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Mobility Algorithm Based on the Prediction of Wrong Decisions for Vertical Handover

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Abstract: *Continuous connectivity guaranteeing Quality of Service (QoS) is a common demand of the users due to the ubiquity of wireless technologies. The demand to be "always best connected" among heterogeneous wired and wireless networks is achieved through a technique called Vertical Handover (VHO), for which development of mobility models is one of the important key-point. Mobility models help in issues related to location management, the load and resources sharing aspects and also the radio propagation aspects. In this paper, the mobility pattern of the vehicle-borne Mobile Terminal has been considered to study wrong decisions that are encountered due to user movement at particular time period of the day. An algorithm for reducing the wrong decisions encountered at the junction points near the boundary of the network which are location independent, time period of the day dependent, and velocity of the Mobile Terminal and / or distance of the Mobile Terminal from the Base Station dependent has been proposed.*

Keywords: Vertical handover algorithm, radial movement, peripheral movement, UHP, MHP, WDP

I. Introduction

In recent years, wireless networks have emerged and played a key role in modern telecommunications. Mobile communication has seen a spectacular development with improvement in technology and has been integrated into all sectors of society. Heterogeneous wireless network environment allows the concept of "always connected" to be changed to "always best connected" (ABC) [1]. In heterogeneous networks, the advantage of the best network available and the best access technology for a guaranteed Quality of Service(QoS) requires dynamic selection of networks [2] like the GSM, GPRS, UMTS, LTE, metropolitan area networks like the 802.11a/b/g/n and also the personal area network like the Bluetooth. The interworking between these networks is one of the promising approaches to the next generation wireless networks.

Mobility is one of the most important features of wireless communication and has a tremendous impact on how communication is evolving into the future. Mobility in 4G networks allows the user to be "always best connected" and calls for a new level of technical support [3]. It is achieved through a process called Handover or Handoff. In order to take advantage of the services available from the wide range of wireless networks, a transition of the mobile terminal between networks has to be made. This transition is called as Vertical Handover. 802.21 is an IEEE standard published in 2008 for supporting algorithms enabling seamless handover between networks of the same type or handover between networks of different types, also called as the Media Independent Handover (MIH) [4]. This standard provides a framework that defines the interface between network layers, without having to deal with specifics of the technology implemented in any particular network layer. It offers handover procedures including old link configuration, radio measurement reporting, discovery of new link, scanning of new radio access, checking of resource availability and retrieval of network information. Mobility management issues include mobility scenario, methods, algorithms, protocols, parameters and performance measures. The performance analysis of mobile networks is greatly influenced by the terminal mobility [5]. This calls for efficient Mobility models which are needed not only for location management procedures, but also for the handover statistics. The handover statistics is related to number of network crossings which might depend on size of the network, the dwell time, and the mobility pattern. Research in mobility modeling [6] can be based on designing new models which can emulate a real time scenario or analyze the existing models by studying the mobility metrics or the effect of the models on routing protocol. A variety of mobility models are available in literature which are based on the density of users in the network, the purpose of modeling, the type of traffic that is being transmitted, the users randomness of mobility.

The mobility models can also be based on the geographical region, service type, needs like location update or network planning. In general, mobility models must reflect accurate patterns of environmental displacements these devices operate in. Also, they must reflect almost accurate realistic scenarios for accurate simulation.

Location area planning, paging strategies which come under location management [7], multiple access techniques, channel allocation schemes which come under radio resource management [8], fading, handover decisions which come under propagation related aspects [9] are all analyzed under Mobility modeling.

II.

Taking into account the requirements relevant to mobile communications, mobility modeling can be based on the mobility behavior of the users or on the teletraffic model which involves modeling the possible call cases, where calls are divided into categories like mobile-to-fixed/mobile-to-mobile, business/residential etc. Though individual mobility is not yet fully understood and still being modeled in very roughly and insufficient ways under unrealistic assumptions, considering mobility is one of the useful methods to relieve ping-pong effect in cellular networks since a mobile device can efficiently determine whether it should perform handover or not through the estimation of its moving direction or velocity. Also the degree of randomness of the user movement plays an important role in designing an efficient mobility model.

Mobility behavior of an individual or a set of individuals can be studied through mobility modeling. Study of mobility modeling can be done either analytically or through computer simulations with both approaches having their own advantages and disadvantages. In [10] three basic types of mobility models which considers a specific range of design issues are introduced which are appropriate for almost all of the third generation mobile systems design issues like location and paging area planning, handover strategies or channel assignment schemes.

- The City Area Model which caters to a set of area zones connected via high capacity routes.
- The Area Zone Model which caters to a street network and a set of building blocks.
- The Street Unit model which considers the highways, streets with traffic light and high / low priority streets.

The paper is organized as follows: Section II presents the related work; Section III gives the mobility algorithm based on the prediction of wrong decisions. Finally conclusions and future work are presented in Section IV.

III. Related work:

In [11] a generic mobility model with a set of input and output parameters that are dependent on the type of mobility model has been described. The City Area model described considers the radial and peripheral movement of the Mobile Terminal. The city area has been divided into different zones like the city centre, urban, sub-urban and rural with the mobile users being categorized as Working People, Residential Users and High Mobility Users. Based on these assumptions, the city area model developed provides information of the traffic distribution over certain area zone which in turn are dependent on the time period of the day, the distribution of user movements with respect to an area zone, the amount of area zone border crossings for outgoing users with respect to the area zone for the busy and the rush hours. A further on the effect of border crossings on the network base station needs to be made.

Frost *et. al.* [12] in their paper have considered the amount of traffic flowing out of a region to be proportional to the population density within the region, the average velocity, and the length of the region boundary to formulate the model. A simple formula for calculating the average number of site crossings per unit time has been used which is also applicable for an arbitrary cell shape. But this model will not be accurate as the layout of the streets will become irregular and the movement of the users is considered to be uniform with respect to the boundary.

Bar-Noy *et. al.* [13] have described a Markovian model wherein individual movement of the users has studied. The user will either remain within a region or move to an adjacent region according to the transition probability distribution. But the model does not consider the number of trips or the consecutive movements of the user through a series of regions.

In [14] the authors have aimed at avoiding restrictions on the movement of the users, such that the call can originate or change its direction anywhere, anytime. This model is more suitable for pedestrian subscribers, but in the case of vehicular motion, the users are street bound and speed regulated.

IV. Mobility algorithm based on the prediction of wrong decisions

In this section, the mobility pattern of the vehicle-borne Mobile Terminal has been considered to study wrong decisions that are encountered due to user movement at particular time period of the day. A mobile user can move through several networks while being involved in a call. The number of times a mobile crosses different boundaries during a call is a random variable dependent on the network size, call holding time, and several mobility parameters. Each handover requires network resources to reroute the call through a new base station / access point. Hence it is preferable to have as few handovers as possible in order to alleviate the switching load and to decrease the processing required in the system. The number of handovers has a lower bound which is equal to the number of boundary crossings a mobile undergoes. In this analysis, user mobility and traffic behavior within a city area environment is simulated where the density of population is concentrated around work places or near residences or shopping centers at different times of the day.

In this simulation, two cases are dealt with, namely

Case A: Radial Movement (Mobile Terminal moving normal to the boundary)

Case B: Peripheral Movement (Mobile Terminal moving parallel to the boundary)

These two cases are depicted in figure 1 and figure 3.

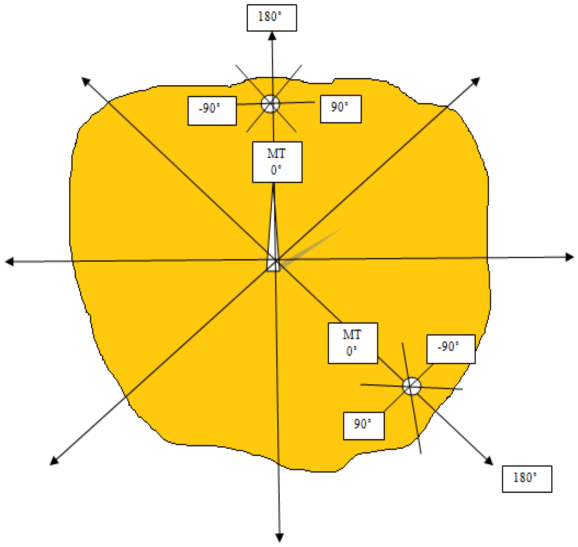

Figure 1: Radial movement (Case A) of the Vehicle borne Mobile Terminal

In figure1, it is assumed that Mobile Terminal is near the boundary and that there are two junction points, close to, but just inside the boundary of the network. The figure depicts the user moving normal (perpendicular movement) to the periphery of the coverage area at the two sample junction points which can be at any location but close to the boundary of the network. Also, depending on the user needs like offices, residences, commercial zones, public diversion, airport and train stations or parking zones and also the time of the day at the junction, the user can take a U-turn, right turn, left turn or continue to move in the same direction based on his needs. The model proposed is for the vehicular environment and is a random mobility model with a well defined street structure.

Since the user environments can vary depending on the requirements or time of the day and also a mobile call can be initiated or received at any point within the coverage area, several set of scenarios are considered. The relative change in direction at each of the crossroads is considered as φ_i, and only the highest probability scenarios of the user taking either a U-turn (180^{o}), a left turn (-90^{o}), a right turn (90^{o}) or moving ahead in the same direction (0^{o}) is considered as basis probabilities for computing the probabilities in all other directions. It is also assumed that the probability of the user moving in the cross roads (at angles different from 0^{o}, 90^{o}, -90^{o}, and 180^{o}) at the junction is minimum. Thus taking the different scenarios into account, the probability density function of φ_i [15] can be shown as in equation 1.

$$p.d.f(\varphi_i) = p_{0^0}\frac{1}{\sigma_\varphi\sqrt{2\pi}}e^{-\frac{\varphi_i^2}{2\sigma_\varphi^2}} + p_{90^0}\frac{1}{\sigma_\varphi\sqrt{2\pi}}e^{-\frac{\left(\varphi_i-\frac{\pi}{2}\right)^2}{2\sigma_\varphi^2}} + p_{-90^0}\frac{1}{\sigma_\varphi\sqrt{2\pi}}e^{-\frac{\left(\varphi_i+\frac{\pi}{2}\right)^2}{2\sigma_\varphi^2}} + \frac{1}{\sigma_\varphi\sqrt{2\pi}}e^{-\frac{(\varphi_i-\pi)^2}{2\sigma_\varphi^2}} \qquad (1)$$

A call may be initiated or may be in progress when the user is moving towards the periphery of the network. When this is the case, and as the vehicle-borne Mobile Terminal is near the boundary of the coverage area, two cases of handover may arise: one in which a successful handover is made as the Mobile Terminal just leaves the coverage area or a wrong decision for handover has been made as depicted in figure 2. The wrong decision can be due to

- An Unnecessary Handover- When the Mobile Terminal is near the edge of the coverage area, handover takes place assuming that the Mobile

Terminal will exit the coverage area but actually it does not,

- A Missing Handover- When the Mobile Terminal is near the edge of the coverage area, assuming that the Mobile Terminal will not exit the coverage area, handover is not made, but the Mobile Terminal actually does exit the coverage area.

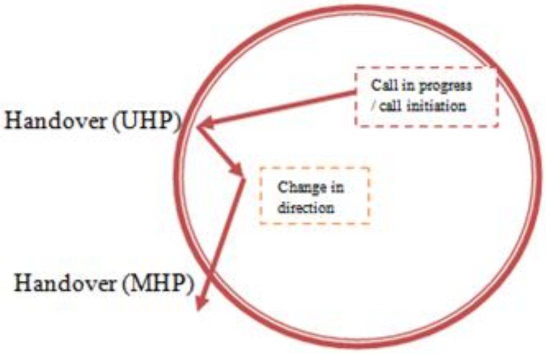

Figure 2: Wrong decision conditions near the boundary of the coverage area

In other words, since the Mobile Terminal is near the edge of the coverage area, a decision to handover might lead to an Unnecessary handover as the vehicle-borne Mobile Terminal, though near the boundary of the coverage area, may still continue to exist within the current networks coverage area or assuming that the Mobile Terminal will continue to be within the coverage area, a handover might not be initiated leading to a missing handover.

Analysis is done by considering the junction point to have eight roads connected to it, which are 45^0 relative to each other. When the Mobile Terminal is moving normal to the peripheral of the coverage area, the probability of unnecessary handover is calculated as

$$UHP = P\left(\frac{\pi}{2}\right) + P\left(\frac{3\pi}{4}\right) + P(\pi) + P\left(\frac{5\pi}{4}\right) + P\left(\frac{3\pi}{2}\right) \quad (2)$$

and the probability of missing handover is calculated as

$$MHP = P\left(\frac{7\pi}{4}\right) + P(0) + P\left(\frac{\pi}{4}\right) \quad (3)$$

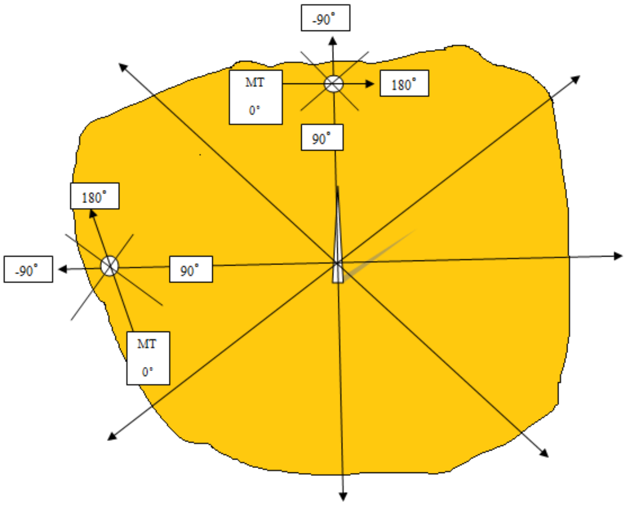

Figure 3: Peripheral movement (Case B) of the Vehicle borne Mobile Terminal

Similarly, when the Mobile Terminal is moving along the periphery of the coverage area, the probability of unnecessary handover increases, since the tendency towards making a handover increases. This increases the unwanted ping pong effect which can be overcome by considering the speed and / or distance of the Mobile Terminal from the base station. The probability of unnecessary handover for the case of the Mobile Terminal moving along the periphery of the coverage area is calculated as

$$UHP = P(0) + P\left(\frac{\pi}{4}\right) + P\left(\frac{\pi}{2}\right) + P\left(\frac{3\pi}{4}\right) + P(\pi) \quad (4)$$

and the probability of missing handover is calculated as

$$MHP = P\left(\frac{7\pi}{4}\right) + P\left(\frac{3\pi}{2}\right) + P\left(\frac{5\pi}{4}\right) \quad (5)$$

with the wrong decision probability being calculated as WDP = UHP+MHP in both the cases.

As the Mobile Terminal has been considered to take either a U-turn, right turn, left turn or continue to move in the same direction or in the cross roads, the corresponding probability function for any direction change is written as $P(180^o)$, $P(90^o)$, $P(-90^o)$, $P(0^o)$ and $P(n*45^o)$ respectively. Thus they sum up to be $P(180^o) + P(90^o)$ +, $P(-90^o) + P(0^o) + P(n*45^o) = 1$, where $n = \pm 1,2$. σ_φ is the standard deviation of all four directions and is assumed to be equal for all four distributions.The analysis is made by considering five scenarios and the probability values are only representative values at the junctions of a metropolitan city**.** The simulation results are shown in Figure 4 to Figure 7. In the first scenario, $P(0^o)$ i.e., users continuing to move along the same direction is 0.785, $P(90^o)$) i.e., users taking a right direction is 0.085, $P(-90^o)$ i.e., users taking a left direction is 0.125 and $P(180^o)$ i.e., users taking a U-turn is 0.005 [118]. So in this scenario, the probability of user's continuing to proceed in the same direction is maximum. The same analysis is used for the remaining scenarios. Table 1 shows the representative probabilities of user's taking different directions at any five junctions considered as scenarios in a metropolitan city. Figure 4 is a graphical representation of the same which shows the probabilities for $P(0^o)$, $P(90^o)$, $P(-90^o)$ and $P(180^o)$ as 1,2,3 and 4 respectively for different scenarios and figure 5 shows the probability of Mobile Terminal moving in a direction relative to its current direction of movement. Here each direction is considered to be 45^o relative to each other.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
P(0)	0.785	0.75	0.9	0.1	0.05
P(90)	0.085	0.1	0.05	0.4	0.8
P(-90)	0.125	0.1	0.05	0.4	0.1
P(180)	0.005	0.05	0	0.1	0.05

Table 1: Representative probabilities of user's taking different directions at five different junctions

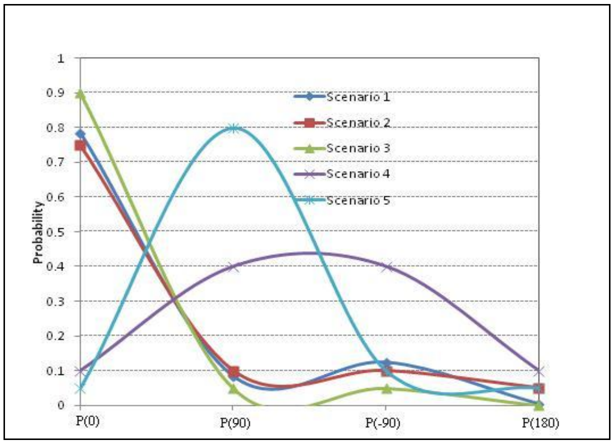

Figure 4: Probabilities for P (0), P(90), P (-90) and P (180) for the five scenarios

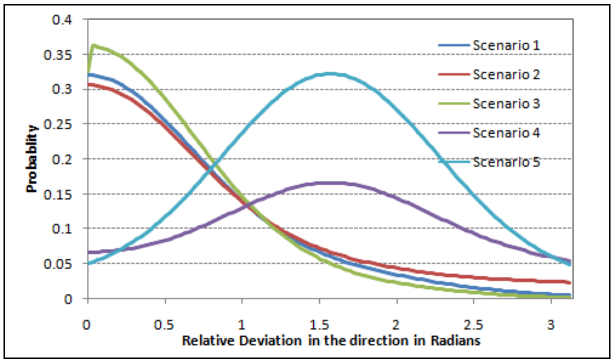

Figure 5: Probability of Mobile Terminal moving in a direction relative to its current direction of movement

Case A: Mobile Terminal moving normal to boundary

While the case of the Mobile Terminal moving normal to boundary is being considered, unnecessary handover probability is the probability of not crossing the boundary after completion of the handover process. Here, the movement of the Mobile Terminal is normal to boundary and though the Mobile Terminal is still below the boundary of the coverage area, handover takes place assuming that Mobile Terminal will cross the boundary. The probability of UHP is calculated as in equation 2. Similarly, Missing Handover probability is the probability of the Mobile Terminal crossing the boundary but a handover has not been made assuming the Mobile Terminal will not exit the coverage area, leading to a call termination. The probability of MHP is calculated as in equation 3. Figure 6 shows the UHP, MHP and WDP conditions for the Mobile Terminal moving normal to the boundary of coverage area.

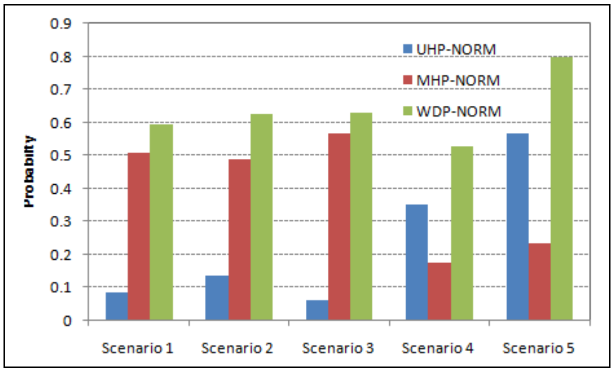

Figure 6: UHP, MHP and WDP for the Mobile Terminal moving normal to the boundary of coverage area

In scenario 4 & 5, as seen from the table, the probability of the Mobile Terminal continuing in the same direction is very low, and hence, if a handover is made, the probability that the handover will be an unnecessary one is very high. In scenario 3, 2 & 1, the probability of the Mobile Terminal continuing to move in the same direction is much higher, and hence, if a handover is made, the probability that it will be an unnecessary handover is very low. But, if the handover is not made, indicating a missing handover, call terminations increase due to missing handovers increasing.

Case B: Mobile Terminal moving along the periphery of the boundary

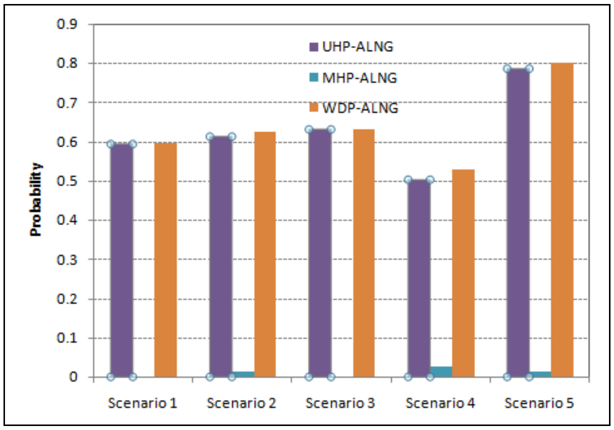

Figure 7: UHP, MHP and WDP for the Mobile Terminal moving along the periphery of the boundary of coverage area

While the case of the Mobile Terminal moving along the periphery of the coverage area is considered, unnecessary handover probability for this case is calculated as in equation 4 and the Missing Handover probability is calculated as in equation 5.

While moving along the periphery of the network, the ping pong effect increases. This is due to the fact that since the Mobile Terminal is closer to the boundary of the network, tendency of the base station assuming that the Mobile Terminal will cross the coverage area increases leading to a handover execution. But as the movement of the Mobile Terminal is along the periphery of the network and it does not cross the coverage area, a handover back to the current network is performed leading to increased unnecessary handovers as seen in figure 7. To overcome these wrong decisions encountered based on the mobility pattern of a vehicle borne Mobile Terminal at the junction points of the network, an algorithm which is 'time period of the day' dependent and 'speed and / or distance of the Mobile Terminal from the base station' has been proposed.

In the algorithm proposed for reducing the wrong decisions encountered at the junction points which are location independent, a threshold value 'N' for any probable wrong decisions encountered is considered. The value of the threshold can be a fraction of the total calls that are in progress while near the junction.

Following list of steps describe the algorithm:

1. Let the threshold value be set as N for the time period t_1 to t_2 by the network based on which the UHP value is varied for consecutive days for the set time period.
2. On, say, day 1 of the week, let N_1 be the number of unnecessary handovers that have occurred during the time period t_1 to t_2.
3. On day 2, if $N_1 > N$, during the time period t_1 to t_2, reduce the number of handovers occurring near the junction by a predefined value so that $UHP \leq N$, else retain the set value of UHP. The decision as to which handover not to be performed in order to achieve the condition $UHP \leq N$, is based on the speed of the vehicle and / or distance of the Mobile Terminal from the base station.
4. On day 3, if $N_2 > N$, (where N_2 is the number of unnecessary handovers that have occurred on day 2), during the same time period t_1 to t_2, further reduce the number of handovers occurring near the junction based on the speed of the vehicle and / or distance of the Mobile Terminal from the base station, so that $UHP \leq N$, else retain the set value of UHP.

Thus, by varying the UHP above or below the set threshold, the number of wrong decisions can be minimized thus leading to optimal usage of network resources.

Since UHP and MHP are complementary process, in order to minimize missing handovers which indicates call termination, the algorithm should increase the number of handovers occurring near the junction such that MHP does not fall below the set threshold. The complement of the above algorithm is applicable for reducing Missing handover probability.

Conclusion:

In this paper, the usage of network resources based on mobility-related factors is studied. An algorithm which is able to minimize the number of wrong decisions encountered at the junction points near the boundary of the network; which are location independent, time period of the day dependent, and velocity of the Mobile Terminal and/or distance of the Mobile Terminal from the Base Station dependent has been proposed.

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