surrounded by 3G network. In our system model initially MT is connected to 3G.As it moves towards the AP of WLAN, received signal strength increases gradually. After some time the signal strength increases even above 3G. At that point it seamlessly detaches from 3G and start accessing WLAN making handoff. If WLAN signal strength is much enough it accesses the WLAN even though 3G is present. Thus continuous connectivity to internet is maintained. Similarly, when MT starts receiving higher signal strength from 3G than RSS from WLAN it switches to former making handoff again.

In 3G networks, channel and time slots are allocated to a MT beforehand by its BS, so it can be assumed that the bandwidth is constant when the MT moves within hundreds of meters. In 802.11 WLAN systems, the data rate is chosen based on achievable RSS to meet a certain link quality, so the bandwidth is dynamic. Measured signal strength has three components

- Path loss
- Large-scale fluctuations (shadow fading)
- Small-scale fluctuations (multipath fading)

Multipath fading is not considered (average, low-pass filter) to avoid unnecessary handovers and no termination (hang-up) probability is considered.

By considering path loss and shadow fading, the received power at a distance 'd' from WLAN is:

$$P_w(d) = \mu_{RSS}(d) + S(\sigma, d) \qquad (1)$$

The average signal strength $\mu_{rss}(d)$ can be expressed as

$$\mu_{RSS}(d) = K - P_L(d) \qquad (2)$$

where K is the parameter, that include transmitted power and transmitting/receiving antenna gain and $P_L(d)$ is the path loss. Which is represented as [10].

$$PL\ (d) = 32.5 + 20 \log F + 10n_I \log_{10} d \qquad (3)$$

S(σ,d) represents shadowing effect, denotes Gaussian random variable with standard deviation σ.
Now the probability that MT receiver can translate the data correctly can be represented as [11]

$$\Pr[P_w(d) > S_R] = 1 - Q\left(\frac{S_R - \mu_{RSS}(d)}{\sigma}\right) \qquad (4)$$

where Q(•) is Q-function.

The data rates in the WLAN are as below.

$$DR_W[\mu_{RSS}(d)] = \begin{cases} r_1, \mu_{RSS}(d) \in (-\infty, S_1) \\ r_2, \mu_{RSS}(d) \in (S_1, S_2) \\ \quad M \\ r_m, \mu_{RSS}(d) \in (S_{m-1}, \infty) \end{cases}, r_1 < r_2 < \Lambda < r_m \qquad (5)$$

where $S_1, S_2, \Lambda, S_{m-1}$ are receiver sensitivity values required for different level of data rate from $r_2\, to\, r_m$.
The bandwidths in WLAN can be represented as [10]

$$B_W(d) = \Pr[P_w(d) > S_R] * DR_W[\mu_{RSS}(d)] \qquad (6)$$

The band width of 3G network can be converted to the equivalent RSS of WLAN network.

III. Simulation Model

In this section, we evaluate the performance of our proposed model by using hysteresis and dwell timer based algorithms. We consider that a mobile terminal moves from 3G cellular network to indoor environment of WLAN. The indoor propagation channel differs considerably from the outdoor one [12]. Indoor channels may be classified as line-of-sight (LOS) or obstructed (OBS). We assume 3G will provide global coverage with constant RSS denoted by P_{3G} whereas RSS from WLAN has two parts. Firstly the average signal strength $\mu_{rss}(d)$ which depends on whether MT is inside or outside the building [10]. When the MT is inside the building, the indoor average signal strength can be expressed as:

$$\mu_{RSS}(d) = C - 10n_I \log_{10} d, d \in (0, d_d) \qquad (7)$$

where d_d is the distance between the door and the AP, and n_I is the path loss exponent for indoor environment and

$$C = K - 32.5 - \log_{10} f \qquad (8)$$

where f is the operating frequency (in GHz) of WLAN system.

Now when the MT is outside the building, a portion of the signal is coming by penetrating through the walls and another

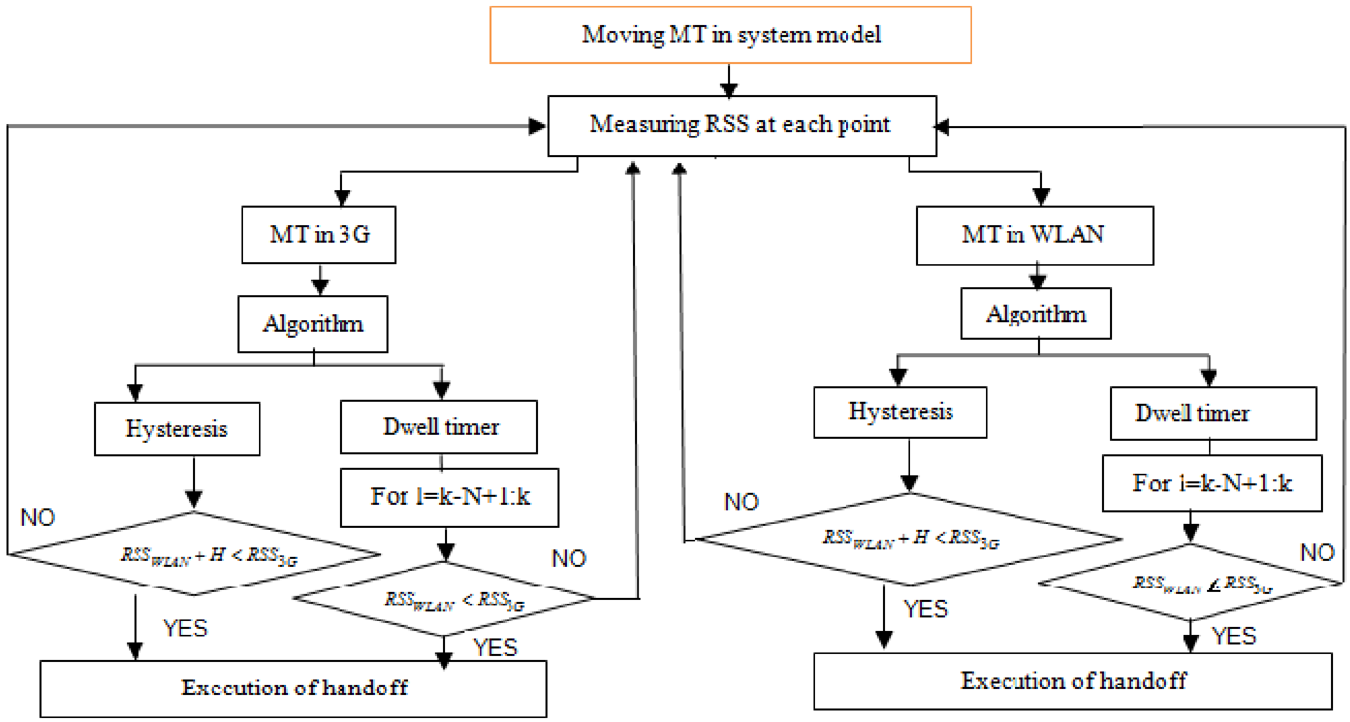

Figure 2. Flow chart for VHO algorithms

portion is coming after diffraction. The strength of penetrating and diffracted signal strength [10] are as below

$$P_{Pe}(d) = C - 10*n_I \log_{10} d_d - O_L - 10*n_0 \log_{10}(d/d_d) \quad (9)$$

$$P_{Di}(d) = C - 10*n_I \log_{10} d_d - 10*n_0 \log_{10}(d - d_d + 1) \quad (10)$$

where O_L is the obstacle loss and n_O is path loss exponent for outdoor environment. Thus the outdoor average signal strength of the WLAN is [12]:

$$\mu_{RSS}(d) = 10\log_{10}(10^{P_{Pe}(d)} + 10^{P_{Di}(d)}), d \in (d_d, \infty) \quad (11)$$

The shadowing effect S(σ,d) is caused by obstacle. The autocorrelation coefficient between $S(\sigma,d_1)$ and $S(\sigma,d_2)$ is assumed to be

$$\rho_{S(\sigma,d_1),S(\sigma,d_2)} = \rho^{|d_1-d_2|}, \rho \in (0,1) \quad (12)$$

where d_1 and d_2 are two different distances from an AP. The MT is moving from 3G towards WLAN at constant speed (v m/s). Received signal strength from an AP are sampled at the MT of interest at a distance $k.d_s$ from the AP, where k is an integer (0,1,2….) indicating sampling instant and d_s is the sampling distance (= $v.T_s$,where the T_s is the sampling interval in sec).

Now we analyze the metrics the decision delay as performance evaluation function.

A. *Decision Delay*

In ideal case only one VHO should occur at the position where $\mu_{RSS}(d)$ of WLAN equal to P_{3G} of 3G network. Let us refer the sampling instance corresponding to such position as optimum handoff instan k_O. Due to the presence of shadowing part S(σ,d) in the RSS, MT will face more than one VHO (back-and-forth) during the movement. Let us consider that the first and last handoffs occur at k_F and k_L Sampling instant respectively. The decision delay is defined as mean of first and last handoff decision delay as follows [10]

$$D = T*\left(\frac{E(k_L)+E(k_F)}{2} - k_O\right) \quad (13)$$

In our proposed model we analyze and evaluate the decision delay for dwell-timer and hysteresis based handoff algorithm subsequently**.** A handover to the network with appropriate service is performed according to the algorithms as shown in flow chart (Fig.2).

B. *Hysteresis based algorithm:*

Handoff is made if the RSS of AP (BS) exceeds that of the current network BS (AP) by hysteresis margin (H) i.e condition for vertical handoff from X-th network to Y-th network at k-th instant as considered in [17] is

$$RSS_Y(k) > RSS_X(k) + H$$

C. *Dwell timer based algorithm:*

In this algorithm [17] a counter of predefined threshold is started when the RSS from a BS (AP) of another network exceeds the RSS from the current AP (BS). Here RSS means the equivalent RSS converted from the bandwidth of the corresponding network. If this condition continues till the counter is expired, a vertical handoff is initiated. i.e. the condition for vertical handoff from X-th network to Y-th network at k-th instant [17] is

for $l=k-N+1: k$

$RSS_X(l) < RSS_Y(L)$

end;

Here we assume that the MT is connected to X-th network at (k-N)-th instant. And N is equivalent sampling instant corresponding to dwell timer value Dw sec.

IV. Results and Discussion

The main parameters of the analytical framework are set as follows:[10]

TABLE 1 : PARAMETER VALUES

Parameter	Description	Value
K	Transmitted power and transmitting/ receiving antenna gain in dB	20.1 dBm
F	Carrier frequency	2.4 Ghz
P	Correlation Coefficient	0.8
n_I	Path loss exponent for indoor environment	3.2
n_O	Path loss exponent for outdoor environment	3.5
T	Sampling interval	0.1s
B_{3G}	Bandwidth of 3G network	2.4 Mbps
S_R	Receiver Sensitivity	-94 dBm

A MT is moving from 3G network through the AP of WLAN with constant velocity, v = 2m/s. Received Signal Strength are sampled with sampling duration of 0.1s. The transmission data rate for WLAN is a function of received signal strength. A details regarding data rate in WLAN as a function of receiver sensitivity is discussed in [13] .

$$DR_w(\mu_{RSS}(d)) = \begin{cases} 1Mbps, \mu_{RSS}(d) \in (-\infty, -91dBm) \\ 2Mbps, \mu_{RSS}(d) \in [-91dBm, -87dBm) \\ 5.5Mbps, \mu_{RSS}(d) \in [-87dBm, -82dBm) \\ 11Mbps, \mu_{RSS}(d) \in [-82dBm, \infty) \end{cases} \quad (13)$$

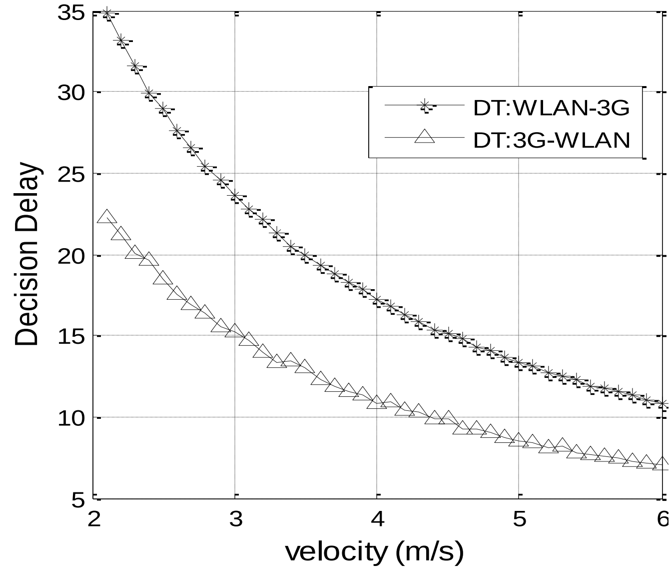

Figure 3.The decision delay vs velocity for σ = 8dB, d_d = 20m, and O_L = 7dB.

In Fig.3, the decision delay is shown as a function of velocity for dwell timer based VHO algorithm when the MT moved from 3G network to the centre of WLAN. . Here DT:3G-WLAN indicates time taken by MT to access WLAN connectivity and DT:WLAN-3G indicates delay between first and last handoff from WLAN to 3G. Fig.4 shows that the decision delay decreases with velocity for hysteresis based handoff algorithm for our network model. HYS:3G-WLAN, HYS:WLAN-3G are similar to DT:3G-WLAN,DT:WLAN-3G except algorithm used is hysteresis based algorithm. With increasing velocity, sampling distance increases and hence RSS increases rapidly with respect to time which makes less sampling points between k_F and k_L, so it takes less decision delay. In dwell-timer based algorithm we get less decision delay. Because in dwell-timer based algorithm handoff may occur only once in the entire timer period which reduces the frequency of handoffs for 3G to WLAN movement.

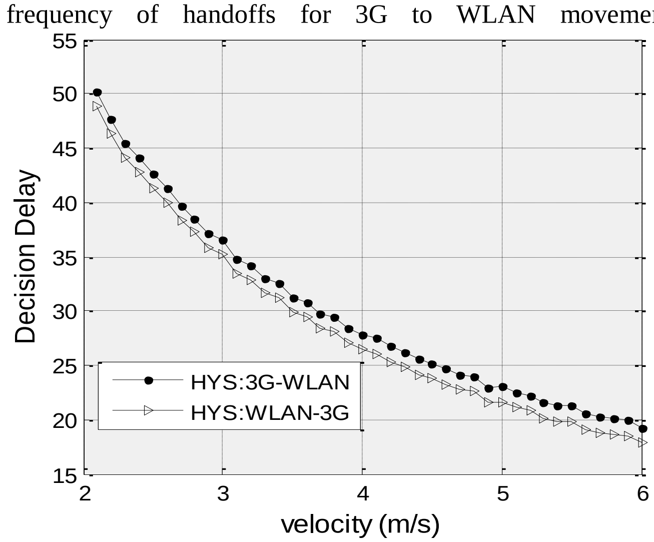

Figure 4. The decision delay vs velocity for σ = 8dB, d_d = 20m, and O_L = 7dB.

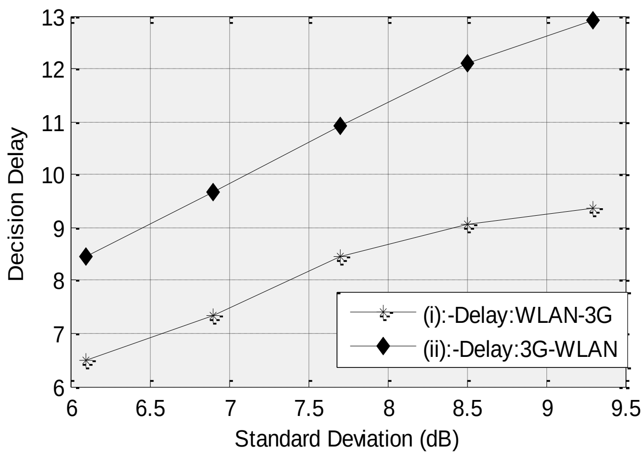

Figure 5. The decision delay vs standard deviation of shadow fading for v=5m/s, d_d = 20m and O_L = 7dB

In Fig.5, the decision delay is shown as a function of standard deviation of shadow fading. As shown in figure decision delay increases with standard deviation. With the increased standard deviation uncertainty increases. So received signal fluctuates more at MT. Due to this user's connection oscillates between these networks and increases number of handoffs. Which makes more handoff sampling points between k_F and k_L. The distance between first handoff and last hand off also increases as standard deviation increases. So the decision delay is increases with standard deviation of shadow fading term.

V. Conclusion

In this paper, we consider a simulation framework to evaluate the performance of two VHO algorithms in a new network model. We evaluate vertical handoffs and decision delay for 3G and WLAN integrated network model. From the simulation results it is clear that dwell timer algorithm produced less number of handoffs and less decision delay comparing to hysteresis based algorithm.

This integration process may be deployable for various heterogeneous networks, for example 4G networks. Reducing the decision delay in this kind of network will be a major focus in our future work.

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