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A Survey of Vertical Handoff Algorithms to Minimize Probability of False Handoff

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ABSTRACT

To achieve seamless mobility in unified network of heterogeneous wireless networks, vertical handoff is challenging problem.

In this paper, we compare three vertical handoff algorithms, namely, HNE (Handoff Necessity Estimation) which determines the necessity of making a handoff to an available network and which works well for WLAN to cellular networks and vice versa, ALIVEHO (Adaptive Lifetime based Vertical Handoff) which uses RSS and expected duration after which the MT will be able to maintain its connection with WLAN to decide the vertical handoff and ARSST (Adaptive RSS Threshold) which achieves lower false handoff initiation probability and well suited for handoff from WLAN to 3G network. All these three algorithms are based on RSS and minimize the probability of false handoff.

Keywords - ALIVEHO, ARSST, False Handoff, HNE, RSS

1. INTRODUCTION

In the 4G wireless environment, a mobile user is able to continue using the mobile device while moving from one point of attachment to another. Such process is called a handoff, by which a MT keeps its connection active when it migrates from the coverage of one network access point to another. Depending on the access network that each point of attachment belongs to, the handoff can be either horizontal or vertical [1].

1.1 Horizontal Handoff:

A horizontal handoff or intra-system handoff takes place between PoA (Point of Access) supporting the same network technology, e.g., two geographically neighboring BSs of a 3G cellular network [1].

1.2. Vertical Handoff:

A vertical handoff or inter-system handoff occurs between PoA supporting different network technologies, e.g., an IEEE 802.11 AP and a 3G BS. An example of horizontal and vertical handoffs is illustrated in Figure 1.1,

Where a horizontal handoff happens between two cellular BSs and a vertical handoff takes place between an AP of a WLAN and a BS of a cellular BS. Vertical handoffs are implemented across heterogeneous cells of access systems, which differ in several aspects such as bandwidth, data rate, frequency of operation, etc. The different characteristics of the networks involved make the implementation of vertical handoffs more challenging as compared to horizontal handoffs [1].

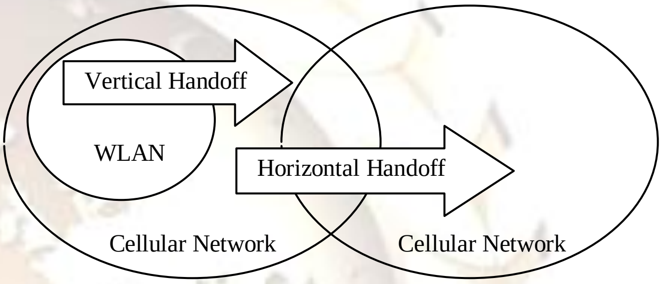

Figure 1.1: Horizontal and Vertical Handoff.

Three stages are involved in a vertical handover process: network discovery, handover decision, and handover execution. During the system discovery, mobile terminal equipped with multiple interfaces have to determine which networks can be used and what services are available in each network. During the handoff decision phase, the mobile device determines which network it should connect to. During the handoff execution phase, connections are needed to be re-routed from the existing network to the new network in a seamless manner .This requirement refers to the Always Best connected (ABC) concept, which includes the authentication ,authorization , as well as the transfer of user's context information [1].

Many algorithms have been developed recently in order to optimize the vertical handoff between WLAN and cellular networks. In each algorithm, different factors have been considered. RSS based algorithms are less complex and can be used between macro cellular and microcellular networks. High handoff failure probability is observed for algorithm without inclusion of RSS [2].

Yan et al. [3] and Li Renfa [1] developed a VHD algorithm that takes into consideration the time the mobile terminal is expected to spend within a WLAN cell. The method relies on the estimation of WLAN traveling time (i.e. time that the mobile terminal is expected to spend within the WLAN cell) and the calculation of a time threshold. A handoff to a WLAN is triggered if the WLAN coverage is available and the estimated traveling time inside the WLAN cell is larger than the time threshold.

Zahran et al. proposed an algorithm for handoffs between 3G networks and WLANs by combining the RSS measurements either with an estimated lifetime metric (expected duration after which the mobile terminal will not be able to maintain its connection with the WLAN) [2].

ALIVE-HO always uses an uncongested network whenever available. It continues using the preferred network (i.e. WLAN) as long as it satisfies the QoS (Quality of service) requirements of the application [2].

Mohanty and Akyildiz proposed a WLAN to 3G handoff decision method based on comparison of the current RSS and a dynamic RSS threshold when a mobile terminal is connected to a WLAN access point [4].

These algorithms could reduce the number of handoffs. In the following chapter of report briefly describe three RSS based algorithms. This is focusing on various Mathematical Models in RSS based vertical handoff decision algorithms. These algorithms could reduce the number of handoffs. Report gives a comparative analysis of three RSS based vertical handoff algorithms [2].

2. RSS BASED VHD ALGORITHMS

2.1. Handoff necessity estimation (HNE)

Handoff necessity estimation (HNE) [1] [3] [6] method which estimates the necessity of a handoff is proposed. HNE includes two VHD algorithms. The first algorithm predicts the user's traveling time within a network coverage area, and the averaged Received Signal Strength (RSS) samples and the MT's velocity information are used in the traveling time prediction in a mathematical model. The second algorithm calculates a time threshold based on various network parameters and the handoff failure or unnecessary handoff probability information. The expression of handoff failure or unnecessary handoff probability is generated by developing a mathematical model which assumes uniform distribution of entry and exit points of a network coverage area. The predicted traveling time is compared against the time threshold and a handoff is necessary only if the traveling time is longer than the threshold. This method leads to a reduction of handoff failures of up to 80% and unnecessary handoffs of up to 70%.

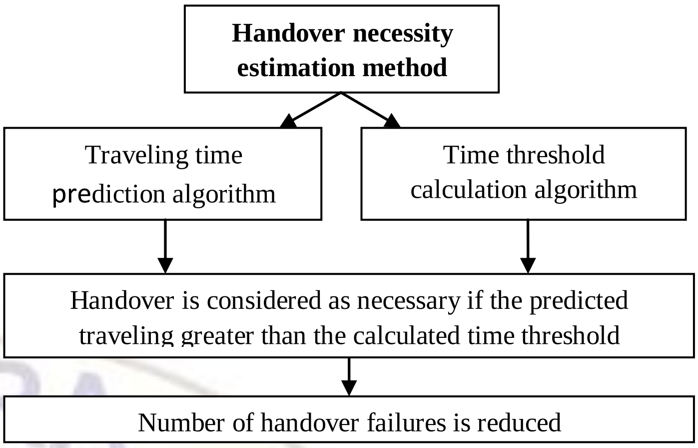

Figure 2.1: System architecture

HNE determines the necessity of making a handoff to an available network. HNE takes various network parameters as its inputs and generates a binary value as its output. The inputs include: the AP power level, RSS samples, the radius of the network, the velocity of the MT, the handoff latency, and the handoff failure and unnecessary handoff probability requirements. An output describes of '1' means a handoff is necessary, and an output of '0' means the handoff is not necessary. The block diagram of HNE is shown in Figure 2.2.

HNE consists of two units, traveling time estimation and time threshold calculation. The condition of triggering the HNE process is that a more preferable network is available, e.g. WLAN coverage becomes available while the MT is currently connected to a cellular network.

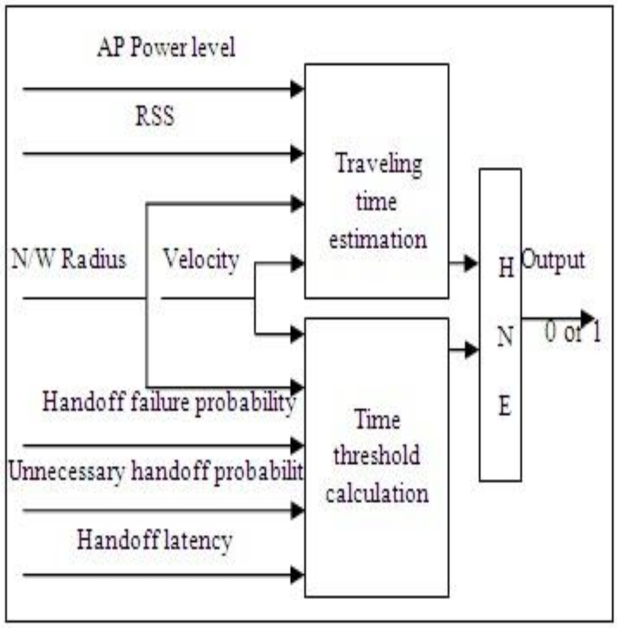

Figure 2.2: Block Diagram of Handoff Necessity Estimation (HNE)

Once the process is triggered, the HNE unit estimates the traveling time inside a candidate network and calculates a time threshold. The traveling time is estimated by using RSS samples collected by the MT, the power level and radius of the AP of the network, and the velocity of the MT. The time threshold is calculated based on the radius of the AP, the velocity of the MT, the handoff latency, and the handoff failure and unnecessary handoff probability requirements. HNE then compares the estimated traveling time against the time threshold: if the traveling time is greater than the threshold, an output of '1' is generated and a handoff is necessary; otherwise an output of '0' is generated and a handoff is unnecessary. HNE carries out this process for all the candidate networks and generates a binary output for each of them.

2.1.1. Traveling Time Prediction Using RSS measurement and speed information

The handoff necessity estimation relies on an algorithm which attempts to predict the traveling time in a WLAN cell coverage area by using successive RSS measurements. The algorithm works under the following assumptions:

- the WLAN cell has a circular geometry;
- the MT travels through the WLAN cell coverage in a straight line with a constant speed;
- the propagation environment in the WLAN coverage is modeled using the log-distance path loss model.

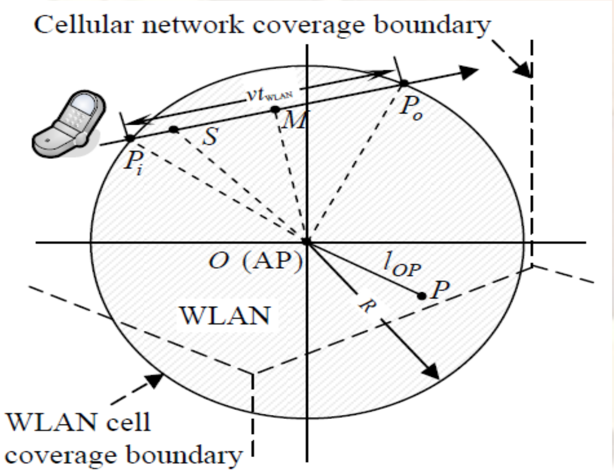

Figure 2.3: A scenario for traveling time prediction in a WLAN cell.

Figure 2.3 [6] shows the traveling time prediction scenario. The relationship between RSS (in dBm), and the distance between the AP and the MT at any point P inside the WLAN coverage area is obtained by using the log-distance path loss model:

$$RSS_p = P_{Tx} - PL_{ref} - 10\beta\log_{10}\frac{l_{op}}{d_{ref}} + X_\sigma \qquad (1)$$

where P_{Tx} is the transmit power of the WLAN AP in dBm, l_{OP} is the distance between the AP and point P, d_{ref} is the distance between the AP and a reference point, PL_{ref} is the path loss at the reference point in dB, β is the path loss exponent, and X_σ is a Gaussian distributed random variable with a mean of zero and a standard deviation σ in dB.

Estimation of the traveling time of the MT by using RSS measurements is done in the following way. It is assumed that the MT starts receiving sufficiently strong signals (i.e., it "enters" the WLAN cell) at point Pi and the signal strength drops below the usable level at point Po, and M is the middle point of the traveling trajectory, as shown in Figure 2.3. By using (1), when the MT enters the WLAN cell coverage area (i.e., the RSS level detected by the MT reaches a pre-determined threshold) at time t_{Pi}, the distance l_{OPi} (an approximate value for the cell radius R) can be calculated using:

$$R \cong l_{op_i} = d_{ref}10^{\frac{P_{Tx} - PL_{ref} - RSS_{P_i}}{10\beta}} \qquad (2)$$

Where RSS_{Pi} is the RSS at the entry point Pi.

To estimate the traveling time t_{WLAN}, the MT takes another RSS sample at point S at time t_S. Using Equation (1), the distance between O and S, l_{OS}, is estimated by:

$$l_{os} = d_{ref}10^{\frac{P_{Tx} - PL_{ref} - RSS_S}{10\beta}} \qquad (3)$$

Where RSS_S is the RSS at the sampling point S.

From the geometric configuration of Figure 2.3, the following equations are obtained:

$$l^2_{PiM} + l^2_{OM} = l^2_{OP_i} = R^2 \qquad (4)$$

$$l^2_{OM} + l^2_{SM} = l^2_{OS} \qquad (5)$$

$$l_{SM} = l_{PiM} - l_{PiS} \qquad (6)$$

Where l_{PiM}, l_{OM}, l_{SM}, l_{OS} and l_{PiS} are the distances between the entry point Pi and the middle point M, the AP location O and point M, the sampling point S and point M, points O and S, and points Pi and S, respectively.

By substituting Equation (6) in Equation (5), the following equation is obtained:

$$(l_{PiM} - l_{PiS})^2 + l^2_{OM} = l^2_{OS} \qquad (7)$$

Let v be the speed of the MT, which is a constant during the time period when the MT crosses the WLAN cell coverage t. Thus:

$$l_{PiM} = \frac{vt}{2} \qquad (8)$$

$$l_{PiS} = v(t_s - t_{Pi}) \qquad (9)$$

Where t_S and t_{Pi} are the times at sampling and entry points S and Pi, respectively.

By substituting Equation (8), (9) in Equations (4) and (7), the following equations are obtained:

$$\left(\frac{vt}{2}\right)^2 + l^2_{OM} = R^2 \qquad (10)$$

$$\left[\left(\frac{vt}{2}\right)^2 - v(t_s - t_{pi})\right]^2 + l^2{}_{OM} = l^2{}_{OS} \qquad (11)$$

Based on Equation (7), an estimate of traveling time t_{WLAN} is calculated as:

$$t_{WLAN} = \frac{R^2 - l_{os}{}^2 + V^2(t_s - t_{pi})^2}{V^2(t_s - t_{in})} \qquad (12)$$

Substituting Equations (2) and (3) in Equation (12), the ultimate equation of tWLAN is:

$$t_{WLAN} = \frac{d_{ref}10^{\frac{2(P_{Tx} - PL_{ref} - RSS_{P_i})}{10\beta}} - d_{ref}10^{\frac{2(P_{Tx} - PL_{ref} - RSS_S)}{10\beta}} + V^2(t_s - t_{pi})^2}{V^2(t_s - t_{in})} \qquad (13)$$

The traveling speed of the MT v is measured by an accelerometer embedded in the MT. Accelerometers can be used in handsets for various purposes and one purpose is to accurately estimate the speed of the MT.

2.1.2. Time Threshold Calculation for Minimizing Handoff Failures

The purpose of the time threshold calculation presented in this section is to keep the number of handoff failures under a desirable threshold. That is, for example, if the system designer has a requirement of limiting the probability of handoff failures under 1%, then the time threshold is adjusted to make the ratio of the number of failed handoffs to the total number of handoffs below 1%. The time threshold is calculated using mathematical modeling and probability calculation as explained below.

It is assumed that the entry and exit points Pi and Po can be any arbitrarily chosen points on the circle enclosing the WLAN coverage area, with equal probability (Figure 2.3). Then the angles θi and θo are both uniformly distributed in [0, 2π], and $\theta = \theta_i - \theta_0$

The first step is to calculate the probability density function (PDF) of θ.

The PDFs of the locations of Pi and Po are given, respectively, by:

$$f_{P_i}(\Theta_i) = \begin{cases} \frac{1}{2\pi}, & 0 \le \Theta_i \le 2\pi \\ 0, & otherwise \end{cases} \qquad (14)$$

$$f_{P_o}(\Theta_o) = \begin{cases} \frac{1}{2\pi}, & 0 \le \Theta_o \le 2\pi \\ 0, & otherwise \end{cases} \qquad (15)$$

Since the locations of Pi and Po are independent from each other, their joint PDF is given by:

$$f(\Theta_i, \Theta_o) = \begin{cases} \frac{1}{4\pi^2}, & 0 \le \Theta_i, \Theta_o \le 2\pi \\ 0, & otherwise \end{cases} \qquad (16)$$

The probability that $\theta \le \Theta$, which is also the cumulative distribution function (CDF) of θ, can be derived using the following integral:

$$F(\Theta) = P(\theta \le \Theta) = \iint_{\Omega} f(\theta_i, \theta_o)\, d\theta_o\, d\theta_i \qquad (17)$$

Where Ω is the space of locations of entry and exit points Pi and Po such that $\theta\Theta$ and $0 \le \Theta \le 2\pi$. $P(\theta \le \Theta) = 0$ for $\Theta < 0$ and $P(\theta \le \Theta) = 1$ for $\Theta > 2\pi$. From the observation of Figure 2.3 Equation (17) can be rewritten as:

$$F(\Theta) = P(\theta \le \Theta) = \frac{1}{4\pi^2}\left(\int_0^{\Theta}\int_0^{\Theta+\theta_i} + \int_{\Theta}^{2\pi-\Theta}\int_{\theta_i-\Theta}^{\Theta+\theta_i} + \int_{2\pi-\Theta}^{2\pi}\int_{\theta_i-\Theta}^{2\pi}\right) d\theta_o\, d\theta_i$$

$$= 4\pi\Theta - 4\Theta^2 \;, \quad 0 \le \Theta \le 2\pi \qquad (18)$$

The PDF of θ can be derived by taking the derivative of Equation (18) and is given by:

$$f(\Theta) = \begin{cases} \frac{1}{\pi}\left(1 - \frac{\Theta}{2\pi}\right), & 0 \le \Theta \le 2\pi \\ 0, & otherwise \end{cases} \qquad (19)$$

The next step is to use the PDF of, and the expression of the traveling time t_{WLAN} as a function of θ to obtain the PDF of t_{WLAN}.

From the geometric configuration in Figure 2.3 and by using the cosine formula, the following equation is obtained:

$$vt_{WLAN}{}^2 = 2R^2(1 - cos\theta) \qquad (20)$$

Thus,

$$t_{WLAN} = g(\theta) = \sqrt{\frac{2R^2}{v^2}(1 - cos\theta)} \qquad (21)$$

The PDF of tWLAN is expressed as:

$$f(T) = \sum_{1}^{n} \frac{f(\theta_n)}{|g'(\theta_n)|} \qquad (22)$$

Where $\theta_1 \ldots \theta_n$ are the roots of function g(θ), and g' (.) is the derivative of g(.).

In Equation (21), for g(θ) there are two roots, θ_1 and θ_2, which are expressed as:

$$\theta_1 = \cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right) \qquad (23)$$

$$\theta_2 = 2\pi - \cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right) \qquad (24)$$

From (21), $g'(\theta)$ is expressed as:

$$g'(\theta) = \frac{R \sin\theta}{v\sqrt{2((1 - cos\theta))}} \qquad (25)$$

So

$$|g'(\theta_1)| = \left|\frac{R\sin\left(\cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right)\right)}{v\sqrt{2\left(1 - cos\left(\cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right)\right)\right)}}\right| = R\sqrt{1 - \frac{v^2 t_{WLAN}{}^2}{4R^2}} \qquad (26)$$

$$|g'(\theta_2)| = \left| \frac{R\sin\left(2\pi - \cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right)\right)}{v\sqrt{2\left(1 - \cos\left(2\pi - \cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right)\right)\right)}} \right| = R\sqrt{1 - \frac{v^2 t^2}{4R^2}} \quad (27)$$

And

$$f(\theta_1) = \frac{1}{\pi}\left[1 - \frac{\cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right)}{2\pi}\right] \quad (28)$$

$$f(\theta_2) = \frac{1}{\pi}\left[1 - \frac{2\pi - \cos^{-1}\left(1 - \frac{v^2 t_{WLAN}{}^2}{2R^2}\right)}{2\pi}\right] \quad (29)$$

Thus, using Equations (22), (26) and (28) the PDF of t_{WLAN} is calculated by:

$$f(T) = \begin{cases} \frac{f(\theta_1)}{|g'(\theta_1)|} + \frac{f(\theta_2)}{|g'(\theta_2)|}, & 0 \le T \le \frac{2R}{v} \\ 0, & otherwise \end{cases}$$

$$= \begin{cases} \frac{2}{\pi\sqrt{4R^2 - v^2T^2}}, & 0 \le T \le \frac{2R}{v} \\ 0, & otherwise \end{cases} \quad (30)$$

The third step is to use the PDF of t_{WLAN} to obtain the CDF of t_{WLAN}, which is derived from the integral of Equation (30) as:

$$F(T) = Pr[t \le T] = \int_0^T f(T)\,dT \quad (31)$$

$$= \begin{cases} 1, & \frac{2R}{v} \le T \\ \frac{2}{\pi}\cos^{-1}\left(\frac{vT}{2R}\right), & 0 \le T \le \frac{2R}{v} \end{cases} \quad (32)$$

A time threshold parameter T1 is introduced to make handoff decisions: whenever the estimated traveling time t_{WLAN} is greater than T1, the MT will initiate the handoff procedure. A handoff failure occurs when the traveling time inside the WLAN cell is shorter than the handoff latency from the cellular network to the WLAN, Ti. Thus, using Equation (31) the probability of a handoff failure for the method using the threshold T1 is given by:

$$P_f = \begin{cases} \frac{2}{\pi}\left[\cos^{-1}\left(\frac{vT_i}{2R}\right) - \sin^{-1}\left(\frac{vT_1}{2R}\right)\right], & 0 \le T1 \le Ti \\ 0, & Ti < T1 \end{cases} \quad (33)$$

By using (33), an equation which can be used by the MT to calculate the value of T1 for a particular value of P_f when $0 < P_f < 1$:

$$T1 = \frac{2R}{v}\sin\left(\sin^{-1}\left(\frac{vT_i}{2R}\right) - \frac{\pi}{2}P_f\right) \quad (34)$$

To calculate T1, the speed of the MT v and the handoff latency Ti need to be obtained. In this research, the knowledge of v and Ti is assumed, and they can be measured by using accelerometers.

2.2. ALIVE-HO (Adaptive Lifetime Based Vertical Handoff) Algorithm

For handover between 3G networks and WLAN, an algorithm was proposed in [2] [5] by considering a life time metric which shows the application specific time period in which a user can still get services from WLAN. The algorithm evolves two different scenarios which will be described as follows:

First Scenario: In this scenario, a handover from WLAN to 3G network will happen if the average RSS of a WLAN connection is less than the predefined threshold and if the lifetime is less than or equal to the handover delay. The mobile terminal continuously calculates the RSS average using the moving average method

$$\overline{RSS}[k] = \frac{1}{W_{av}} \sum_{i=0}^{W_{av}-1} \overline{RSS}[k-i]$$

Where *Wav* → a variable that changes with the velocity of mobile terminal and is called window size

k → is the time index.

By using *RSS[k]*, the life time metric *EL[k]* is

$$EL[k] = \frac{\overline{RSS}[k] - ASST}{S[k]}$$

The Application Signal Strength Threshold (*ASST*) depends on a composite channel bit error rate, application error resilience and application QoS requirements. The *S[k]* varies with the window size of the slope estimator and the RSS sampling interval.

Second Scenario: In this scenario, a handover is initiated if a mobile terminal moves from a 3G network to WLAN network. The handover will be triggered if sufficient bandwidth is available on the WLAN network and if the threshold of a 3G network falls below the average RSS measurement of a WLAN signal.

The author could achieve many benefits in handover between mentioned networks. By using the lifetime metric, the number of extra handovers will be decreased and throughput of the network will dramatically increase. Moreover, increasing the lifetime metric causes an increase in the packet delay which is the disadvantage of this algorithm. In solving this problem, the *ASST* is adjusted based on different parameters such as delay thresholds, mobile terminal velocities, handover signaling costs and packet delay penalties.

2.3. ARSST (Adaptive RSS Threshold) Algorithm

"A cross-layer (Layer 2 + 3) Handover Management Protocol" [2] [4] proposed a WLAN to 3G handover decision method. In this method, RSS of current network is compared with dynamic RSS threshold (Sth) when MT is connected to a WLAN access point. It is observed that the following notations with reference to fig 2.4 [4] which shows a handover from current network (AP) referred as WLAN, to the future network (BS), referred as 3G.

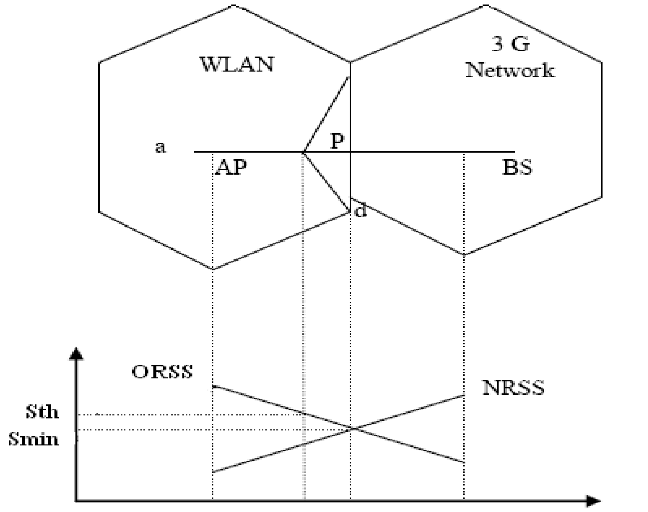

Figure 2.4: Analysis of the Handover Process

Here Sth → the threshold value of the RSS to initiate the handover process.

Therefore, when the RSS of WLAN referred to as ORSS (old RSS) in fig drops below Sth, the registration procedures are initiated for MT's handover to the 3G network.

a → is the cell size we assume that the cells are of hexagonal shape.

d → is the shortest distance between the point at which handover is initiated and WLAN boundary.

Path loss Model is given by

$$P_r(x) = P_r(d_0)\left(\frac{d_0}{x}\right)^{\alpha} + \varepsilon$$

Where x is the distance between the AP and MT, and $P_r(d_0)$ is the received power at a known reference distance (d_0) . The typical value of d_0 is 1 km for macro cells, 100m for outdoor microcells, and 1 m for indoor picocells.

The numerical value of $P_r(d_0)$ depends on different factors, such as frequency, antenna heights, and antenna gains, α is the path loss exponent. The typical values of α range from 3 to 4 and 2 to 8 for macrocellular and microcellular environment respectively.

ε - is a Zero mean Gaussian random variable that represents the statistical variation in Pr(x) caused by Shadowing. Typical std. deviation of **ε** is 12 dB.

The path loss model applied to the scenario.

$$P_r(a-d) = P_r(a)\left(\frac{a}{a-d}\right)^{\alpha} + \varepsilon$$

$$P_r(a-d) = P_r(a) + 10\alpha\log_{10}\left(\frac{a}{a-d}\right) + \varepsilon$$

$$S_{th} = S_{min} + 10\alpha\log_{10}\left(\frac{a}{a-d}\right) + \varepsilon$$

When the MT is located at point P, the assumption is that it can move in any direction with equal probability, i.e. the pdf of MT's direction of motion θ is

$$f_\theta(\theta) = \frac{1}{\pi-(\pi)} = \frac{1}{2\pi} \qquad -\pi < \theta < \pi \ldots\ldots\ldots\ldots (1)$$

As per assumption, that MT's direction of motion and speed remains the same from point P until it moves out of the coverage area of WLAN. As the distance of P from WLAN boundary is not very large, this assumption is realistic.

The need for handover to cellular network arises only if MTs direction of motion from P is in the range [θ ($-\theta_1,\theta_1$)]

Where $\theta_1 = arctan\left(\frac{a}{2d}\right)$, otherwise the handover initiation is false. The probability of false handover initiation is

$$P_a = 1 - \int_{-\theta_1}^{\theta_1} f_\theta(\theta)d\theta$$

P (unfavorable event) = 1 – P (favorable event)

= 1-$\frac{1}{2\pi}(2\theta_1)$ = 1-$\frac{1}{\pi} arctan\left(\frac{a}{2d}\right) \ldots\ldots\ldots\ldots\ldots\ldots (2)$

When the direction of motion of MT from P β ε $[(-\theta_1, \theta_1)]$the time it takes to move out of the coverage area of WLAN cell is given by

$$time = \frac{distance}{speed}$$

From fig.

$$\cos\beta = \frac{d}{x}$$

$$\sec\beta = \frac{x}{d}$$

$$x = d\sec\beta$$

Hence

$$t = \frac{x}{v}$$

$$t = \frac{d\sec\beta}{v} \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

Pdf of β is

$$f_\beta(\beta) = \begin{cases} \frac{1}{2\theta_1} & -\theta_1 < \beta < \theta_1 \\ 0 & otherwise \end{cases} \qquad \ldots\ldots\ldots\ldots (4)$$

From (3), t is a function of β i. e. t = g (β) in $[-\theta_1, \theta_1]$

$$g(\beta) = \frac{d\sec\beta}{v}$$

Therefore pdf of t is given by

$$f_t(t) = \sum_i \frac{f_\beta(\beta_i)}{g'(\beta_i)} \qquad \ldots\ldots\ldots\ldots (5)$$

Where β_i are the roots of equation t = g (β) in $[-\theta_1, \theta_1]$

And for each of these roots

$$f_\beta(\beta_i) = \frac{1}{2\theta_1} \qquad \text{for i} = 1 \text{ and } 2$$

$$f_t(t) = \frac{1}{2\theta_{1|g(\beta_i)|}} + \frac{1}{2\theta_{1|g(\beta_i)|}}$$

$$f_t(t) = \frac{1}{\theta_{1|g(\beta_i)|}} \qquad \dots\dots\dots\dots\dots(6)$$

Where $g(\beta_i)$ is derivative of g β given by

$$g(\beta_i) = \frac{d \sec\beta \tan\beta}{v}$$

$$g(\beta_i) = \frac{d \sec\beta\left(\sqrt{sec^2\beta} - 1\right)}{v}$$

$$g(\beta_i) = \frac{vt\left(\sqrt{\left(\frac{vt}{d}\right)^2} - 1\right)}{v}$$

$$g(\beta_i) = t\sqrt{\frac{v^2t^2}{d^2}} - 1 \qquad \dots\dots\dots\dots\dots(7)$$

Using (6) & (7), the pdf of t is given by

$$f_t(t) = \begin{cases} \frac{d}{\theta_1 t\sqrt{v^2t^2 - d^2}}, & \frac{d}{v} < t < \frac{\sqrt{\frac{a^2}{4} + d^2}}{v} \\ 0, & otherwise \end{cases} \qquad \dots\dots\dots\dots\dots(8)$$

The probability of handover failure is given by

$$P_f = \begin{cases} 1, & \tau > \frac{\sqrt{\frac{a^2}{4} + d^2}}{v} \\ P(t<\tau), & \frac{d}{v} < \tau < \frac{\sqrt{\frac{a^2}{4} + d^2}}{v} \\ 0, & \tau \le \frac{d}{v} \end{cases} \qquad \dots\dots\dots\dots\dots(9)$$

Where $\tau \rightarrow$ is handover signaling delay

$P(t < \tau) \rightarrow$ is the probability that t < τ when

$$\frac{d}{v} < \tau < \frac{\sqrt{\frac{a^2}{4} + d^2}}{v}$$

$$P(t < \tau) = \int_0^\tau f_t(t)\, dt$$

$$P(t < \tau) = \int_{\frac{d}{v}}^{\tau} \frac{d}{\pi t\sqrt{v^2t^2 - d^2}} dt$$

$$P(t < \tau) = \int_{\frac{d}{v}}^{\tau} \frac{d}{\pi dt\sqrt{\frac{v^2t^2}{d^2}} - 1} dt$$

$$P(t < \tau) = \int_{\frac{d}{v}}^{\tau} \frac{1}{\pi \frac{vt}{d}\frac{d}{v}\sqrt{\frac{v^2t^2}{d^2}} - 1} dt$$

$$P(t < \tau) \approx \frac{1}{\theta_1}\ arccos\left(\frac{d}{vt}\right) \qquad \dots\dots\dots\dots\dots(10)$$

Using (9) and (10)

$$P_f = \begin{cases} 1, & \tau\frac{\sqrt{\frac{a^2}{4} + d^2}}{v} \\ \frac{1}{\theta_1}\ arccos\left(\frac{d}{v\tau}\right), & \frac{d}{v} < \tau < \frac{\sqrt{\frac{a^2}{4} + d^2}}{v} \\ 0, & \tau \le \frac{d}{v} \end{cases}$$

$$P_f = \frac{arccos\left(\frac{d}{v\tau}\right)}{arctan\left(\frac{d}{vt}\right)}$$

$$P_f = \frac{\frac{\pi}{2} - \frac{d}{v\tau}}{\frac{\pi}{2} - \frac{2d}{\sqrt{4d^2 + a^2}}}$$

The use of adaptive RSS threshold helps reducing the handover failure probability and also reducing unnecessary handovers. The exact value of S_{th} will depend on MT's speed and handover signaling delay at a particular time. Adaptive S_{th} is used to limit handover failure. However, in this algorithm, the handover from 3G network to a WLAN is not efficient when MTS traveling time inside a WLAN cell is less than the than the handover delay. This may lead to wastage of network resources.

3. COMPARISONS OF RSS BASED VHD ALGORITHMS

A comparison of the RSS based VHD algorithm is shown in table 3.1. [6]

The main advantage of these algorithms is that it minimizes handoff failures.

Papers	HNE	ALIVE-HO	ARSST
Heuristic	Yan et al.'s heuristic	Zahran et al.'s heuristic	Mohanty and Akyildiz's heuristic
Applicable area	Between cellular networks and WLANs	Between 3G and WLANs	Between 3G and WLANs
Feature	A dynamic time threshold is calculated and compared with the predicted traveling time inside the WLAN to help with handoff decisions	The RSS is combined with an estimated lifetime or the available bandwidth to decide the handoff time	A dynamic RSS threshold is calculated and compared with the current RSS to determine the handoff time
Advantages	Minimization of the handoff failure, unnecessary handoff and connection breakdown probabilities	•Adaptation to application requirements and user mobility •Improvement on the available bandwidth	Reduction of the false handoff initiation and handoff failure probabilities
Disadvantages	Extra handoff delay	• Long packet delay •Extra lookup table	• Increased handoff failure • Wastage of network resources
Delay	Extra RSS sampling delay (up to 2s)	Relatively high packet delay probability (up to 1%) but can be reduced by adjusting ASST	Not provided

Number of Handoffs	Decreases as the velocity increases; The unnecessary handoff probability can be always kept under the desirable value (0.04)	Reduces up to 85% comparing with traditional hysteresis VHD	Not provided
Handoff Failure Probability	Can be always kept under the desirable value (0.02) as the velocity increases	Not provided	Can be always kept under the desirable value (2%) as the velocity increases
Throughput	Not provided	Decreases as the velocity increases; Can provide overall higher throughput (up to 33%) than traditional hysteresis VHD)	Not provided

Table 3.1: A Comparison of RSS Based VHD Algorithms.

4. Conclusion

Adaptive lifetime based method gives an Improvement in average throughput for user because MT prefers to stay in WLAN cell. But, packet delay grows near edges of the WLAN cell due to fading of signal which results in degradation of QoS. To solve this issue ARSST is tuned according to various parameters such as delay thresholds, MT velocities, handover signaling costs and packet delay penalties. Adaptive RSS threshold algorithm works good for handover from WLAN to 3G network .It helps in reducing handover failure probability and also reducing unnecessary handover between WLAN to 3G as dynamic RSS threshold is dependent on MTs speed and handover signaling delay. This algorithm is not efficient when handover is from 3G to WLAN, if traveling time inside WLAN cell is less than the handover delay. For this case traveling distance prediction based method works fine. These algorithms minimize unnecessary handover for handover from 3G to WLAN.

Future work is recalculate and refine the estimations for *v* (Velocity of the Mobile Terminal) to improve the performance, and eliminate the assumption that the MTS speed remains fixed inside the WLAN cell.

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