



MITIGATING VERTICAL HANDOVER PREDICTION IN 4G WIRELESS NETWORKS

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ABSTRACT

The Provision of full mobility and good quality of service (QoS) are some of the key challenging tasks in mobile wireless networking. Interoperability between multiple access technologies (VHO) should be able to realize the vision of 4G technology and beyond that will allow mobile user equipment (UE) to roam freely when intersecting the cell-boundaries of different network platforms without losing the service. However, handover prediction seen as the method of determining the best network a mobile user should connect to, tend to prove difficult. This paper, therefore proposes a technique for predicting signal quality between the UE and base stations in two different (WiMAX and LTE-A) networks. The technique proposed makes use of two different thresholds to select the target base station with the strongest signal strength. Results from the proposed technique show that great improvement in network prediction was achieved.

Key Words: LTE-advanced, HHO, VHO, WiMAX, MDHO, FBSS, RSS, Delay, Inter-RAT

INTRODUCTION

Quality of service guarantee has become an important and a must indicator for mobile wireless networks which enable users full mobility anywhere and at all times. Whenever mobile user equipment roams, it gets updated accordingly from the serving Base Station (SeNB) to which it is connected. For handover to take place, the mobile user equipment (UE) continuously scans the neighborhood surrounding eNBs and monitors, the signal strength or packet delay (channel parameters). The moment the signal level of the serving eNB drop below a predefined level, the UE perform a handover to provide the required QoS.

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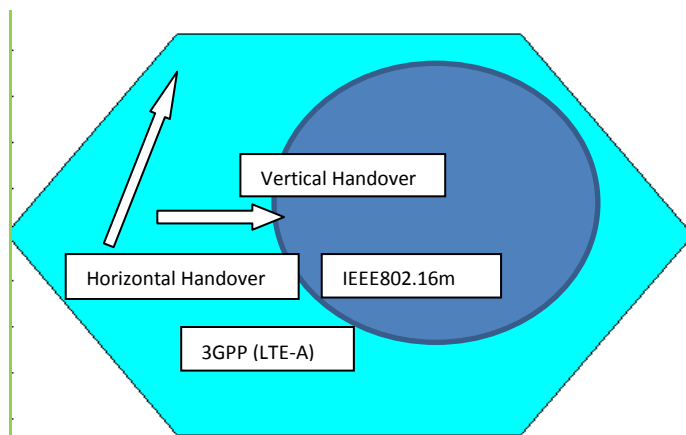
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Location prediction is a dynamic strategy in which the system proactively estimates the mobile's location based on a user movement model. Tracking capability depends on the accuracy of this model and the efficiency of the prediction algorithm. Thus, to sum it up, the above discussions on connection and location management make a compelling case for placing emphasis on developing algorithms and techniques for mobile trajectory prediction.

Three types of handovers are defined in wireless networks; vis-a-viz: hard handover, Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS) (Zdenek *et al.*, 2011). Hard handover is mandatory in inter-RAT handovers between LTE-Advanced and WiMAX systems (as depicted in Figure 1), while the other two types of handover are optional. One of the important characteristics of the Wi-MAX system is that it can perform the handover by either the "make-before-break (MBB)" or "break-before-make (BBM)" configuration (Fazli *et al.*, 2001). Consequently, by default, WiMAX systems incorporate the BBM mechanism. This approach however, introduces long delays which are not acceptable when real-time applications are. This short time off, known as handover interruption, handover delay, or handover latency, should either be eliminated or minimized drastically since it downgrades the QoS (Fazli *et al.*, 2001), (IEEE, 2006). The interruption in Handover occurs only when a hard handover is utilized. However, the UE may likely be connected at the same time to other APs in the case of MDHO or FBSS. There is the need for the number of APs in the diversity set to be optimized in compliance with the network conditions and signal quality in order to ensure optimum network performance. Both the handover interruption and the optimization of soft handover can be tackled by predicting the target eNodeB (TeNB).

Fig-1. Vertical and Horizontal Handovers in Wireless Heterogeneous Network



Therefore the introductions of this new technique will efficiently predict the best network in which the users of the network and the network itself may not require any modification. According to IEEE 802.16 m standard, the assessment of the prediction efficiency falls in line with the recommendation on evaluation of networks (IEEE, 2009).

The rest of the paper is structured as follows. Section two provides a synopsis of related studies on handover prediction. Section 3 introduces the techniques for elimination of unnecessary handovers while section 4 describes the proposed prediction technique. The fourth section defines simulation scenarios and parameters considered for assessing efficient prediction. The results of the simulations are analyzed and presented in Section 5 in which the impact of the proposed technique clearly outlined. Section 6 concludes the paper.

RELATED STUDY

Achieving optimal diversity (soft handover) and minimizing interruption during hard handover are the two advantages of handover prediction. The possibility of eliminating or reducing unnecessary handovers (sometimes termed “redundant handovers” in the literatures) is achievable only when a proper and efficient handover prediction is performed. It is caused by ping-pong effect that is when the UE is continuously being switched between two neighboring APs since it is moving along the edge of cells’ boundaries (Zonoozi and Dassanayake, 1996). There are so many reasons why handover prediction is utilized. One of such is for the reservation of resources for admission control (Lu and Wu, 2005). While two admission control schemes were proposed for optimizing the bandwidth, (Perato and Al Agha, 2002), (Becvar and Mach, 2010) used resource allocation for investigating predictions in wireless networks. In one of the references, “cell” approach and “user” approach were investigated (Perato and Al Agha, 2002), to predict the number of users and mobility prediction in cells as well as to determine information for the next handover. The advantages of the two approaches and their suitability for utilization in different scenarios were summarized by the paper. The authors propose in (Perato and Al Agha, 2002) a new resource allocation mechanism that indicates that the user approaches stand to be better for reduction in handover failures, while the cell approach together with the proposed resource allocation mechanism tend to improve cell blocking probability. A modified handover procedure for mobile WiMAX exploiting the prediction of target AP and thus significantly reducing handover interruption was proposed in (Becvar and Mach, 2010). It was stated that the prediction can reduce the downlink handover interruption by up to 90% compared to a conventional IEEE 802.16e handover. The prediction of target AP can be based on several approaches utilizing: handover history, user’s movement trajectory, and radio channel characteristics.

Prediction based on the channel (or network) characteristics, exploits information which is usually exchanged among UEs and core network (represented by eNodeBs) during normal operation (e.g., for handover purposes). Hence, no additional requirements are implied for either the UEs or the eNodeBs. The efficiency of techniques using the channel characteristics is significantly higher than the efficiency of techniques based purely on the handover history (Bellavista *et al.*, 2006), (Becvar, 2009). On the other hand, these techniques are usually outperformed by position based prediction. Prediction utilizing channel characteristics is investigated in (Zhou *et al.*, 2006). The authors generally describe the new network evaluation method as a criterion for handover decision with user preference and the usual estimation standards. Handover prediction is performed according to a weighted combination of several network parameters such as bit rate, latency, or power consumption. In (Bellavista *et al.*, 2006), the authors evaluate several filtering methods for handover prediction. The authors compare the efficiency of handover prediction for Grey (Lin and Liu, 2004), Kalman (Welch and Bishop, 2004), Fourier (Bloomfield, 2000), and Particle (van der Merwe *et al.*, 2000) filtering of RSSI (Received Signal Strength Indication) values. The prediction is based on the mutual relation of RSSIs of the target and serving access points (APs) and is performed when the difference between the two RSSI levels falls into a predefined interval. The results show the best performance (successful handover prediction) for Grey filtering. The paper evaluates and proves the positive impact of Grey prediction on the reduction of redundant handovers. Chan presents QoS adaptive prediction combined with the second type of prediction in (Chan *et al.*, 1998).

In (Kwon *et al.*, 2008), several handover prediction techniques like the handover history, mobility pattern, movement extrapolation, or distance were used. The paper demonstrated that the best performance (highest ratio of correct predictions) can be achieved by prediction based on a movement extrapolation (mobility pattern) for a road mobility model or a random waypoint mobility model (RWPM) (Kwon *et al.*, 2008) respectively.

The goal of this paper therefore is to conceptualize an efficient prediction technique that can achieve an equally better quality of service as high as what was obtained by other techniques in the literatures. As a result, consideration is given to prediction using channel characteristics as the basis of the proposed technique. It is interesting to note that the improvement of the prediction efficiency has been achieved through the utilization of hierarchical thresholds for making a decision on the selection of the predicted target AP. Furthermore, this paper also investigates the improvement of efficiency using other prediction techniques to reduce or eliminate the number of unwanted handovers (avoiding the ping-pong effect). Three techniques are considered: Hysteresis Margin (HM) (IEEE, 2006), (Zonoozi *et al.*, 1997), signal averaging (also known as windowing) (Zonoozi *et al.*, 1997), and Delayed Handover Time (DHT) (Hoymann, 2007). All assumptions for the proposed prediction are based only on parameters and metrics that can be obtained during conventional activities of networks according to the IEEE 802.16 standards (IEEE, 2009).

RELATED STUDY

The Fundamental of handover procedure

Handover procedure can be represented as: network topology advertisement and scanning of neighborhood APs by the UE. These stages are executed before the handover process begins. Additionally, cell re-selection, handover decision and initiation, and network re-entry are procedures performed after the handover. These procedures performed by the UE is to search and collect information on neighboring APs in the vicinity with the aim of finding a suitable target AP (IEEE, 2006). Depending on the results of the process (scanning), the possible target AP is selected. It is only when all the handover conditions are fulfilled, that the handover decision and initiation take effect. Immediately after wards, synchronization between the UE and the target AP begins thereby initiating network re-entry by the UE and consists of three sub-stages: ranging, re-authorization, and re-registration. After successful accomplishment of all three sub-stages, the UE can start exchanging data with the new serving AP (Fazli *et al.*, 2001).

The description above explains the principle of hard handover procedure. Similar principle is applied in the case of MDHO or FBSS but differ in the sense that the UE is simultaneously connected to more APs. When the MDHO or FBSS is supported, a list of APs which are involved in the handover procedure (i.e., the diversity set) is maintained by the UE and eNBs. This set is updated via MAC (Medium Access Control) management messages (IEEE, 2006) and (Perato and Al Agha, 2002). The diversity set is defined for each UE in the network. In the case of MDHO, the UE continuously monitors all APs in the diversity set and selects an anchor eNodeB. The UE is synchronized, authorized, and registered to the anchor AP. Furthermore, the UE performs ranging and monitors a downlink channel of the anchor eNodeB for control information. The UE communicates simultaneously (including user traffic) with the anchor BS and with all active APs in the diversity set. Unlike the MDHO, the UE communicates only with the anchor eNB for all types of uplink and downlink traffic including management messages while FBSS is utilized. The anchor eNB can be changed on a frame to frame basis depending on a BS selection scheme. This means that the UE can receive individual frames from different eNBs out of all eNBs in the diversity set.

Reducing unwanted handovers

In general, the hard handover is of low complexity and easy to implement in mobile networks. On the other hand, it results in more significant degradation of QoS (Fazli *et al.*, 2001). Moreover, any type of handover is interconnected with the generation of additional management overhead. To avoid both negative phenomena, the elimination of so-called redundant handovers has to be ensured. The redundant handover represents the case when handover is executed but not finished before the time when the next handover decision takes place. Also, handovers repeated frequently between two adjacent cells in a short time interval (i.e., ping-pong effect) should be considered as redundant handovers since the MS cannot take advantage of the connection to the new BS.

Redundant handovers are usually caused either by fading effects or by movements of users along the edges of cells. Several techniques can be utilized for minimization of the number of redundant handovers. Standard IEEE 802.16e defines HM and Time-To-Trigger (TTT) (IEEE, 2006). Other commonly used techniques are, for example, windowing or HDT extending conventional TTT. All methods are based on delaying the handover for a predefined time interval. The utilization of these methods for prediction purposes does not increase the management overhead since the parameters are already incorporated in MAC management messages in WiMAX. Thus, these parameters are distributed within the network regardless of whether the prediction is used or not.

In the case of HM, the handover decision and initiation are based on a comparison of one or several signal parameters of the serving and target eNodeBs. The handover is initiated if the signal parameter of the target BS exceeds the signal parameter of the serving AP plus HM, as defined by the equation:

$$S_{tar} > S_{serv} + HM \quad \text{-----}(1)$$

If windowing is applied, the handover decision is made if the average value of the observed signal parameter from the target AP drops below the average level of the same parameter at the serving AP:

$$\frac{\sum^{WS} S^{Tar}}{WS} > \frac{\sum^{WS} S^{Serv}}{WS} \quad \text{-----}(2)$$

where, WS corresponds to the window size, that is, the number of samples over which the average value is calculated.

Implementation of the DHT is based on the insertion of a short delay between the time when the handover conditions are first met and the time when handover initiation is executed. This method is based on TTT. In the case of TTT, the signal is continuously monitored for each frame, whereas the DHT evaluates only several signal samples measured during longer periodic intervals. The handover is performed if:

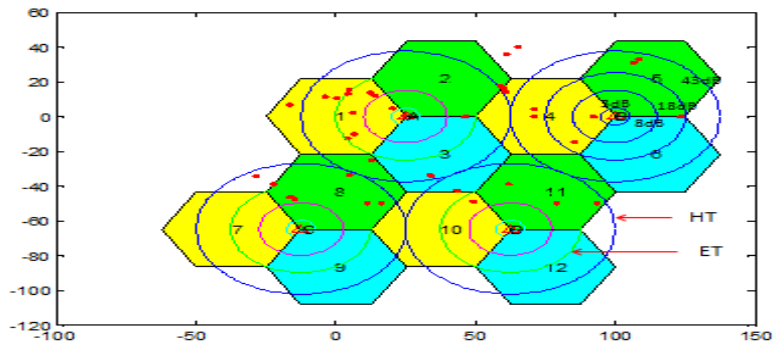
$$S_{i_serv} < S_{i_tar} \quad \text{-----}(3)$$

where DHT represents the duration of the handover delay timer and tHO is the time instant when the handover conditions are fulfilled.

THE PROPOSED PREDICTION TECHNIQUE

The graph presented in Fig. 3 explains the principle of the proposed technique. It exploits the scanning procedure of the UE in detecting the best signal (channel) quality as continuously obtained by the network. The improvement could be deduced from three independent thresholds as depicted in Fig. 3(b). One of the thresholds is obtained from the signal level received by the UE from the serving AP, the second threshold is related with the signal level measured by the UE from the potential target AP, while the third is associated with the signal strength of eNodeB of different network. Hence the prediction is entitled Hierarchical Thresholds Prediction (HTP). Fig. 3(b) depicts RSSI evolution between the UE and several APs during the UE's movement along a straight line (red trajectory in Fig. 3(a)). The speed of the MS is 10 m/s and the observation time is 100 s; that is, the distance covered by the UE within one observation cycle is 1km. Each curve in Fig. 3(b) represents the set of RSSIs received by the UE from all the four (4) APs obtained within several movements of the UE along the straight line. Fading and fluctuation of RSSI is caused by variations in channel parameters among all runs of the UE.

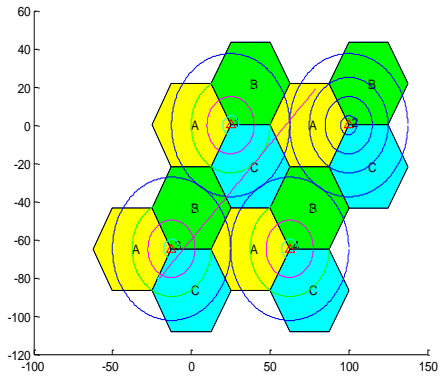
Fig-2. System model showing the RSSI regions (ET & HT)



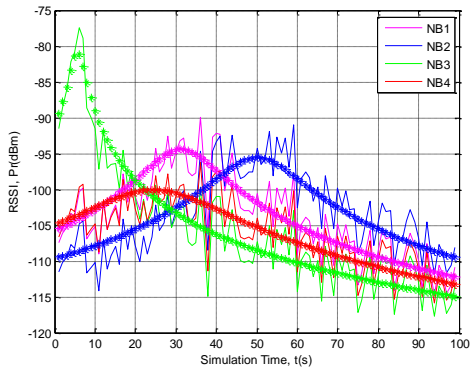
In order to facilitate forced handovers and to predict a UE's future movements, the study proposes two types of threshold circles in the WLAN coverage vis-a-viz, the handover threshold (HT) circle and the exit threshold (ET) circle as shown in Figure 3. The handover threshold (HT) circle in the WLAN cell represents the coverage boundary. It is the distance from the AP at which a UE performs a vertical handover to another network reaches the Trigger and the Threshold lines for effective handover with the network chosen by the algorithm. The UE monitors the RSS by receiving data streams coming from the Access Point (AP). Thus, the UE and the AP remain as receiver and transmitter respectively.

The figure 3(b) represents the RSSI level of the serving AP at the moment of the initiation of the UE's handover to the target AP. AP3 is the transmitter in this case while AP1 stand as the target AP. The second threshold corresponds to a typical RSSI level of the predicted target AP4 at the moment of initiation of the UE's handover from the serving AP3. In practice, both threshold levels are usually very close in most cases; nevertheless they are not equal. In mobile WiMAX, the level of HO for target AP is slightly higher than HO for Serving AP since the handover decision is made possible if the target AP is capable of providing better received signal sensitivity than the serving AP. Moreover, both thresholds are also unequal due to fluctuation in signal levels.

Fig-3. Prediction of UE trajectory and the threshold region



(a). Movement of UE along defined direction



(b). Handover showing the RSSI threshold against Time.

As the RSSI of the serving AP decreases and draws near to handover threshold of the server (HO_{Th_serv}), the probability of a handover from AP3 to AP1 increases. If on the other hand, the RSSI from one of the neighboring APs increases and draws near to handover threshold of the target (HO_{Th_tar}), the probability of a handover from AP3 to AP1 also rises. However, if the RSSI of the serving AP drops below threshold (HO_{Th_serv}) and simultaneously the RSSI of a neighboring AP rises and exceeds HO_{Th_tar} , then the prediction result is the expected handover of the UE from AP3 to AP1. This means that AP1 is labeled as the ‘‘predicted target AP’’. Both thresholds for each pair of AP3 and AP1 (thresholds HO_{Th_serv} and thresholds HO_{Th_tar}) are averaged out in order to derive one specific value that relates to the serving AP threshold as well as the value that relates to the target AP threshold. The mean values of the typical thresholds for the handover are calculated as an average of several previous signal levels leading to the handover initiation (NB_Serv in Fig. 5). The mean thresholds can be described by the following equations:

$$\overline{RSSI[Serv]} = 1/W_{ave} \sum \overline{RSS} \text{ -----(4)}$$

$$\overline{RSSI[Tar]} = 1/W_{ave} \sum \overline{RSS} \text{ -----(5)}$$

where $HO_serving$ represents the number of handovers that occur between the current serving AP and the potential target AP during the observed time interval;

RSSI HO_i UE; AP3 and RSSI HO_i UE; AP1 are RSSIs received at the UE from AP3 and AP1 respectively at the time instant of the handover decision; and index i specifies the individual handover event. It is not appropriate to perform the target AP prediction only when the typical thresholds are reached since the prediction would be made too late for exploitation of the prediction results in advance of the handover execution. Therefore, the target AP should be selected when the RSSIs between the UE and the serving and target APs are within intervals of handover zone (HO_{Zone}) defined by the following formulas

$$HO_{Th_serv} + HO_{zone} > RSSI \text{ -----(6)}$$

$$HO_{Th_tar} + HO_{zone} < RSSI \text{ -----(7)}$$

where HO_{Zone} represents the interval when the AP1 is marked as the predicted target AP (see Fig. 2b) and RSSI, AP3 and RSSI, AP1 correspond to the signal level currently received by the UE from the serving and target APs respectively.

The two stages of thresholds used instead of the conventional method of prediction (one threshold) may lead to achieving higher efficiency since it can reduce the ratio of incorrect target AP prediction. In (Perato and Al Agha, 2002), prediction efficiency can be influenced by signal level fluctuation due to shadowing, fast fading, and so on. If two thresholds are considered, the fluctuation of only one signal level may not necessarily lead to selection of AP1 as the predicted

target AP since the condition related to the second RSSI is still not fulfilled. The proposal comprises factors such as position, velocity and coverage to advise the mobile UE whether a handover would be suitable at a given time or not (prediction).

SIMULATION PARAMETERS

Simulation Parameters

The simulation depicts a coverage area of two different overlapping network technologies (IEEE802.16m and 3GPP) as shown in Figure 3(a). The hexagons represents the LTE-A network, while the circular rings represents the various signal levels of the WiMAX network as dissipated energy. The values of the parameters used in the simulation are given in the table 1.

Table-1. Simulation parameters and scenario definition for channel characteristics

Parameter	Value
Number of APs	4
Number of UE	1
BS transmitting power [dBm]	46
MS speed [m/s]	3,10,15
Frequency band [GHz]	2.5
Scanning reporting period [s]	1
Simulation duration [s]	120
Handover Delay Time [s]	1 and 2
Path loss model Urban macro-cell	1
Mobility Model	PRWMM
Area of Simulation	2330m x 2150m

Simulation Scenario

Four APs were used in the simulation which was conducted using the MATLAB simulation software. It is to confirm and evaluate the model presented. The results obtained from the simulation were used to establish parameter values and to set the threshold for predicting the handover. The scenario is made up of an IEEE 802.16m cell, overlaid on a 3GPP cell that offers a wider coverage area. With correct assumptions and the signal level degrading to a predicted threshold level, a link degrading event is triggered and the associated handshake process performed.

All the APs are deployed in a symmetric manner (see Fig. 2(a)) and transmit at the same power level according to the recommendations on evaluation of an IEEE 802.16m network (Tong *et al.*, 1998). At the beginning of the simulation, the positions of the UE are randomly generated. A Probabilistic Random Waypoint Mobility Model (PRWMM) (Kwon *et al.*, 2008) was considered for the UE's movement since it provides a higher level of movement randomness than other

mobility models. Signal strengths of the UE and APs are calculated using the urban macro-cell path loss model defined in equation 1. Channel variation is represented by low signal level fluctuation (Rezaei and Khalaj, 2009). The path loss with channel variation is equal to;

$$PL_{CV_i} = PL_i + (CV_{randi} \times S_i); \quad \text{-----}(8)$$

where *i* indicates a step of the simulation, PL is the macro-cell path loss defined in (Tong *et al.*, 1998), CV_{rand} is a random level of fluctuation, the exact value of fluctuation is randomly selected according to lognormal distribution with $l = 0$ and $r = 0$, 0.3, 0.6, or 0.8 (depending on the specific scenario) (Rezaei and Khalaj, 2009), and *S* is the sign (positive or negative) of CV_{rand} .

The performance of the proposed prediction scheme is evaluated by means of three parameters: the ratio of successfully predicted handovers (SPHO), the ratio of not predicted handovers (NPHO), and the ratio of wrong prediction (WPHO). The handover prediction is assumed to be successful if the UE executes the handover to the predicted target AP. The number of successfully predicted handovers

(SPHO) is used for the calculation of the prediction according to the following formula:

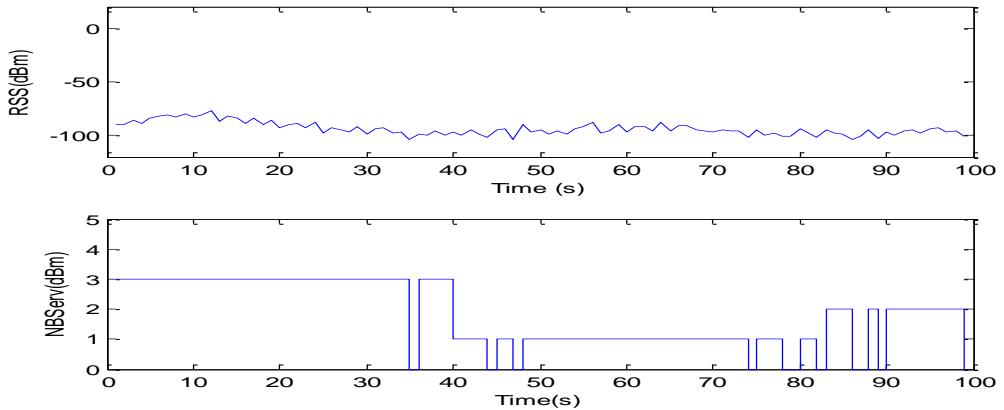
$$HR = SP_{HO} / N_{HO} < 1 \quad \text{-----}(9)$$

RESULTS AND ANALYSIS

Several sets of simulations were performed considering different types of scenarios. The first one analyses the impact of the HO Zone parameter on the prediction efficiency if no other technique for efficiency improvement is considered (i.e. HM, HDT, or windowing). However coverage predictability could be achieved through the precise knowledge of time before vertical handover is executed. This is believed to assist in the efficient allocation of radio resources in both the serving and target networks, based on the UE's needs.

RSS threshold value was set for the UE to trigger when the signal strength starts degrading. Fig. 4(a) shows the trajectory of the received signal against time. The degraded Signal (fading) is seen to go beyond RSS_{th} (-100dBm) and so is the corresponding handover time as demonstrated in figure 4 (b). This degradation shows how many times handover (horizontal and vertical) occurs as the UE roam across the boundaries of the APs as well as across the different networks. It is clear from the results that the UE hardly stays longer than necessary (about 2 seconds) in the 3GPP network. However, the UE spend most of the time in the serving AP (IEEE802.16m) rather than in the cellular 3GPP network.

Fig-4. Number of Handovers (Vertical and Horizontal) as UE crosses cell boundaries.



As the RSS of the serving network (WiMAX) gets stronger, less VHO occur. The reverse is the case when the signal strength degrades as the frequency of VHO increases. As earlier stated, the frequency of vertical handover might stem from the network topology.

The results of the simulation are shown in Figs. 5(a) and (b). They represent how prediction efficiency depends on the simulation time. These results are the SPHO, NPHO, and WPHO. It shows that when the WPHO decreases together with the NPHO, a proportionate/corresponding increase is recorded of the overall ratio of successful prediction (SPHO) and they could be related as: $HR = 1 - NPR - WPR$. Additionally, the figures made it possible to determine the minimum time interval for the collection of RSSI which ensures sufficient high prediction efficiency. This takes roughly three hours (10800s) with a large number of handovers might have been performed. The individual figures differ in diverse parameter settings of the channel model. While Fig. 3 assumes that the handover prediction is performed only according to RSSI evolution, Fig. 4 also takes into account another factor, i.e., channel variation with $r = 0.8$ and shadowing with a standard deviation of 8 dB. Windowing, HDT, and HM are not considered in Figs. 5(a) and (b).

Fig-5(a). Results of handover prediction based on RSSI, without channel variation.

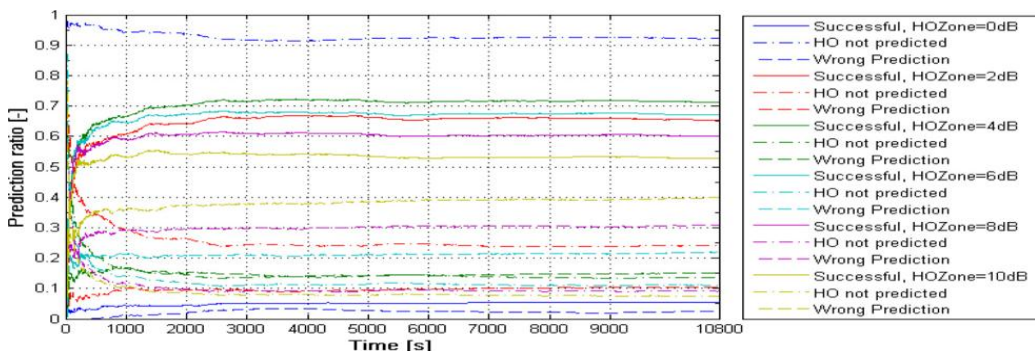
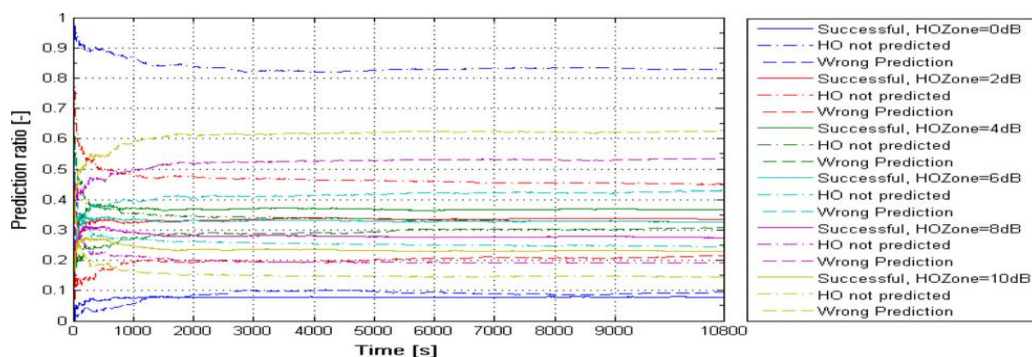


Fig-5(b). Results of handover prediction based on RSSI, with channel variation ($r = 0.8$).

CONCLUSION

A technique for handover prediction based on channel characteristics has been proposed and differs from other prediction techniques in the definition of two thresholds derived from the signal levels among the UE and the neighboring APs at the time of the handover initiation. One threshold is related to the serving AP and the second is related to the potential target AP. As the results indicate, the prediction can be positively influenced by the use of HM, DHT, and windowing techniques. The best prediction performance is usually achieved for HO_{Zone} equal to 3 dB. The proposed technique enables significantly improved prediction efficiency to be obtained in comparison to signal filtering methods.

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